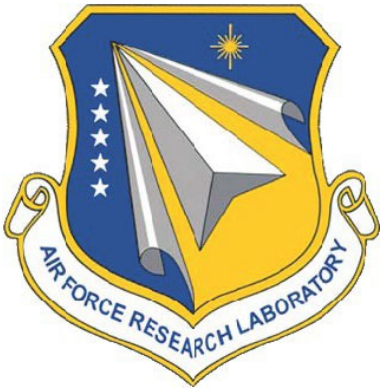


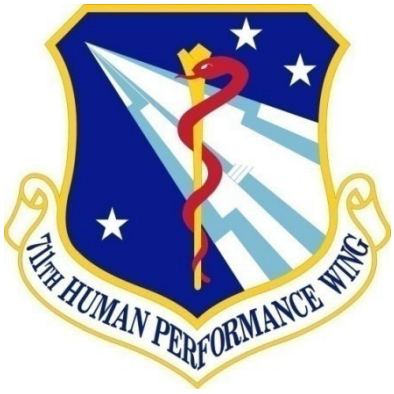


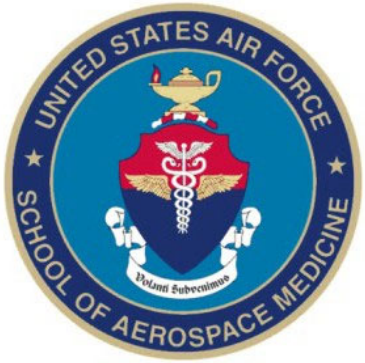


# AFRL-SA-WP-TR-2025-0004

# Missile Community Cancer Study Cancer and Health Risk Assessment for Minot Air Force Base, North Dakota

**Lt Col Scott M. Boyd**
**Occupational & Environmental Health Department**

**Report Date**
**29 May 2025**



**Date of Determination: 20 May 2025**
**Air Force Research Laboratory 711th Human Performance Wing**
**U.S. Air Force School of Aerospace Medicine**
**Occupational & Environmental Health**
**2510 Fifth Street, Bldg. 840**
**Wright-Patterson AFB, OH 45433-7913**

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The Missile Community Cancer Study Cancer and Health Risk Assessment for Minot Air Force Base, North Dakota (Technical Report) study was designed to be in compliance with the U.S. Environmental Protection Agency (EPA), Health Effects Test Guidelines, Office of Prevention, Pesticides, and Toxic Substances (OPPTS) 870.2500, Acute Dermal Irritation published in August 1998 and the Organization for Economic Cooperation and Development (OECD) Guideline for Testing of Chemicals, Acute Dermal Irritation/Corrosion, Section 404, adopted on July 28th 2015. This study was performed in a Good Laboratory Practice (GLP) Standards certified laboratory at:

A. Alliance Technical Group (Formerly Summit Environmental Technologies, Inc.), 3310 Win Street, Cuyahoga Falls, Ohio, 44223;

B. Australian Laboratory Services, 301 Fulling Mill Road, Middletown, Pennsylvania, 17057;

C. Bureau Veritas North America, 22345 Roethel Drive, Novi, Michigan, 48374;

D. Defense Centers for Public Health – Aberdeen, 8252 Blackhawk Road, Aberdeen Proving Ground, Maryland, 21010.

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
This report summarizes and analyzes the three rounds of environmental health surveillance conducted at Minot AFB, North Dakota. The three rounds at Minot AFB were part of an overall missile community environmental sampling campaign that included Malmstrom AFB, Montana; F.E. Warren AFB, Wyoming; Vandenberg Space Force Base (SFB), California; and Hill AFB, Utah. The purpose of these environmental health surveys was to assess the potential etiology of elevated non-Hodgkin Lymphoma (NHL) concerns within the Air Force missile community by characterizing and documenting exposures to potential environmental hazards in the Missile Alert Facilities (MAFs) and Missile Procedure Trainers (MPTs).

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| Lt Col Scott M. Boyd | (937) 255-3865 |

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DEPARTMENT OF THE AIR FORCE
711TH HUMAN PERFORMANCE WING (AFMC)
WRIGHT-PATTERSON AFB OHIO

29 May 2025

MEMORANDUM FOR: AFGSC/SGPB

FROM: USAFSAM/OE
2510 Fifth Street, Building 840
WPAFB OH 45433-7913

SUBJECT: Consultative Letter, AFRL-SA-WP-TR-2025-0004, Missileer Cancer Study Cancer and Health Risk Assessment for Minot Air Force Base, North Dakota

References: (a) Air Force Manual 48-148, *Ionizing Radiation Protection* (Department of the United States Air Force, 2020)

(b) 40 Code of Federal Regulations Part 761, Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions (Washington, D.C.: USEPA, 2025)

(c) United States Environmental Protection Agency, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment (EPA-540-R-070-002)* (Washington, D.C.: USEPA, 2009)

(d) Agency for Toxic Substances & Disease Registry, *Cancer Classification Systems* (Atlanta: ATSDR, 2020)

(e) American Conference of Governmental Industrial Hygienists, *2024 TLVs and BEIs Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices* (Cincinnati, 2024)

(f) Department of the Air Force, *Officer Career Briefs: Narrative Guidance, 13N – Nuclear & Missile Operations Career Development Guidance* (AF/A1. Washington, D.C.: 2023)

(g) United States Environmental Protection Agency, *Regional Guidance on Handling Chemical Concentration Data Near the Detection Limit in Risk Assessments* (Washington, D.C.: 2024)

(h) National Institute of Occupational Safety and Health, *Current Intelligence Bulletin 68: NIOSH Chemical Carcinogen Policy* (Washington, D.C.: NIOSH, 2017)

(i) Agency for Toxic Substances & Disease Registry, *Guidance on Inhalation Exposures, Version 5* (Atlanta: ATSDR, 8 September 2021)

(k) Agency for Toxic Substances & Disease Registry, *Exposure Dose Guidance for Dermal and Ingestion Exposure to Surface Water, Version 2* (Atlanta: ATSDR, 25 September 2018)

(l) United States Environmental Protection Agency, *Regional Screening Levels (RSLs) – User's Guide* (Washington, D.C.: 2024)

(m) United States Environmental Protection Agency, *Exposure Factors Handbook (EFH)* (Washington, D.C.: 2025)

(n) International Commission on Radiological Protection, *Lung Cancer Risk from Radon and Progeny and Statement on Radon* (New York, 1993)

(o) United States Environmental Protection Agency, *Science Policy Council Handbook: Risk Characterization* (Washington, D.C.: 2000)

(p) American Cancer Society, Lifetime Risk of Developing or Dying From Cancer (Atlanta, 2025)

## 1. EXECUTIVE SUMMARY

In response to concerns with perceived elevated Non-Hodgkin Lymphoma (NHL) rates among the Air Force Missile Community, the United States Air Force School of Aerospace Medicine Occupational and Environmental Health Department (USAFSAM/OE) performed three rounds of environmental exposure assessments at the fifteen (15) Missile Alert Facilities (MAFs) and two (2) Missile Procedure Trainers (MPTs) at Minot Air Force Base (AFB), North Dakota. This environmental surveillance effort consisted of collecting over 2,700 environmental samples across inhalation, ingestion, and absorption exposure pathways assessing over 164 total chemicals. The determinations associated with this investigation include:

A. Collecting environmental samples using calibrated equipment and methods endorsed by the United States Environmental Protection Agency (USEPA), National Institute of Occupational Safety and Health (NIOSH), and National Environmental Compliance Institute (NECi) using accredited laboratories;

B. Assessing carcinogens by using protocols that exceed established methods endorsed by the Agency for Toxic Substances and Disease Registry (ATSDR);

C. Conducting cancer risk, health risk, and target organ risk methodologies published by the USEPA; and

D. Utilizing public health, environmental health, and statistical experts in NIOSH and the Air Force Institute of Technology (AFIT) Scientific Test and Analysis Techniques Center of Excellence (STATCOE) to advise and perform statistical analysis.

It is USAFSAM/OE's determination that the current environmental conditions within the Minot AFB MAFs have the:

A. Current potential to contribute to excess cancer risks ranging from a lower-bound estimate of less than one (1) excess cancer risk in ten thousand (10,000) assigned MAF personnel to a conservative, upper-bound estimate of six (6) excess cancer risks out of ten thousand (10,000) assigned MAF personnel. This potentially increases a male MAF workers' probability of developing cancer from 39.9% to 39.96% and a female MAF workers' probability of developing cancer from 39% to 39.06%, and;

B. Current potential to contribute to a regulatory-based, non-cancer health risk which negligibly impacts no human organs or system to a conservative, upper-bound non-cancer health risk which impacts the skin.

## 2. INTRODUCTION

This report summarizes and analyzes the three rounds of environmental health surveillance conducted at Minot AFB. Table 1 lists the interim reports that were published. The three rounds at Minot AFB were part of an overall missile community environmental sampling campaign that included Malmstrom AFB, Montana; F.E. Warren AFB, Wyoming; Vandenberg Space Force Base (SFB), California; and Hill AFB, Utah. The purpose of these environmental health surveys was to assess the potential etiology of elevated non-Hodgkin Lymphoma (NHL) concerns within the Air Force missile community by characterizing and documenting exposures to potential environmental hazards in the MAFs and MPTs. Rounds 1 through 3 of the environmental health survey occurred from:

A. Round 1: 20 to 27 July 2023

B. Round 2: 2 to 12 October 2023

C. Round 3: 28 May to 4 June 2024

Radon surveillance occurred at the 15 MAFs beginning on 12 June 2023 and ending on 21 March 2024.

Interim reports were published for Rounds 1, 2 and 3 and are available on the Defense Technical Information Center (DTIC) website. Table 1 lists the Round 1-3 reports produced by USAFSAM/OE in support of the Missile Community Cancer Study (MCCS).

**Table 1: MCCS Reports Published for F.E. Warren, Malmstrom, and Minot AFBs**

| | **F.E. Warren AFB** | **Malmstrom AFB** | **Minot AFB** | **Consolidated Radon** |
|---|---|---|---|---|
| **Round 1** | AFRL-SA-WP-TR-2023-0012 | AFRL-SA-WP-TR-2023-0010 | AFRL-SA-WP-TR-2023-0009 | AFRL-SA-WP-TR-2023-0014 |
| **Round 2** | AFRL-SA-WP-OT-2024-0001 | AFRL-SA-WP-TR-2024-0003 | AFRL-SA-WP-TR-2024-0001 | AFRL-SA-WP-TR-2024-0002 |
| **Round 3** | AFRL-SA-WP-TR-2024-0010 | AFRL-SA-WP-TR-2024-0009 | AFRL-SA-WP-TR-2024-0008 | AFRL-SA-WP-TR-2024-0012 |

Additionally, USAFSAM/OE conducted surveillance at Vandenberg SFB and Hill AFB. Vandenberg SFB is the assigned base of the 377th Test and Evaluation Group (TEG) and the 532nd Training Squadron (TRS). The 377th TEG oversees testing, planning, execution, analysis,

and reporting of all Minuteman III intercontinental ballistic missile (ICBM) tests. The 532nd TRS delivers Air Force Specialty Code training to 450 Nuclear and Missile Operations Officers (13Ns) and Missile and Space Systems Maintenance Specialists (2M0) each year. The Strategic Missile Integration Complex at Hill AFB is the Department of Defense's (DoD) sole test environment for system integration and operational testing of modifications and upgrades to ICBM weapon systems. MCCS reports for these installations are also available on the DTIC website.

Table 2 lists historical reports produced by USAFSAM/OE in support of Vandenberg SFB and Hill AFB which can be found on DTIC.

**Table 2: MCCS Reports for Vandenberg SFB and Hill AFB**

| | **Vandenberg SFB** | **Hill AFB** |
|---|---|---|
| **Environmental Surveillance** | AFRL-SA-WP-TR-2024-0009 | AFRL-SA-WP-TR-2024-0011 |
| **Radon Surveillance** | AFRL-SA-WP-TR-2024-0007 | AFRL-SA-WP-CL-2024-0001 |

## 3. MINOT AFB ENVIRONMENTAL SURVEILLANCE RESULTS SUMMARY

Six types of samples (air-chemical and chemical mixture agents, air-radiological agent, drinking water-chemical chemical mixture agents, surface swipe-chemical mixture agent, soil-chemical agent and moisture, and direct read indoor air-quality parameters) were collected. The sampling encompassed over 160 individual chemical and radiological agents. Twelve (12) agents had one or more detected concentrations above the laboratory or direct-reading equipment limit of detection (LOD)/limit of quantification (LOQ) as follows:

A. Air-Chemical: Benzene, Methylene Chloride, and Toluene;

B. Air-Radiological: Radon;

C. Drinking Water: Total Nitrate/Nitrite;

D. Surface Swipe: Aroclor 1254;

E. Direct Read: Carbon monoxide, carbon dioxide, ozone in indoor air and potential of hydrogen (pH), total chlorine, and free chlorine in drinking water.

Considering these chemicals/mixtures were detected at Minot AFB, these chemicals/mixtures were not detected:

A. At every MAF;

B. Every round; and

C. In both the TopSide Support Buildings and the LCCs.

**3.1. Air-Chemical:** Environmental air sampling was conducted to assess inhalation exposure. Samples were collected in each of the fifteen (15) MAF Topside Support Buildings and Launch Control Centers (LCCs) and analyzed for volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), and organophosphates. Sampling for VOCs and organophosphates occurred during Rounds 1, 2, and 3 and sampling for PCBs occurred during Rounds 1 and 2 (see Table 1).

Of the sixty-nine (69) chemical agents assessed in each of the fifteen (15) MAFs, three (3) chemical agents (Benzene, Methylene Chloride, and Toluene) had one or more detected concentration above the laboratory or direct-reading equipment LOD/LOQ. Chemicals/mixtures where were below the laboratory LOD/LOQ are addressed in paragraph 4.7.

**3.1.1. Volatile Organic Compound (VOC) Sampling:** Ninety (90) VOC air samples were collected, each assessing fifty-one (51) individual VOCs, equating to four-thousand five hundred and ninety (4,590) total data points. Of the fifty-one (51) VOCs assessed, three (3) chemical agents (Benzene, Methylene Chloride, and Toluene) had one or more detected concentrations greater than the sampling and analytical method LOD/LOQ.

**3.1.2. Polychlorinated Biphenyl (PCB):** A total of thirty-two (32) PCB air samples were collected in the MAFs, LCCs and MPTs. Seven (7) unique PCB isomers were analyzed for, equating to two hundred twenty-four (224) data total points. All PCB air sample concentrations were less than the sampling and analytical method LOD/LOQ.

**3.1.3. Organophosphates:** A total of ninety (90) organophosphate air samples were collected, each assessing ten (10) individual organophosphates, equating to nine hundred (900) total data points. All organophosphate air sample concentrations were less than the sampling and analytical method LOD/LOQ.

**3.2. Air-Radiological:** Environmental air sampling to assess inhalation exposure to radon was conducted from 12 June 2023 to 21 March 2024. Inhalation exposure to radon in each location within each MAF that was sampled was less than four (4) Working Level Months per year (WLM/yr), which is the published annual exposure limit in Air Force Manual (AFMAN) 48-148, *Ionizing Radiation Protection* (20 July 2020).

**3.3. Drinking Water:** Drinking water sampling to assess ingestion exposure occurred during Rounds 1, 2, and 3 (see Table 1). Samples were collected from each of the fifteen (15) MAF Topside Support Building kitchen sinks and LCC bathroom sinks and analyzed for semi-volatile organic compounds (SVOCs), organophosphates, PCBs, diquat, paraquat, total nitrate/nitrite and dioxin. Of the seventy-nine (79) chemical agents analyzed for in each of the fifteen (15) MAFs, one (1) chemical (Total Nitrate/Nitrite) had one or more detected concentrations greater than the sampling and analytical method LOD/LOQ.

**3.3.1. Semi-Volatile Organic Compounds (SVOCs) & Organophosphates:** Ninety (90) SVOC/organophosphate water samples were collected, each assessing the concentrations of fifty-two (52) chemicals equating to four thousand six hundred eighty (4,680) total data points. Of the fifty-two (52) SVOCs & organophosphates assessed in drinking water, no chemicals were detected at concentration above the sampling and analytical method LOD/LOQ.

**3.3.2. Polychlorinated Biphenyl (PCB):** A total of eighty-nine (89) PCB water samples were collected, each assessing the concentrations of seven (7) individual PCB isomers, Total PCBs, Toxaphene, and Technical Chlordane which equate to eight hundred ninety (890) total data points. Of these ten (10) chemicals/mixtures assessed in drinking water, all concentrations of PCBs in drinking water were less than the sampling and analytical method LOD/LOQ.

**3.3.3. Diquat and Paraquat:** A total of ninety (90) water samples were collected assessing the concentration of diquat and paraquat equating to one hundred eighty (180) total data points. All concentrations of diquat/paraquat in drinking water were less than the sampling and analytical method LOD/LOQ.

**3.3.4. Dioxin:** A total of ninety (90) water samples were collected assessing the concentration of 2-3-7-8-Tetrachlorodibenzo-p-dioxin equating to ninety (90) data points. Of the ninety dioxin

samples collected, no detected concentrations of 2-3-7-8-Tetrachlorodibenzo-p-dioxin were found in any sample.

**3.3.5. Total Nitrate/Nitrite:** A total of ninety (90) Total Nitrate/Nitrite samples were collected. Of the ninety samples collected, detected concentrations of Total Nitrate/Nitrite were found in all ninety (90) samples.

**3.4. Dermal Absorption – PCB Swipe Sampling:** On 21 August 2023, USAFSAM published the Minot Air Force Base PCB Environmental Air and Swipe Sample Results, which documented the presence of PCBs on surfaces in the MAFs. Twenty (20) surfaces within each of the fifteen (15) MAFs were collected for a total of 300 samples. An additional thirty-six (36) surface swipe samples were collected in the MPTs. PCBs were detected in:

A. Ten (10) LCCs where concentrations were less than the USEPA surface contamination mitigation thresholds mandated by 40 Code of Federal Regulations (CFR) 761, and

B. One (1) LCC where concentrations were greater than the USEPA surface contamination mitigation thresholds mandated by 40 CFR 761.

As documented in Appendix 1 Minot AFB Consolidated Surface Contamination Exposures), one (Aroclor 1254) of the seven PCB isomers were detected in the 336 swipes collected at Minot AFB.

**3.5. Soil:** Soil sampling for organophosphates occurred during Rounds 1, 2 and 3 (see Table 1). A total of two hundred sixty nine (269) soil samples were collected at locations surrounding each MAF, each assessing the concentrations of ten (10) organophosphates equating to two thousand six hundred and ninety (2,690) data points. All concentrations of organophosphates in the two hundred sixty nine (269) soil samples were less than the sampling and analytical method LOD/LOQ.

**3.6. Direct Read Parameters:** Direct reading instruments were used to directly measure several indoor air quality and water quality parameters.

**3.6.1 Indoor Air Quality:** Direct reading instruments were used to directly measure instantaneous indoor air concentrations of carbon monoxide, carbon dioxide, percent relative humidity, and ozone.

A. Carbon monoxide (CO) concentrations ranged from less than 0.1 parts per million (ppm) to 7.2 ppm. These concentrations fall below the American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour Threshold Limit Value (TLV) of 25 ppm.

B. Carbon dioxide ($CO_2$) concentrations ranged from four hundred (400) ppm to one thousand sixty (1,060) ppm. Most $CO_2$ levels were below the current recommended levels for indoor air environments (1,000 ppm) established by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

C. Ozone concentrations ranged from less than 0.01 ppm to 0.07 ppm. ACGIH has an eight (8) hour TLV of 0.05 ppm for heavy work, 0.08 ppm for moderate work, and 0.10 ppm for light work.

D. Percent relative humidity (RH) ranged from 28.0% RH to 79.3% RH. Systems with dehumidification capability should maintain RH to less than 65% per ASHRAE.

E. Air temperature ranged from 59.8 degrees Fahrenheit (ºF) to 79.3ºF. The ASHRAE guidelines recommend 68ºF to 74ºF in the winter and 72ºF to 80ºF in the summer.

**3.6.2 Drinking Water Quality:** Direct reading instruments were used to directly measure several instantaneous drinking water quality parameters.

A. Potential of hydrogen (pH) ranged from 6.5 to 9.2 and indicated the water was slightly basic in pH. The USEPA established a secondary, unenforceable maximum contaminant level (MCL) for pH ranging from 6.5 to 8.5.

B. Total chlorine ranged from less than the instrument detection limit to 2.03 ppm and is the sum of combined chlorine and free chlorine.

C. Free chlorine ranged from less than the instrument detection limit to 1.56 ppm and is chlorine available to eliminate harmful microbes and neutralize contaminants. For chlorine, the USEPA has an MCL of four (4) ppm.

## 4. HEALTH RISK ASSESSMENT METHODOLOGY

USAFSAM/OE conducted the health risk assessment in accordance with Chapter 8 of the USEPA *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* (Part F, Supplemental Guidance for Inhalation Risk Assessment) {Version January 2009, Document # EPA-540-R-070-002}. In accordance with EPA-540-R-070-002 (USEPA, 2009), USAFSAM/OE performed a:

A. Total Estimated Cancer Risk Determination (TECRD);

B. Non-Cancer Estimated Health Risk Determination (NCEHRD);

C. Target Organ Risk Determination (TORD).

These assessments assume health is impacted by simultaneous exposure to multiple chemicals (USEPA, 2009). AFIT STATCOE performed statistical analysis for each chemical, which will be discussed in Section 4.6.

### 4.1. CARCINOGEN BACKGROUND

Cancer classification systems maintained by several agencies were consulted. Per ATSDR, three United States agencies and one international agency have cancer classification systems for carcinogens (ATSDR, 2020). These agencies are:

A. National Toxicology Program (NTP) within the United States Department of Health and Human Services (DHHS);

B. USEPA;

C. International Agency for Research on Cancer (IARC); and

D. NIOSH within the DHHS.

Although not specifically identified as one of the three United States agencies for cancer classification, USAFSAM included carcinogen classifications determined by ACGIH. By using the ACGIH carcinogen classification, four additional drinking water chemicals (Atrazine, Bromacil, Cyanazine, and Simazine) would have been included in the TECRD, if any of these chemicals had been detected above the laboratory LOD/LOQ. Appendix 2 (Minot AFB MAF Carcinogen Listing) documents the cancer determination for each chemical included in the TECRD.

#### 4.1.1. NTP

The NTP publishes the Report on Carcinogens (RoC), which is a congressionally mandated listing of chemicals that are *Known to be a Human Carcinogen* or *Reasonably Anticipated to be a Human Carcinogen* (ATSDR, 2020). The NTP classifies a chemical as:

A. **Known to be a Human Carcinogen when** there is sufficient evidence of carcinogenicity from studies in humans which indicates a causal relationship between exposure to the agent and human cancer (ATSDR, 2020).

B. **Reasonably Anticipated to be a Human Carcinogen when:**

(1) There is limited evidence of carcinogenicity from studies in humans, which indicates that causal interpretation is credible, but that alternative explanations, such as chance, bias, or confounding factors, could not adequately be excluded (ATSDR, 2020).

(2) There is sufficient evidence of carcinogenicity from studies in experimental animals, which indicates there is an increased incidence of malignant and/or a combination of malignant and benign tumors (ATSDR, 2020).

(3) There is less than sufficient evidence of carcinogenicity in humans or laboratory animals, but the agent, substance, or mixture belongs to a well-defined, structurally related class of substances whose members are listed in a previous RoC as either known to be a human carcinogen or reasonably anticipated to be a human carcinogen, or there is convincing relevant information that the agent acts through mechanisms indicating it would likely cause cancer in humans (ATSDR, 2020).

#### 4.1.2. USEPA

The USEPA Integrated Risk Information System (IRIS) conducts hazard analysis and quantitative risk assessments to assess cancer risks posed by chemicals (ATSDR, 2020). The USEPA IRIS utilizes the following carcinogen classifications:

A. **Group A/Carcinogenic to Humans** when there is adequate human data to demonstrate the causal association of the agent with human cancer (ATSDR, 2020)

B. **Group B/Probably Carcinogenic to Humans** when there is sufficient evidence from animal bioassay data but with either:

(1) **Group B1** when there is limited human evidence that is indicative of a possible causal relationship, but not exclusive of alternative explanations (ATSDR, 2020).

(2) **Group B2** when there is little or no human data (ATSDR, 2020).

C. **Group C/Possibly Carcinogenic to Humans** when there is limited animal evidence and little or no human data (ATSDR, 2020).

D. **Group D/Not Classifiable as to Human Carcinogenicity** when there is not adequate data either to support or refute human carcinogenicity (ATSDR, 2020).

E. **Group E/Evidence of Non-Carcinogenicity for Humans** when there is no evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiologic and animal studies (ATSDR, 2020).

#### 4.1.3. IARC

IARC is an organization within the World Health Organization (WHO). According to their mission statement, “The objective of IARC is to promote international collaboration in cancer

research. The Agency is interdisciplinary, bringing together skills in epidemiology, laboratory sciences, and biostatistics to identify the causes of cancer so that preventive measures may be adopted and the burden of disease and associated suffering reduced". The agency produces "Monographs on the Evaluation of Carcinogenic Risks to Humans", which utilize the following classification system (ATSDR, 2020):

A. **Group 1/Carcinogenic to Humans** when there is sufficient evidence in humans; or if there is both strong evidence in exposed humans that the agent exhibits key characteristics of carcinogens and sufficient evidence of carcinogenicity in experimental animals (ATSDR. 2020).

B. **Group 2A/Probably Carcinogenic to Humans** when there is at least two of the following evaluations, including at least one that involves either exposed humans or human cells or tissues (ATSDR, 2020):

(1) Limited evidence of carcinogenicity in humans (ATSDR, 2020).

(2) Sufficient evidence of carcinogenicity in experimental animals (ATSDR, 2020).

(3) Strong evidence that the agent exhibits key characteristics of carcinogens (ATSDR, 2020).

(4) If there is inadequate evidence regarding carcinogenicity in humans, there should be strong evidence in human cells or tissues that the agent exhibits key characteristics of carcinogens (ATSDR, 2020).

C. **Group 2B/Possibly Carcinogenic to Humans** when one of the following evaluations have been made (ATSDR, 2020):

(1) Limited evidence of carcinogenicity in humans (ATSDR, 2020).

(2) Sufficient evidence of carcinogenicity in experimental animals (ATSDR, 2020).

(3) Strong evidence that the agent exhibits key characteristics of carcinogens (ATSDR, 2020).

D. **Group 3/Not Classifiable as to Carcinogenicity to Humans (ATSDR, 2020):**

(1) Agents that do not fall into any other group, including when there is strong evidence that the mechanism of carcinogenicity in experimental animals does not operate in humans for one or more tumor sites in experimental animals, the remaining tumor sites do not support an evaluation of sufficient evidence in experimental animals, and other categories are not supported by data from studies in humans and mechanistic studies (ATSDR, 2020).

(2) An evaluation in Group 3 is not a determination of non-carcinogenicity or overall safety. It often means that the agent is of unknown carcinogenic potential and that there are significant gaps in research (ATSDR, 2020).

#### 4.1.4. NIOSH

NIOSH will determine whether a chemical is an occupational carcinogen by using one of the three following methods (ATSDR, 2020):

A. Evaluation of chemical carcinogen hazard assessments developed by the DHHS NTP, USEPA, and IARC (ATSDR, 2020).

B. Nomination by NIOSH for classification by NTP; or (ATSDR, 2020)

C. Classification by NIOSH (ATSDR, 2020).

NIOSH may perform its own chemical hazard assessment to determine if the chemical should be classified as an occupational carcinogen when the institute has determined that the chemical has the potential for worker exposure and when (ATSDR, 2020):

A. No prior carcinogen classification by NTP, EPA or IARC has been published, or (ATSDR, 2020).

B. Information in the occupational relevance evaluation indicates the need for reconsideration of the evidence underlying a published chemical carcinogen assessment (ATSDR, 2020).

When developing a new chemical carcinogen classification, NIOSH will use the criteria for carcinogenicity contained in the United Nations' Globally Harmonized System for Classification and Labelling of Chemicals (GHS) (ATSDR, 2020).

#### 4.1.5. ACGIH

The ACGIH independently determines chemical carcinogenicity according to the following classifications:

A. A1 – Confirmed Human Carcinogen

B. A2 – Suspected Human Carcinogen

C. A3 – Confirmed Animal Carcinogen with Unknown Relevance to Humans

D. A4 – Not Classifiable as a Human Carcinogen

E. A5 – Not Suspected as a Human Carcinogen

### 4.2. HEALTH SCREENING VALUES (HSVs)

Health Screening Values (HSVs) for all analytes were obtained from credible sources such as USEPA Regional Screening Levels (RSLs) for air and water, California EPA for air, EPA MCLs for drinking water, ATSDR for Minimal Risk Levels, and other state entities such as Florida, Michigan, Minnesota, Nevada, Pennsylvania, and Texas. In some cases, differing exposure timeframes, populations, and/or routes of exposure were encountered. In those situations, the HSV selected was the longer term, general population based HSV corresponding to the route of exposure (i.e. inhalation for air, ingestion for water).

Where applicable, 40 CFR requirements (environmental regulations set by the USEPA) took priority with second priority to ATSDR Minimal Risk Levels (MRLs). The USEPA CompTox portal and PubChem websites were used to search for health screening levels from the USEPA, United States Geological Survey (USGS), DoD, Department of Energy (DoE), and State agencies. The European Chemical Agency's (ECHA) website was used to search for European standards. The most conservative guideline was used as the HSV with a preference priority of:

A. Health Advisories (HA)

B. Screening levels

C. Regional Screening Levels (RSL)

D. Health-Based Screening Levels (HBSL)

E. State or European Derived Standards: Medium Specific Concentrations (MSC)

F. Environmental Quality Standards (EQS)

G. Military Exposure Guidelines (MEGs)

H. Derived No-Effect Level (DNEL)

I. Protective Action Criteria (PAC)

When no other guidelines could be found for the analyte and exposure route, the USEPA provisional peer reviewed toxicity values (PPRTVs) for inhalation reference concentrations (RfC) or ingestion reference doses (RfD) were used.

When multiple HSVs were being considered, the order of priority in HSV selection were:

A. 40 CFR (National Primary Drinking Water Regulations Maximum Contaminant Limit and Surface Contamination)

B. ATSDR MRL

C. United States Air Force Action Limits

D. USEPA HA

E. USEPA RSL Target Hazard Quotient (THQ) = 0.1

F. USEPA RSL Target Risk (TR)-1e-6

G. USGS HBSL

H. State derived (Ex: Pennsylvania Department of Environmental Protection Medium Specific Concentrations)

I. European Union (EU) EQS

J. MEG

K. ECHA DNEL

L. DOE PAC

M. USEPA Provisional Peer-Reviewed Toxicity Values (PPRTV) RfC

N. USEPA PPRTV RfD

When an analyte had multiple levels of risk associated with an adverse outcome, the THQ of 0.1 or target cancer risk TR of 1e-6 (one excess cancer case in one million people who are exposed) was used. Appendix 3 (Minot AFB Statistical Base Exposure, Confidence, Health Screening Value, & Cancer Curves) references the SBE, Confidence, and HSVs for detected chemicals included in the TECRD, NCEHRD, and TORD.

The HSVs are based on long-term, chronic exposure where the exposure timeframe extends well beyond the duration personnel would be present in a MAF. Where appropriate and with the approval of Air Force Global Strike Command Operations (AFGSC/A3), HSVs were recalculated from their original exposure duration to a standardized exposure over an eight (8) year timeframe. Eight years was selected given the duration conforms with the 13N Officer Career Development Briefs: Narrative Guidance (30 January 2023). Where typical 13N duties will transition from routine MAF duties to administrative staff positions, which drastically reduces MAF alert duties and exposure to the agents listed in Appendix 4 (Minot AFB Detected Chemicals Included in the Health Risk Assessment).

**Example of the 8-Year Calculation of the Benzene Air HSV:**

$HSV_{Benzene\text{-}Air}$ = Total Risk x Averaging $Time_{Days}$ ÷ (Inhalation Unit $Risk_{Benzene\text{-}Air}$ $(units)^{-1}$ x Exposure $Frequency_{Days/Year}$ x Exposure $Duration_{Years}$)

$$HSV_{Benzene\text{-}Air} = 0.0001 \times 25{,}550 \text{ days} \times \frac{1}{7.80E\text{-}06} \text{ (Cubic meter / microgram)}^{-1} \times \frac{\text{year}}{125 \text{ days}} \times \frac{1}{8 \text{ years}}$$

$HSV_{Benzene\text{-}Air}$ = 327.56 microgram / Cubic meter ($\mu g/m^3$)

Notes:

(1) Total Risk is 0.0001 given one (1) excess cancer risk in ten thousand (10,000) as defined by National Institute of Occupational Safety and Health, *Current Intelligence Bulletin 68: NIOSH Chemical Carcinogen Policy.*

(2) Averaging Time of 25,550 (equal to 70 years times 365 days per year) is in accordance with the practices published in the United States Environmental Protection Agency *Regional Screen Levels (RSLs) – User's Guide (November 2024).*

(3) Inhalation Unit Risk is in accordance with United States Environmental Protection Agency Integrated Risk Information System (IRIS).

(4) Exposure Frequency is based on current MAF operations at Malmstrom, Minot, and F.E. Warren AFBs. Historically, Malmstrom and Minot AFBs MAF operations were executed under a one week on, two weeks off tempo while F.E. Warren AFB MAF operations were executed under a one day one, two days off tempo. Under both tempos, MAF operations equate to one-third of a year at the MAF while the remaining two-thirds of the time are at the Main Operating Base, home, or elsewhere. Therefore, 125 days/year is conservatively used considering 1/3 x 365 days/year = 121 days.

(5) Eight (8) years is utilized in accordance with 13N Officer Career Development Briefs: Narrative Guidance (30 January 2023) and with the approval of AFGSC/A3.

For carcinogenic agents listed in Appendix 3 (Minot AFB Statistical Base Exposure, Confidence, Health Screening Value, & Cancer Curves), the Inhalation Unit Risk and/or Oral Cancer Slope is provided. The USEPA defines Inhalation Unit Risk (USEPA, 2024):

A. As an estimate of the increased risk from inhalation exposure to a concentration of one microgram per cubic meter (1 $\mu g/m^3$) for a lifetime

B. Can be multiplied by an estimate lifetime exposure to estimate the lifetime cancer risk to inhalation.

The USEPA defines Oral Slope Factor (USEPA, 2024):

A. As an estimate of the increased cancer risk from oral exposure to a dose of one milligram per kilogram-day for a lifetime (1 mg/kg-day)

B. Can be multiplied by an estimate lifetime exposure to estimate the lifetime cancer risk to ingestion.

Inhalation Unit Risks and Oral Slope Factors are derived assuming a 70-year lifetime exposure and may be adjusted for shorter exposure durations. Due to uncertainty in cancer outcomes at shorter exposure durations and adjustment models (linear, other), this analysis used the more conservative unadjusted Inhalation Unit Risks and Oral Slope Factors for upper bound cancer risk estimates.

## 4.3. EXPOSURE FACTORS (EFs)

Per the ATSDR, cancer risk can be adjusted to meet the actual duration of exposure by using the appropriate factor calculation (ATSDR, 2021). To recalculate Inhalation Unit Risks from a 70-year lifetime exposure to an adjusted eight (8) year exposure referenced in paragraph 4.2, the Exposures Factor (EF) formula associated with chronic, cancer exposures is applicable considering 13N exposure exceed a period more than 365 days.

**Example of Inhalation Exposure Factor Calculation for an Eight (8) Year MAF Exposure:**

$EF_{Cancer\text{-}Chronic\text{-}Inhalation}$ = [24 hours/day x 7 days/week x 17 weeks/year x 8 years ] ÷ [ 24 hours/day x 7 days/week x 52.14 weeks/year x 78 years]

$EF_{Cancer\text{-}Chronic\text{-}Inhalation}$ = 22,848 hours ÷ 683,243 hours

$EF_{Cancer\text{-}Chronic\text{-}Inhalation}$ = 0.033

Notes:

(1) Seventeen (17) weeks is based on current MAF operations at Malmstrom, Minot, and F.E. Warren AFBs. Historically, Malmstrom and Minot AFBs MAF operations were executed under a one week on, two weeks off tempo while F.E. Warren AFB MAF operations were executed under a one day one, two days off tempo. Under both tempos, MAF operations equate to one-third of a year at the MAF while the remaining two-thirds of the time are at the Main Operating Base, home, or elsewhere. Therefore, 17 weeks/year is equal to 1/3 x 52 weeks/year = 17 weeks.

(2) Eight (8) years is utilized in accordance with 13N Officer Career Development Briefs: Narrative Guidance (30 January 2023) and with the approval of AFGSC/A3.

(3) Remaining values (24 hours/day, 7 days/week, 52.14 weeks/year & 78 years) are in accordance with the Occupational Exposure Scenarios equation on page 8 of the ATSDR *Guidance for Inhalation Exposures, Version 5* (8 September 2021).

**Example of Absorption Exposure Factor Calculation for an Eight (8) Year MAF Exposure:**

$EF_{Cancer\text{-}Chronic\text{-}Absorption}$ = Frequency of Exposure x Exposure Duration ÷ Averaging Time

$EF_{Cancer\text{-}Chronic\text{-}Absorption}$ = 7 days/week x 17 weeks/year x 8 years ÷ 7 days/week x 52.14 weeks/year x 78 years

$EF_{Cancer\text{-}Chronic\text{-}Absorption}$ = 7 days/week x 17 weeks/year x 8 years ÷ 7 days/week x 52.14 weeks/year x 78 years

$EF_{Cancer\text{-}Chronic\text{-}Absorption}$ = 952 days ÷28,484.8 days

$EF_{Cancer\text{-}Chronic\text{-}Absorption}$ = 0.033

Notes:

(1) Seventeen (17) weeks is based on current MAF operations at Malmstrom, Minot, and F.E. Warren AFBs. Historically, Malmstrom and Minot AFBs MAF operations were executed under a one week on, two weeks off tempo while F.E. Warren AFB MAF operations were executed under a one day one, two days off tempo. Under both tempos, MAF operations equate to one-third of a year at the MAF while the remaining two-thirds of the time are at the Main Operating Base, home, or elsewhere. Therefore, 17 weeks/year is equal to 1/3 x 52 weeks/year = 17 weeks.

(2) Eight (8) years is utilized in accordance with 13N Officer Career Development Briefs: Narrative Guidance (30 January 2023) and with the approval of AFGSC/A3.

(3) Remaining values (24 hours/day, 7 days/week, 52.14 weeks/year & 78 years) are in accordance with the Occupational Exposure Scenarios equation on page 5 of the ATSDR *Exposure Dose Guidance for Dermal and Ingestion Exposure to Surface Water*, Version 2 (25 September 2018).

By using the EFs, a minimum cancer risk can be determined, which is addressed in paragraph 5.

## 4.4 TOTAL ESTIMATED CANCER RISK DETERMINATION (TECRD) METHODOLOGY

In accordance with EPA-540-R-070-002, the TECRD was calculated from the cancer risk of each individual agent within each exposure pathway combination, then added together (USEPA, 2009). This yields an estimate of total cancer risk, which represents the cumulative estimated cancer risk (USEPA, 2009). This recommended method assumes "independence of action by the compounds involved" (additive effects/risk) and assumes there are no synergistic (compound (agent) interactions resulting in greater than additive effects/risk) or antagonist (compound (agent) interactions resulting in less than additive effects/risk) interactions between chemicals (USEPA, 2009).

To calculate each chemical's Estimated Cancer Risk Determination (ECRD), the Statistical Base Exposure (SBE) for air & drinking water is multiplied by its individual cancer risk unit (i.e., inhalation unit risk for air, oral unit risk for drinking water). There is no calculated ECRD for ingestion since no carcinogens were detected in drinking water. The ECRD for dermal absorption of PCBs is calculated based on Appendix 5 (Minot AFB Estimated PCB Dermal Exposure Cancer Risk Determination). These separate risks are then added together to calculate the TECRD (See example calculations below). The Minot AFB TECRD calculated is then compared to the NIOSH Risk Management Limit for Carcinogens (RL-CA), which is set at one excess cancer case in ten thousand (10,000) workers in a 45-year working lifetime (NIOSH, 2017). The TECRD for Minot AFB is annotated on Appendix 6 (Minot AFB Total Estimated Cancer Risk Determination for Missile Alert Facilities AFSCs).

**Example of ECRD Calculation for Benzene in Air:**

$ECRD_{Benzene\text{-}Air} = SBE_{Benzene\text{-}Air} \times \text{Inhalation Unit Risk}_{Benzene}$

$$ECRD_{Benzene\text{-}Air} = 68 \frac{\text{micrograms}}{\text{Cubic Meter}} \times \frac{7.8E\text{-}06 \text{ Cubic Meter}}{\text{microgram}}$$

$ECRD_{Benzene\text{-}Air} = 5.3E\text{-}04$

**Example of ECRD Calculation for Radon in Air:**

$ECRD_{Radon\text{-}Air} = SBE_{Radon\text{-}Air} \times \text{Inhalation Unit Risk}_{Radon}$

$$ECRD_{Benzene\text{-}Air} = 0.19 \frac{\text{Working Level Months}}{\text{year}} \times 5E\text{-}04 \frac{\text{year}}{\text{Working Level Months}}$$

$ECRD_{Benzene\text{-}Air} = 9.5E\text{-}05$

Note: Inhalation Unit Risk for Radon is based on a "nominal probability coefficient" in Publication 115, *Lung Cancer Risk from Radon Progeny and Statement on Radon* published by the International Commission on Radiological Protection (ICRP). In Publication 115, the ICRP states "Based on recent results from combined analyses of epidemiological studies of miners, a lifetime excess absolute risk of $5 \times 10^{-4}$ per WLM should now be used as the nominal probability coefficient for radon and radon progeny induced lung cancer".

**Example of TECRD Calculation for Minot AFB:**

$TECRD_{Minot\text{-}AFB} = \Sigma\ ECRD_{Detected\text{-}Air\text{-}Chemicals} + \Sigma\ ECRD_{Detected\text{-}Drinking\text{-}Water\text{-}Chemicals} + ECRD_{Worst\text{-}Case\text{-}Dermal}$

$ECRD_{Detected\text{-}Air\text{-}Chemicals} = ECRD_{Benzene\text{-}Air} + ECRD_{Methylene\text{-}Chloride\text{-}Air}\ ECRD_{Radon}$

$ECRD_{Detected\text{-}Air\text{-}Chemicals} = 5.3E\text{-}04 + 1.1E\text{-}07 + 9.5E\text{-}05$

$ECRD_{Detected\text{-}Air\text{-}Chemicals} = 6.25E\text{-}04$

$ECRD_{Detected\text{-}Drinking\text{-}Water\text{-}Chemicals} = 0$

$ECRD_{Worst\text{-}Case\text{-}Dermal} = 4.8E\text{-}05$ (Per Appendix 5)

$TECRD_{Minot\text{-}AFB} = 6.25E\text{-}04 + 0 + 4.8E\text{-}05$

$TECRD_{Minot\text{-}AFB} = 6.73E\text{-}04$

## 4.5 ESTIMATED CONSERVATIVE, UPPER-BOUND NON-CANCER HEALTH RISK DETERMINATION (NCEHRD) METHODOLOGY

All detected chemicals, both carcinogens and non-carcinogens were included in the conservative, upper-bound NCEHRD. In accordance with EPA-540-R-070-002, the conservative, upper-bound NCEHRD from multiple chemicals were assessed via each individual Health Quotient (HQ) for each substance (ATSDR, 2020). Conservative, upper-bound NCEHRDs are calculated by dividing the BSE of a detected air and/or drinking water chemical by its respective HSV. NCEHRDs are assumed to be overly conservative since these exposures are compared to HSVs, defined in paragraph 4.2, are non-compliance screening values, and are not supported by studies validating adverse health impacts from exposure.

The Total NCEHRDs (TNCEHRD) are summed from each individual NCEHRD only when exposures to these chemicals occurred simultaneously (previously referred to as Exposure Profiles). Exposure pathway combinations (referred to as an Exposure Profile) for the TNCEHRD are MAF exposures consisting of Radon, air inhalation, & drinking water ingestion. Per EPA 540-R-070-002, any incident of the TNCEHRD being greater than one (1) was repeated by deriving a TORD for each target organ (ATSDR, 2020).

**Example of Conservative, Upper-Bound NCEHRD Calculation for Benzene in Air:**

$NCEHRD_{Benzene\text{-}Air} = BSE_{Benzene\text{-}Air} / HSV_{Benzene\text{-}Air}$

$NCEHRD_{Benzene\text{-}Air} = 68\ \frac{micrograms}{Cubic\ Meter} \times \frac{Cubic\ Meter}{327.56\ micrograms}$

$NCEHRD_{Benzene\text{-}Air} = 0.208$

**Example of NCEHRD Calculation for Total Nitrate/Nitrite in Drinking Water:**

$NCEHRD_{Total\text{-}Nitrate/Nitrite\text{-}Water} = BSE_{Total\text{-}Nitrate/Nitrite\text{-}Water} / HSV_{Total\text{-}Nitrate/Nitrite\text{-}Water}$

$$NCEHRD_{Total\text{-}Nitrate/Nitrite\text{-}Water} = 1{,}400 \frac{\text{micrograms}}{\text{Liter}} \times \frac{\text{Liter}}{10{,}000 \text{ micrograms}}$$

$NCEHRD_{Total\text{-}Nitrate/Nitrite\text{-}Water} = 0.140$

**Example of NCEHRD Calculation for Aroclor-1254 Dermal Exposure:**

$NCEHRD_{Aroclor\text{-}1254\text{-}Skin} = Maximum\text{-}High\text{-}Touch\text{-}Concentration_{Aroclor\text{-}1254} / HSV_{Aroclor\text{-}1254}$

$$NCEHRD_{Aroclor\text{-}1254\text{-}Skin} = 9.69 \frac{\text{micrograms}}{100 \text{ cm}^2} \times \frac{100 \text{ cm}^2}{10 \text{ micrograms}}$$

$NCEHRD_{Aroclor\text{-}1254\text{-}Skin} = 0.122$

**Example of Conservative, Upper-Bound TNCEHRD Calculation for Minot AFB:**

$TNCEHRD_{Minot\ AFB} = \Sigma\ NCEHRD_{Detected\text{-}Air\text{-}Chemicals} + \Sigma\ NCEHRD_{Detected\text{-}Drinking\text{-}Water\text{-}Chemicals} + NCEHRD_{Aroclor\text{-}1254\text{-}Dermal}$

$NCEHRD_{Detected\text{-}Air\text{-}Chemicals} = NCEHRD_{Benzene\text{-}Air} + NCEHRD_{Methylene\text{-}Chloride\text{-}Air} + NCEHRD_{Toluene\text{-}Air} + NCEHRD_{Radon}$

$NCEHRD_{Detected\text{-}Air\text{-}Chemicals} = 0.208 + 0.006 + 0.01 + 0.048$

$NCEHRD_{Detected\text{-}Air\text{-}Chemicals} = 0.263$

$NCEHRD_{Detected\text{-}Drinking\text{-}Water\text{-}Chemicals} = NCEHRD_{Total\text{-}Nitrate/Nitrite\text{-}Water} = 0.140$

$NCEHRD_{Detected\text{-}Dermal\text{-}Chemicals} = NCEHRD_{Aroclor\text{-}1254\text{-}Skin} = 0.969$

$TNCEHRD_{Minot\text{-}AFB} = 0.263 + 0.140 + 0.969$

$TNEHCRD_{Minot\text{-}AFB} = 1.372$

## 4.6 TARGET ORGAN RISK DETERMINATION (TORD)

Target organs for each chemical are referenced in Appendix 7 (Minot AFB Exposure Pathway and Non-Cancerous Target Organ Listing). When determining target organs for each chemical, USAFSAM referenced the online NIOSH Pocket Guide, ACGIH 2024 Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, the ATSDR, and the National Institute of Health PubChem database.

Appendix 8 (Minot AFB Conservative, Upper-Bound Target Organ Risk Determination) documents the TORD for Minot AFB. The conservative, upper-bound target organ risk calculated in Appendix 8 is assumed to be overly conservative since these exposures are compared to HSVs, defined in paragraph 4.2, are non-compliance screening values, and are not supported by studies validating adverse health impacts from exposures. Per EPA 540-R-070-002, any incident of the TNCEHRD being greater than one (1) was repeated by deriving a TORD for each target organ (ATSDR, 2020). Any TORD being greater than one (1) indicates environmental conditions have the potential to adversely impact that specific target organ and

warrant further assessment.

In the event Appendix 8 identifies one or more target organs exceeding one (1), a Health-Based Target Organ Risk Determination (HBTORD) was conducted. An HBTORD replicated the process of the conservative, upper-bound TORD, but is a more accurate tool to assess health risk considering exposures are compared to Federal health compliance standards in lieu of HSVs. For chemical inhalation exposures, the United States Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) is used (the ACGIH TLV is used only in absence of an OSHA PEL). For ingestion exposures, the USEPA MCL is used. Absorption exposures remain compared to limits set forth by 40 CFR 761 while radon exposure remain compared to limits in AFMAN 48-148. Appendix 9 (Minot AFB Health-Based Target Organ Risk Determination) documents the HBTORD for Minot AFB.

**Example of Conservative, Upper-Bound TORD Calculation for the Cardiovascular System for Minot AFB:**

$TORD_{Cardiovascular\text{-}System} = NCEHRD_{Methylene\text{-}Chloride\text{-}Air} + NCEHRD_{Toluene\text{-}Air} + NCEHRD_{Total\text{-}Nitrate/Nitrite\text{-}Water}$

$TORD_{Cardiovascular\text{-}System} = 0.006 + 0.001 + 0.140$

$TORD_{Cardiovascular\text{-}System} = 0.140$

**Example of Health-Based TORD Calculation for the Cardiovascular System for Minot AFB:**

$HBTORD_{Cardiovascular\text{-}System} = HBNCEHRD_{Methylene\text{-}Chloride\text{-}Air} + HBNCEHRD_{Toluene\text{-}Air} + HBNCEHRD_{Total\text{-}Nitrate/Nitrite\text{-}Water}$ $HBTORD_{Cardiovascular\text{-}System} = 0.000 + 0.000 + 0.140$

$HBTORD_{Cardiovascular\text{-}System} = 0.140$

## 4.7 STATISTICAL ANALYSIS

A tolerance interval of sample concentration was chosen as the most relevant feature to report for the cancer study. The upper-bound for the 95th percentiles were percentiles calculated with 95% statistical confidence. There are two scenarios present which require different analysis methods to make full use of available information from the data:

A. **Scenario 1: In The Presence of Measurable Concentrations**

In this scenario there are some samples with detected concentrations of an agent/compound. However, most of the data is left-censored, meaning there is a known minimum detectable concentration such as an analytical Reporting Limit (RL) and/or LOD, and no detected presence of the agent/compound. In this situation, there are not enough observed/detected values to verify whether the data was parametrically distributed, so the non-parametric estimation was used. The Kaplan Meier estimator was used to construct tolerance intervals (a range of values within a statistical level of confidence) for the analyte concentrations.

B. **Scenario 2: No Measurable Concentrations:**

The USEPA provides guidance to improve the quality and consistency of risk assessments from data near the RL/LOD (USEPA, 2024). Under this guidance, the USEPA proposes four options where data is below the RL/LOD:

(1) **Non-Detect concentrations are assumed to be same as the RL/LOD:** The USEPA guidance indicates assuming the Non-Detect to be the same as the RL/LOD is highly

conservative, biased, and not consistent with the best science in risk assessments (USEPA, 2024).

(2) **Non-Detect concentrations are reported as zero (0):** The USEPA indicates this approach is the "best-case approach" when the risk assessor determines the chemicals are unlikely to be present (USEPA, 2024).

(3) **Non-Detect concentrations are reported as half the RL/LOD:** The USEPA states this approach assumes that, on average, all values are between the LOD and zero (USEPA, 2024).

(4) **Statistical estimates for concentrations below the LOD:** The USEPA states this approach is superior to reporting non-detects as half the RL/LOD; however, is most effective for data sets having greater than 50% detects (USEPA, 2024).

To balance risk calculation without erroneously inflating the risk, USAFSAM used the USEPA "best-case approach" (Non-detect concentrations reported as zero) for chemicals which were non-detected throughout the three phases of the study. Therefore, the TECRD, TNCEHRD, and TORD were based on detected chemicals only. All concentrations below the LOD/LOQ were not included in the TECRD or NCEHRD (See Appendix 10, Minot AFB Chemicals Not Assessed for Health Risk: All Sample Results Less Than LOQ). Those chemical agents listed in Appendix 10 were not included in the TECRD or NCEHRD:

**4.7.1** Because the air sample results were less than the sampling and analytical method RL/LOD, the remaining forty-eight (48) non-detected VOCs are concluded to not be present in the MAFs at concentrations impacting occupant health.

**4.7.2** Because all PCB air samples were below the sampling and analytical method RL/LOD, the conclusion is they are not present in the MAFs at concentrations impacting occupant health.

**4.7.3** Because all organophosphate air sample results were below the sampling and analytical method RL/LOD, the conclusion is they are not present in the MAFs at concentrations impacting occupant health.

**4.7.4** Because the drinking water sample results were less than the sampling and analytical RL/LOD, the remaining non-detected SVOCs & organophosphates are concluded to not be present in MAF drinking water at concentrations impacting occupant health.

**4.7.5** Because all diquat/paraquat drinking water sample results were below the sampling and analytical method RL/LOD, the conclusion is they are not present in MAF drinking water at concentrations impacting occupant health.

**4.7.5** Because all PCB drinking water sample results were below the sampling and analytical method RL/LOD, the conclusion is they are not present in MAF drinking water at concentrations impacting occupant health.

**4.7.6** Because all concentrations of organophosphates in the ninety (90) soil samples were less than the sampling and analytical method RL/LOD, the conclusion is they are not present in the soil surrounding the MAFs at concentrations impacting occupant health.

## 5. ANALYSIS

Appendices 7, 8 and 10 document the TECRD, NCEHRD, and TORD for Minot AFB.

## 5.1 TOTAL ESTIMATED CANCER RISK DETERMINATION (TECRD)

Statistical analysis at a confidence exceeding 95% confirms dermal exposure to Aroclor 1254 is below the surface contamination mitigation thresholds mandated by 40 CFR 761. Appendix 5 (Minot AFB Estimated PCB Dermal Exposure Cancer Risk Determination) conservatively estimates the cancer risk associated with PCB dermal exposure on frequently touched surfaces. The interior elevator button in Delta-01 revealed Aroclor 1254 at 9.69 micrograms per one-hundred square centimeters ($\mu g/100\ cm^2$). The absolute worst-case conditions were assumed and include; a) the entire hand being exposed; b) complete concentration transfer between surface and hand; c) complete chemical absorption through the skin; and d) contact between hand and contaminated surface occurring for 350 continuous days each year. Even with these assumptions, the excess cancer risk was calculated to be less than one MAF occupant per 10,000 MAF occupants (<1 per 10,000). The risk associated with dermal contact to PCBs is incorporated into the overall cancer and non-cancer risks.

### 5.1.1. CONSERVATIVE, UPPER-BOUND CANCER RISK ESTIMATE

The American Cancer Society calculates males have a 39.9% probability of developing cancer across their lifetime while females have a 39% probability of developing cancer in their lifetime (American Cancer Society, 2025). Per Appendix 6, the cumulative cancer risk at Minot AFB has a conservative, upper-bound estimate of 6.73 excess cancers in 10,000 MAF occupants. This cumulative cancer risk does not imply the conditions within the Minot AFB MAFs are 6.73 times more likely to cause an incident of occupational-induced cancer, but that the most conservative estimates determine a potential for elevated incidences of occupationally induced cancer based on the current occupational and environmental conditions at the Minot AFB MAFs. An excess cancer risk of 6.73 out of 10,000 MAF occupants equates to a potential 0.06% increase in probability of developing cancer across a 70-year lifetime (0.06% = 6.73 / 10,000 x 100[%]). The excess cancer risk from MAF occupancy has the potential to increase a:

A. Male MAF workers' probability of developing cancer from 39.9% to 39.96%, and a

B. Female MAF workers' probability of developing cancer from 39% to 39.06%.

### 5.1.2. CONSERVATIVE, LOWER-BOUND CANCER RISK ESTIMATE

As discussed in paragraph 4.3, the inhalation, ingestion, and absorption EFs are 0.033. When applying these EFs to the conservative, upper-bound cancer estimate, the conservative, lower-bound cancer estimate is calculated. Table 3 captures the conservative, lower-bound cancer risk estimate by utilizing equations endorsed by the ATSDR. Specifically, the ATSDR states:

A. Inhalation cancer risk can be adjusted by multiplying the long-term air concentration by the Inhalation Unit risk using the equation *Inhalation Cancer Risk = Inhalation Unit Risk x Exposure Point Concentration x EF* (ATSDR, 2021).

B. Ingestion cancer risk can be adjusted by the number of years of exposure divided by 78 years (the average human life span) using the equation *Ingestion Cancer Risk = Inhalation Unit Risk x Exposure Point Concentration x EF* (ATSDR, 2023).

Therefore, Table 3 and Appendix 6 demonstrate the cumulative cancer risk at Minot AFB is estimated to be between a lower-bound estimate of less than one (1) excess cancer risk in ten thousand (10,000) assigned MAF personnel to a conservative, upper-bound estimate of 6.73 excess cancer risks in 10,000 MAF occupants.

**Table 3: Lower-Bound Cancer Estimate for Minot AFB Based on Eight-Years of Exposure**

| Route of Exposure | Chemical Name | CAS Number | Cancer Risk | Lower-Bound Cancer Risk | Lower-Bound Estimated Cancer Risk By Exposure Pathway | Total Lower-Bound Cancer Risk | Lower-Bound Cancer Risk |
|---|---|---|---|---|---|---|---|
| Inhalation | Benzene | 71-43-2 | 7.8E-06 | 1.75E-05 | 2.1E-05 | 2.3E-05 | Potential Lower-Bound Cancer Risk is less than 1 in 10,000 MAF Occupants |
| | Methylene Chloride | 75-09-2 | 1E-08 | 3.63E-09 | | | |
| | Radon-222 | 14859-67-7 | 9.5E-5 | 3.14E-06 | | | |
| Dermal | Aroclor 1254 | 11097-69-1 | 4.8E-05 | 1.58E-06 | 1.58E-06 | | |

## 5.2 NON-CANCER ESTIMATED HEALTH RISK DETERMINATION (NCEHRD)

The NCEHRD considers carcinogens and non-carcinogens detected at Minot AFB. The NCEHRD was calculated from any chemical containing one-or-more detectable concentrations. Appendix 4 (Minot AFB Detected Chemicals Included in the Health Risk Assessment) documents the:

A. Four (4) carcinogens:

(1) Air: Benzene, Methylene Chloride, Radon

(2) Dermal: Aroclor-1254, and;

B. Two (2) non-carcinogens:

(1) Air: Toluene, and;

(2) Drinking Water: Total Nitrate/Nitrite.

Appendix 11 (Minot AFB Conservative, Upper-Bound Total Non-Cancer Estimated Health Risk Determination for Missile Alert Facilities AFSCs) calculates the most conservative cumulative non-cancer health risk for Minot AFB to be greater than one, (>1) prompting an analysis by target organs known to be impacted by these six (6) chemicals. The cumulative non-cancer health risk calculated in Appendix 11 is assumed to be overly conservative since these exposures are compared to HSVs, defined in paragraph 4.2, are non-compliance screening values and are not supported by studies validating adverse health impacts from exposure.

## 5.3. TARGET ORGAN RISK DETERMINATION (TORD)

The conservative, upper-bound TORD shown in Appendix 8 (Minot AFB Target Organ Risk Determination) calculates a potential elevated risk to one (1) human organ (skin). This conservative, upper-bound TORD does not imply the conditions within the Minot AFB MAFs are more likely to impact the skin, but that the most conservative estimates determine a potential for elevated incidences to the skin based on the current occupational and environmental conditions at Minot AFB MAFs.

The HBTORD shown in Appendix 9 (Minot AFB Health-Based Target Organ Risk Determination) is a regulatory-based analysis which assess target organ risk against known, scientifically accepted health limits. The HBTORD calculates no elevated risks to any human organs or systems. Therefore, the current conditions within the Minot AFB MAFs have the

potential to contribute to health-based non-cancer health risk which negligibly impacts no human organs or system to a conservative, upper-bound non-cancer health risk which impacts the skin.

## 6. UNCERTAINTIES AND LIMITATIONS

Per the USEPA Science Policy Council Handbook: Risk Characterization, the principle of Transparency is fulfilled through the communication of Uncertainty (USEPA, 2000). Appendix 12 (MCCS Risk Assessment Areas of Uncertainty and Mitigating Steps) consolidates all known uncertainties identified by USAFSAM/OE throughout this study.

## 7. ACKNOWLEDGMENTS

Appendix 13 (Acknowledgements) lists all individuals who assisted with this study.

## 8. COMPLETION

If you have any questions, comments, or concerns, please contact the undersigned at 937-255-3865 or by e-mail at scott.boyd.2@us.af.mil.

BOYD.SCOTT.M.1298312030 Digitally signed by BOYD.SCOTT.M.1298312030 Date: 2025.05.29 10:49:33 -04'00'

SCOTT M. BOYD, Lt Col, USAF, BSC
Chief Consulting Executive

THIRTEEN (13) APPENDICES

1. Minot AFB Consolidated Surface Contamination Exposures
2. Minot AFB MAF Carcinogen Listing
3. Minot AFB Statistical Base Exposure, Confidence, Health Screening Value, & Cancer Curves
4. Minot AFB Detected Chemicals Included in the Health Risk Assessment
5. Minot AFB Estimated PCB Dermal Exposure Cancer Risk Determination Per 10,000 Personnel
6. Minot AFB Total Estimated Cancer Risk Determination for Missile Alert Facilities AFSCs Based on 70-Years of Exposure
7. Minot AFB Exposure Pathway and Non-Cancerous Target Organ Listing
8. Minot AFB Conservative, Upper-Bound Target Organ Risk Determination Based on 8-Years of Exposure
9. Minot AFB Health-Based Target Organ Risk Determination
10. Minot AFB Chemicals Not Assessed for Health Risk: All Sample Results Less Than RL/LOQ
11. Minot AFB Conservative, Upper-Bound Total Non-Cancer Estimated Health Risk Determination for Missile Alert Facilities AFSCs Per 10,000 Personnel Based on 8-Years of Exposure
12. MCCS Risk Assessment Areas of Uncertainty and Mitigating Steps
13. Acknowledgements

## ACRONYMS

| | |
|---|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| AFB | Air Force Base |
| AFGSC/A3 | Air Force Global Strike Command Operations |
| AFIT | Air Force Institute of Technology |
| AFMAN | Air Force Manual |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| CFR | Code of Federal Regulations |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| DHHS | United States Department of Health and Human Services |
| DNEL | Derived No-Effect Level |
| DoD | Department of Defense |
| DoE | Department of Energy |
| DTIC | Defense Technical Information Center |
| ECHA | European Chemical Agency |
| ECRD | Estimated Cancer Risk Determination |
| EF | Exposure Factor |
| EFH | Exposure Factors Handbook |
| EPA | Environmental Protection Agency |
| EQS | Environmental Quality Standards |
| EU | European Union |
| GHS | United Nations' Globally Harmonized System for Classification and Labelling of Chemicals |
| GLP | Good Laboratory Practice |
| HA | Health Advisory |
| HBSL | Health-Based Screening Levels |
| HBTORD | Health-Based Target Organ Risk Determination |
| HQ | Health Quotient |
| HSV | Health Screening Values |
| IARC | International Agency for Research on Cancer |
| ICBM | Intercontinental Ballistic Missile |
| ICRP | the International Commission on Radiological Protection |
| IRIS | Integrated Risk Information System |
| LCC | Launch Control Centers |
| LOD | Limit of Detection |
| LOQ | Limit of Quantification |
| MAF | Missile Alert Facility |
| MCCS | Missile Community Cancer Study |
| MCL | Maximum Contaminant Level |
| MEG | Military Exposure Guidelines |
| MPT | Missile Procedure Trainer |
| MRL | Minimal Risk Levels |

## ACRONYMS
**(Continued)**

| | |
|---|---|
| MSC | Medium Specific Concentrations |
| NCEHRD | Non-Cancer Estimated Health Risk Determination |
| NECi | National Environmental Compliance Institute |
| NHL | Non-Hodgkin Lymphoma |
| NIOSH | National Institute of Occupational Safety and Health |
| NTP | National Toxicology Program |
| OPPTS | Office of Prevention, Pesticides, and Toxic Substances |
| OSHA | Occupational Safety and Health Administration |
| PAC | Protective Action Criteria |
| PCB | Polychlorinated Biphenyl |
| PEL | Permissible Exposure Limit |
| pH | Potential of Hydrogen |
| PPM | Parts Per Million |
| PPRTV | Provisional Peer Reviewed Toxicity Values |
| RfC | Reference Concentration |
| RfD | Reference Dose |
| RH | Relative Humidity |
| RL | Reporting Limit |
| RoC | Report on Carcinogens |
| RSL | Regional Screening Levels |
| SBE | Statistical Base Exposure |
| SFB | Space Force Base |
| STATCOE | Scientific Test and Analysis Techniques Center of Excellence |
| SVOC | Semi-Volatile Organic Compounds |
| TECRD | Total Estimated Cancer Risk Determination |
| TEG | Test and Evaluation Group |
| THQ | Target Hazard Quotient |
| TLV | Threshold Limit Value |
| TNCEHRD | Total Non-Cancer Estimated Health Risk Determination |
| TORD | Target Organ Risk Determination |
| TR | Target Risk |
| TRS | Training Squadron |
| USAFSAM | United States Air Force School of Aerospace Medicine |
| USAFSAM/OE | United States Air Force School of Aerospace Medicine Occupational and Environmental Health Department |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| VOC | Volatile Organic Compounds |
| WHO | World Health Organization |
| WLM | Working Level Months |
| Yr | Year |

## APPENDIX 1 – MINOT AFB CONSOLIDATED SURFACE CONTAMINATION EXPOSURES

| CHEMICAL | CAS REGISTRY NUMBER | STATISTICAL BASE EXPOSURE [µg/100 $cm^2$] | CONFIDENCE | HEALTH SCREENING VALUE [µg/100 $cm^2$]* |
|---|---|---|---|---|
| Aroclor 1016 | 12674-11-2 | Non-Detect (<1 microgram per wipe (µg/wipe) | N/A | 10 |
| Aroclor 1221 | 11104-28-2 | Non-Detect (<1 µg/wipe) | N/A | 10 |
| Aroclor 1232 | 11141-16-5 | Non-Detect (<1 µg/wipe) | N/A | 10 |
| Aroclor 1242 | 53469-21-9 | Non-Detect (<1 µg/wipe) | N/A | 10 |
| Aroclor 1248 | 12672-29-6 | Non-Detect (<1 µg/wipe) | N/A | 10 |
| Aroclor 1254 | 11097-69-1 | 1.94 | 95.2% | 10 |
| Aroclor 1260 | 11096-82-5 | Non-Detect (<1 µg/wipe) | N/A | 10 |
| Total PCBs as Aroclor | 1336-36-3 | 1.83 | 95.2% | 10 |

µg/100 $cm^2$ = micrograms per 100 square centimeters

∗ Per 40 CFR 761

## APPENDIX 2 – MINOT AFB MAF CARCINOGEN LISTING

| CHEMICAL NAME | CAS NUMBER | IARC GROUP[1] | USEPA IRIS CLASSIFICATION[2] | DHHS NTP CLASSIFICATION[3] | NIOSH DETERMINATION[4] | ACGIH DETERMINATION[5] |
|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | 1 - Carcinogenic | A – Carcinogenic | Currently Not Classified | Potential Carcinogen | A1 – Confirmed Carcinogen |
| Methylene Chloride | 75-09-2 | 2A - Probably Carcinogenic | "Likely" Carcinogenic | Currently Not Classified | Potential Carcinogen | A3 – Animal Carcinogen |
| Radon-222 | 14859-67-7 | 1 - Carcinogenic | Carcinogen Assessment Withdrawn | Currently Not Classified | Currently Not Classified | Currently Not Classified |

**Sources:**

1. Agents Classified by the IARC Monographs, Volumes 1_136 (Accessed on 23 September 2024)
2. USEPA Integrated Risk Information System (IRIS), Last Updated on 20 August 2024 (Accessed on 24 September 2024)
3. 15th Report on Carcinogens, DHHS, Last Updated on 21 December 2021 (Accessed on 24 September 2024)
4. NIOSH Pocket Guide to Chemical Hazards, Last Reviewed on 18 February 2020 (Accessed on 24 September 2024)
5. ACGIH

**APPENDIX 3 – MINOT AFB STATISTICAL BASE EXPOSURE, CONFIDENCE, HEALTH SCREENING VALUE & CANCER CURVES**

| CHEMICAL | CAS REGISTRY NUMBER | STATISTICAL BASE EXPOSURE [µg/m$^3$] | CONFIDENCE | HEALTH SCREENING VALUE [µg/m$^3$] | INHALATION UNIT RISK [m$^3$/µg] | NUMBER OF SAMPLES WITH DETECTS [%] |
|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | 68 | 95.9% | 327.56 [1] | 7.8E-06 | 4 [5%] |
| Methylene Chloride | 75-09-2 | 11 | 97.9% | 1,752 [1] | 1E-08 | 1 [2%] |
| Toluene | 108-88-3 | 21 | 95.9% | 14,600 [1] | N/A | 4 [5%] |

| CHEMICAL | CAS REGISTRY NUMBER | STATISTICAL BASE EXPOSURE [WLM/yr] | CONFIDENCE | HEALTH SCREENING VALUE [WLM/yr] | INHALATION UNIT RISK [yr/WLM] | NUMBER OF SAMPLES WITH DETECTS [%] |
|---|---|---|---|---|---|---|
| Radon-222 | 14859-67-7 | 0.19 | 96.5% | 4 [3] | 5E-04 [7] | 75 [100%] |

| CHEMICAL | CAS REGISTRY NUMBER | STATISTICAL BASE EXPOSURE [µg/L] | CONFIDENCE | HEALTH SCREENING VALUE [µg/L] | ORAL SLOPE FACTOR [kg-day/µg] | NUMBER OF SAMPLES WITH DETECTS [%] |
|---|---|---|---|---|---|---|
| Total Nitrate/Nitrite | 14797-55-8 | 1,400 | 95.9% | 10,000 [4] | N/A | 90 [100%] |

µg = Micrograms; m$^3$ = Cubic Meter; WLM/yr = Working Level Months per Year; L = Liter; kg = Kilograms

1. **Tier 1:** Regional Screening Level, United States Environmental Protection Agency Integrated Risk Information System (Accessed 1 July 2024)
2. **Tier 2:** Provisional Peer-Reviewed Toxicity Values (PPRTV), United States Environmental Protection Agency (Accessed 1 July 2024)
3. **Tier 3:** Air Force Manual 48-148, *Ionizing Radiation Protection* (20 July 2020)
4. **Tier 1 Equivalent:** Maximum Contaminant Level, United States Environmental Protection Agency (Accessed 1 July 2024)
5. United States Environmental Protection Agency Integrated Risk Information System (Accessed 19 December 2024)

## APPENDIX 4 – MINOT AFB DETECTED CHEMICALS INCLUDED IN THE HEALTH RISK ASSESSMENT

| CHEMICAL NAME | CAS NUMBER | MATRIX | ROUTE OF EXPOSURE | TOTAL NUMBER OF SAMPLES ANALYZED* | TOTAL NUMBER OF TIMES DETECTED | PERCENT DETECTS | LOWEST VALUE OF DETECTS [µg/m$^3$] | HIGHEST VALUE OF DETECTS [µg/m$^3$] | MEDIAN VALUE OF DETECTS [µg/m$^3$] | CARCINOGEN OR NON-CARCINOGEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene*** | 71-43-2 | Air | Inhalation | 90 | 4 | 5% | 12 | 110 | 51 | Carcinogen |
| Methylene Chloride*** | 75-09-2 | | | 90 | 1 | 2% | 11 | 11 | 11 | Carcinogen |
| Toluene | 108-88-3 | | | 90 | 4 | 5% | 12 | 28 | 19 | Non-Carcinogen |

| CHEMICAL NAME | CAS NUMBER | MATRIX | ROUTE OF EXPOSURE | TOTAL NUMBER OF SAMPLES ANALYZED* | TOTAL NUMBER OF TIMES DETECTED | PERCENT DETECTS | LOWEST VALUE OF DETECTS [µg/L] | HIGHEST VALUE OF DETECTS [µg/L] | MEDIAN OF DETECTS VALUE [µg/L] | CARCINOGEN OR NON-CARCINOGEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Nitrate/Nitrite | 14797-55-8 | Drinking Water | Ingestion | 90 | 90 | 100% | 140 | 1,500 | 600 | Non-Carcinogen |

| CHEMICAL NAME | CAS NUMBER | MATRIX | ROUTE OF EXPOSURE | TOTAL NUMBER OF SAMPLES ANALYZED* | TOTAL NUMBER OF TIMES DETECTED | PERCENT DETECTS | LOWEST VALUE OF DETECTS [µg/Swipe] | HIGHEST VALUE OF DETECTS [µg/Swipe] | MEDIAN VALUE OF DETECTS [µg/Swipe] | CARCINOGEN OR NON-CARCINOGEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Aroclor-1254*** | 11097-69-1 | Surface | Absorption | 336 | 30 | 9% | 1.09 | 1710 | 60.05 | Carcinogen |

| CHEMICAL NAME | CAS NUMBER | MATRIX | ROUTE OF EXPOSURE | TOTAL NUMBER OF SAMPLES ANALYZED* | TOTAL NUMBER OF TIMES DETECTED | PERCENT DETECTS | LOWEST VALUE OF DETECTS [WLM/yr] | HIGHEST VALUE OF DETECTS [WLM/yr] | MEDIAN VALUE OF DETECTS** [WLM/yr] | CARCINOGEN OR NON-CARCINOGEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Radon-222*** | 14859-67-7 | Air | Inhalation | 75 | 75 | 100 | 0.08 | 0.55 | 0.15 | Carcinogen |

*Excludes Media Blanks and Trip Blanks.

** Average of the highest radon values for each MAF.

*** Indicates chemical has been deemed a carcinogen per the National Toxicology Program, United States Environmental Protection Agency, International Agency for Research on Cancer, National Institute of Occupational Safety and Health, and/or American Conference of Governmental Industrial Hygienists

**APPENDIX 5: MINOT AFB ESTIMATED PCB DERMAL EXPOSURE CANCER RISK DETERMINATION PER 10,000 PERSONNEL**

| BASED ON HIGHEST SURFACE CONCENTRATION DETECTED ON A FREQUENT CONTACT AREA SUCH AS CONSOLE KEYBOARD OR VISUAL DISPLAY SCREEN | | | | | | |
|---|---|---|---|---|---|---|
| **POLYCHLORINATED BIPHENYL (PCB) Wipes** | **CAS REGISTRY NUMBER** | **BASE EXPOSURE [µg/100 $cm^2$]** | **Location with Greatest Concentration** | **DERMAL UNIT RISK* [mg/kg-day]** | **CANCER RISK** | **TOTAL SURFACE SAMPLES** |
| Aroclor 1016 | 12674-11-2 | <1 | Not Applicable | 0.4 | 0.48 | 336 |
| Aroclor 1260 | 11096-82-5 | <1 | Not Applicable | | | |
| Aroclor 1221 | 11104-28-2 | <1 | Not Applicable | | | |
| Aroclor 1232 | 11141-16-5 | <1 | Not Applicable | | | |
| Aroclor 1242 | 53469-21-9 | <1 | Not Applicable | | | |
| Aroclor 1248 | 12672-29-6 | <1 | Not Applicable | | | |
| Aroclor 1254 | 11097-69-1 | 9.69 | Delta, Elevator Button (Inside Elevator) | | | |
| Total PCBs [unspecified] | 12767-79-2 | 9.69 | ibid | | | |
| **PCB Dermal Exposure Risk for Cancer per 10,000 Personnel** | | | | | **Less than 1** | |

* Source: United States Environmental Protection Agency, Hudson River PCBs Superfund Site/Human Health Tables/PCB Cancer Slope Factors

Background: 100 $cm^2$ is approx. surface area of the hand. µg/1000 = mg. 80 kg body weight [EPA Factors Handbook, Chapter 8]

Dose Calculation: (9.69 ug /1000 ug/mg)/80 kg = 0.00012 mg/kg-day

Cancer Risk Calculation = Dose x Dermal Unit Risk = 0.00012 x 0.4 = 0.000048

Exposure Risk per 10,000 personnel = 0.000048 x 10,0000 = 0.48

Assumptions: a) Entire hand surface exposed; b) Entire concentration transferred to the hand; c) not washed off /complete absorption; and d) Frequency and duration of exposure are aligned to a residential exposure where the occupant encounter dermal contact with the contaminated surface continuously for 24 hours per day, 350 days per year.

**APPENDIX 6 – MINOT AFB TOTAL ESTIMATED CANCER RISK DETERMINATION FOR MISSILE ALERT FACILITIES AFSCs PER 10,000 PERSONNEL BASED ON 70-YEARS OF EXPOSURE**

| CHEMICAL NAME | CAS NUMBER | MATRIX | ROUTE OF EXPOSURE | INHALATION CANCER RISK | INGESTION CANCER RISK | DERMAL CANCER RISK | CUMULATIVE CANCER RISK BY EXPOSURE PATHWAY | TOTAL ESTIMATED CANCER RISK | EXCEEDS ONE EXCESS CANCER RISK IN TEN THOUSAND [0.0001]?* | CANCER RISK** |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | Air | Inhalation | 5.3E-04 | --- | --- | 6.25E-04 | 6.73E-04 | Yes | 6.73 Excess Cancer Risks in 10,000 MAF Occupants |
| Methylene Chloride | 75-09-2 | | | 1.1E-07 | --- | --- | | | | |
| Radon-222 | 14859-67-7 | | | 9.5E-05 | --- | --- | | | | |
| Aroclor 1254 | 11097-69-1 | Surface | Absorption | --- | --- | 4.8E-05 | 4.8E-05 | | | |

* Source: National Institute of Occupational Safety and Health, *Current Intelligence Bulletin 68: NIOSH Chemical Carcinogen Policy* (2017)

** Number is attributed to Total Cancer Risk, which may include Non-Hodgkins Lymphoma (NHL)

## APPENDIX 7 – MINOT AFB EXPOSURE PATHWAY AND NON-CANCEROUS TARGET ORGAN LISTING

| CHEMICAL NAME | CAS NUMBER | EXPOSURE PATHWAY | NON-CANCEROUS TARGET ORGANS |
|---|---|---|---|
| Benzene | 71-43-2 | Inhalation | BL[1], BM[1], CNS[1], EY[1], GIT[4], IS[4], RP[1], SK[1] |
| Methylene Chloride | 75-09-2 | | BL[2], CNS[1], CVS[1], EY[1], Li[4], SK[1] |
| Toluene | 108-88-3 | | CNS[1], CVS[4], EY[1], IS[4], Ki[1], Li[1], RP[1], RS[2], SK[1], UT[4] |
| Radon-222 | 14859-67-7 | | RP[3] |
| Total Nitrate/Nitrite | 14797-55-8 | Ingestion | BL[3], CVS[3], RS[3] |
| Aroclor-1254 | 11097-69-1 | Dermal | SK[2] |

**Target Organs:** BL – Blood, BM – Bone Marrow, CNS – Central Nervous System, CVS – Cardiovascular System, EY – Eyes, GIT – Gastrointestinal Tract, IS – Immune System, Ki – Kidneys, Li – Liver, RP – Respiratory System, RS – Reproductive System, SK-Skin, UT – Urinary Tract

1. NIOSH Pocket Guide to Chemical Hazards, Last Reviewed on 18 February 2020 (Accessed on 25 September 2024)
2. American Conference of Governmental Industrial Hygienists 2024 Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices (Accessed 13 November 2024**)**
3. Agency for Toxic Substances and Disease Registry Toxic Substances Portal (Accessed 13 November 2024)
4. National Institute of Health – PUBCHEM (Accessed 13 November 2024)

## APPENDIX 8 – MINOT AFB CONSERVATIVE, UPPER-BOUND TARGET ORGAN RISK DETERMINATION BASED ON 8-YEARS OF EXPOSURE

| BY TARGET ORGAN | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Name** | **CAS Number** | **BL** | **BM** | **CNS** | **CVS** | **EY** | **GIT** | **IS** | **Ki** | **Li** | **RP** | **RS** | **SK** | **UT** |
| Benzene | 71-43-2 | 0.208 | 0.208 | 0.208 | --- | 0.208 | 0.208 | 0.208 | --- | --- | 0.208 | --- | 0.208 | --- |
| Methylene Chloride | 75-09-2 | 0.006 | --- | 0.006 | 0.006 | 0.006 | --- | --- | --- | 0.006 | --- | --- | 0.006 | --- |
| Toluene | 108-88-3 | --- | --- | 0.001 | 0.001 | 0.001 | --- | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Radon-222 | 14859-67-7 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.048 | --- | --- | --- |
| Total Nitrate/Nitrite | 14797-55-8 | 0.140 | --- | --- | 0.140 | --- | --- | --- | --- | --- | --- | 0.140 | --- | --- |
| Aroclor-1254 | 11097-69-1 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.969 | --- |
| Cumulative Risk By Target Organ | | 0.354 | 0.208 | 0.215 | 0.147 | 0.215 | 0.208 | 0.209 | 0.001 | 0.007 | 0.257 | 0.141 | **1.184** | 0.001 |

**Target Organs:** BL – Blood, BM – Bone Marrow, CNS – Central Nervous System, CVS – Cardiovascular System, EY – Eyes, GIT – Gastrointestinal Tract, IS – Immune System, Ki – Kidneys, Li – Liver, RP – Respiratory System, RS – Reproductive System, SK-Skin, UT – Urinary Tract

**Note:** Values represented in the Cumulative Risk By Target Organ are conservative given they do not consider the Toxicokinetic properties of each contaminant. The Cumulative Risk By Target Organ reflect risk associated with EXPOSURE only without consideration of ABSORPTION, INTERNAL DOSE, DISTRIBUTION, METABOLISM, and EXCRETION. Per the Agency for Toxic Substance and Disease Registration Public Health Assessment Guidance Manual (PHAGM), BIOLOGICAL EFFECTIVE CHANGE to a TARGET ORGAN is impacted by contamination source, exposure point, biological uptake (exposure), absorption, distribution, metabolism, and excretion. Further information on Toxicokinetic can be found at: https://www.atsdr.cdc.gov/pha-guidance/conducting_scientific_evaluations/indepth_toxicological_analysis/reviewContaminantToxInfo.html.

## APPENDIX 9 – MINOT AFB HEALTH-BASED TARGET ORGAN RISK DETERMINATION

**BY TARGET ORGAN**

| Chemical Name | CAS Number | Federal Health Limit [µg/m³] | BL | BM | CNS | CVS | EY | GIT | IS | Ki | Li | RP | RS | SK | UT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | 3,190 | 0.021 | 0.021 | 0.021 | --- | 0.021 | 0.021 | 0.021 | --- | --- | 0.021 | --- | 0.021 | --- |
| Methylene Chloride | 75-09-2 | 86,810 | 0.000 | --- | 0.000 | 0.000 | 0.000 | --- | --- | --- | 0.000 | --- | --- | 0.000 | --- |
| Toluene | 108-88-3 | 753,370 | --- | --- | 0.000 | 0.000 | 0.000 | --- | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Chemical Name** | **CAS Number** | **Federal Health Limit [WLM/yr]** | **BL** | **BM** | **CNS** | **CVS** | **EY** | **GIT** | **IS** | **Ki** | **Li** | **RP** | **RS** | **SK** | **UT** |
| Radon-222 | 14859-67-7 | 4 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.048 | --- | --- | --- |
| **Chemical Name** | **CAS Number** | **Federal Health Limit [µg/L]** | **BL** | **BM** | **CNS** | **CVS** | **EY** | **GIT** | **IS** | **Ki** | **Li** | **RP** | **RS** | **SK** | **UT** |
| Total Nitrate/Nitrite | 14797-55-8 | 10,000 | 0.140 | --- | --- | 0.140 | --- | --- | --- | --- | --- | --- | 0.140 | --- | --- |
| **Chemical Name** | **CAS Number** | **Federal Health Limit [µg/100 cm²]** | **BL** | **BM** | **CNS** | **CVS** | **EY** | **GIT** | **IS** | **Ki** | **Li** | **RP** | **RS** | **SK** | **UT** |
| Aroclor-1254 | 11097-69-1 | 10 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.969 | --- |
| Cumulative Risk By Target Organ | | | 0.161 | 0.021 | 0.021 | 0.140 | 0.021 | 0.021 | 0.021 | --- | --- | 0.021 | 0.140 | 0.990 | --- |

**Target Organs:** BL – Blood, BM – Bone Marrow, CNS – Central Nervous System, CVS – Cardiovascular System, EY – Eyes, GIT – Gastrointestinal Tract, IS – Immune System, Ki – Kidneys, Li – Liver, RP – Respiratory System, RS – Reproductive System, SK-Skin, UT – Urinary Tract

**Note:** Values represented in the Cumulative Risk By Target Organ are conservative given they do not consider the Toxicokinetic properties of each contaminant. The Cumulative Risk By Target Organ reflect risk associated with EXPOSURE only without consideration of ABSORPTION, INTERNAL DOSE, DISTRIBUTION, METABOLISM, and EXCRETION. Per the Agency for Toxic Substance and Disease Registration Public Health Assessment Guidance Manual (PHAGM), BIOLOGICAL EFFECTIVE CHANGE to a TARGET ORGAN is impacted by contamination source, exposure point, biological uptake (exposure), absorption, distribution, metabolism, and excretion. Further information on Toxicokinetic can be found at: https://www.atsdr.cdc.gov/pha-guidance/conducting_scientific_evaluations/indepth_toxicological_analysis/reviewContaminantToxInfo.html.

## APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [µg/m$^3$] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Carbon Tetrachloride | 56-23-5 | Inhalation | EPA TO17 | All Results < 10 | 90 |
| Parathion | 56-38-2 | | NIOSH 5600 | All Results < 10 | 90 |
| Chloroform | 67-66-3 | | EPA TO17 | All Results < 10 | 90 |
| 1,1,1-Trichloroethane | 71-55-6 | | EPA TO17 | All Results < 10 | 90 |
| Bromochloromethane | 74-97-5 | | EPA TO17 | All Results < 10 | 90 |
| Bromoform | 75-25-2 | | EPA TO17 | All Results < 10 | 90 |
| Bromodichloromethane | 75-27-4 | | EPA TO17 | All Results < 10 | 90 |
| 1,1-Dichloroethane | 75-34-3 | | EPA TO17 | All Results < 10 | 90 |
| 1,1-Dichloroethylene | 75-35-4 | | EPA TO17 | All Results < 10 | 90 |
| 1,2-Dichloropropane | 78-87-5 | | EPA TO17 | All Results < 10 | 90 |
| 1,1,2-Trichloroethane | 79-00-5 | | EPA TO17 | All Results < 10 | 90 |
| Trichloroethylene | 79-01-6 | | EPA TO17 | All Results < 10 | 90 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | | EPA TO17 | All Results < 10 | 90 |
| 1,2,3-Trichlorobenzene | 87-61-6 | | EPA TO17 | All Results < 10 | 90 |
| Hexachlorobutadiene | 87-68-3 | | EPA TO17 | All Results < 10 | 90 |
| Naphthalene | 91-20-3 | | EPA TO17 | All Results < 10 | 90 |
| o-Xylene | 95-47-6 | | EPA TO17 | All Results < 10 | 90 |
| 2-Chlorotoluene | 95-49-8 | | EPA TO17 | All Results < 10 | 90 |
| 1,2-Dichlorobenzene | 95-50-1 | | EPA TO17 | All Results < 10 | 90 |
| 1,2,4-Trimethylbenzene | 95-63-6 | | EPA TO17 | All Results < 10 | 90 |
| 1,2-Dibromo-3-Chlororpropane (DBCP) | 96-12-8 | | EPA TO17 | All Results < 10 | 90 |
| 1,2,3-Trichloropropane | 96-18-4 | | EPA TO17 | All Results < 10 | 90 |
| Tert-Butylbenzene | 98-06-6 | | EPA TO17 | All Results < 10 | 90 |
| Isopropylbenzene | 98-82-8 | | EPA TO17 | All Results < 10 | 90 |
| p-Isopropyltoluene | 99-87-6 | | EPA TO17 | All Results < 10 | 90 |
| Ethylbenzene | 100-41-4 | | EPA TO17 | All Results < 10 | 90 |
| Styrene | 100-42-5 | | EPA TO17 | All Results < 10 | 90 |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [µg/m$^3$] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| n-Propylbenzene | 103-65-1 | Inhalation | EPA TO17 | All Results < 10 | 90 |
| n-Butylbenzene | 104-51-8 | | EPA TO17 | All Results < 10 | 90 |
| 4-Chlorotoluene | 106-43-4 | | EPA TO17 | All Results < 10 | 90 |
| 1,4-Dichlorobenzene | 106-46-7 | | EPA TO17 | All Results < 10 | 90 |
| Ethylene Dibromide | 106-93-4 | | EPA TO17 | All Results < 10 | 90 |
| 1,2-Dichloroethane | 107-06-2 | | EPA TO17 | All Results < 10 | 90 |
| 1,3,5-Trimethylbenzene | 108-67-8 | | EPA TO17 | All Results < 10 | 90 |
| Bromobenzene | 108-86-1 | | EPA TO17 | All Results < 10 | 90 |
| Chlorobenzene | 108-90-7 | | EPA TO17 | All Results < 10 | 90 |
| 1,2,4-Trichlorobenzene | 120-82-1 | | EPA TO17 | All Results < 10 | 90 |
| Malathion | 121-75-5 | | NIOSH 5600 | All Results < 10 | 90 |
| Dibromochloromethane | 124-48-1 | | EPA TO17 | All Results < 10 | 90 |
| Tetrachloroethylene | 127-18-4 | | EPA TO17 | All Results < 10 | 90 |
| Sec-Butylbenzene | 135-98-8 | | EPA TO17 | All Results < 10 | 90 |
| Dicrotophos | 141-66-2 | | NIOSH 5600 | All Results < 10 | 90 |
| 1,3-Dichloropropane | 142-28-9 | | EPA TO17 | All Results < 10 | 90 |
| Cis-1,2-Dichloroethylene | 156-59-2 | | EPA TO17 | All Results < 10 | 90 |
| Trans-1,2-Dichloroethylene | 156-60-5 | | EPA TO17 | All Results < 10 | 90 |
| Methyl Parathion | 298-00-0 | | NIOSH 5600 | All Results < 10 | 90 |
| Phorate | 298-02-2 | | NIOSH 5600 | All Results < 10 | 90 |
| Diazinon | 333-41-5 | | NIOSH 5600 | All Results < 10 | 90 |
| 1,3-Dichlorobenzene | 541-73-1 | | EPA TO17 | All Results < 10 | 90 |
| 1,1-Dichloropropylene | 563-58-6 | | EPA TO17 | All Results < 10 | 90 |
| 1,1,1,2-Tetrachloroethane | 630-20-6 | | EPA TO17 | All Results < 10 | 90 |
| Chlorpyrifos | 2921-88-2 | | NIOSH 5600 | All Results < 10 | 90 |
| Trans-1,3-Dichloropropene | 10061-02-6 | | EPA TO17 | All Results < 10 | 90 |
| Methamidophos | 10265-92-6 | | NIOSH 5600 | All Results < 10 | 90 |
| Aroclor 1260 | 11096-82-5 | | NIOSH 5503 | All Results < 2.1 | 32 |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [µg/m$^3$] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Aroclor 1254 | 11097-69-1 | Inhalation | NIOSH 5503 | All Results < 2.1 | 32 |
| Aroclor 1221 | 11104-28-2 | | NIOSH 5503 | All Results < 2.1 | 32 |
| Aroclor 1232 | 11141-16-5 | | NIOSH 5503 | All Results < 2.1 | 32 |
| Aroclor 1248 | 12672-29-6 | | NIOSH 5503 | All Results < 2.1 | 32 |
| Aroclor 1016 | 12674-11-2 | | NIOSH 5503 | All Results < 2.1 | 32 |
| Terbufos | 13071-79-9 | | NIOSH 5600 | All Results < 10 | 90 |
| Ethoprophos | 13194-48-4 | | NIOSH 5600 | All Results < 10 | 90 |
| Aroclor-1242 | 53469-21-9 | | NIOSH 5503 | All Results < 2.1 | 32 |
| Cis-1,3-Dichloropropene | 100061-01-5 | | EPA TO17 | All Results < 10 | 90 |
| p+m-Xylene | 179601-23-1 | | EPA TO17 | All Results < 10 | 90 |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [µg/L] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Dichlorodiphenyltrichloroethane (DDT) | 50-29-3 | Ingestion | EPA 525.2 | All Results < 0.11 | 30 |
| Benzo[a]pyrene | 50-32-8 | | EPA 525.2 | All Results < 0.12 | 90 |
| Dibenz[a,h]anthracene | 53-70-3 | | EPA 525.2 | All Results < 0.11 | 30 |
| Parathion | 56-38-2 | | EPA 525.2 | All Results < 0.54 | 30 |
| Benzo[a]anthracene | 56-55-3 | | EPA 525.2 | All Results < 0.12 | 90 |
| Gamma-BHC Lindane | 58-89-9 | | EPA 525.2 | All Results < 0.12 | 90 |
| Dimethoate | 60-51-5 | | EPA 525.2 | All Results < 0.54 | 30 |
| Dieldrin | 60-57-1 | | EPA 525.2 | All Results < 0.24 | 90 |
| Endrin | 72-20-8 | | EPA 525.2 | All Results < 0.24 | 90 |
| Methoxychlor | 72-43-5 | | EPA 525.2 | All Results < 0.24 | 90 |
| Dichlorodiphenyl dichloroethane (DDD) | 72-54-8 | | EPA 525.2 | All Results < 0.11 | 30 |
| Dichlorodiphenyldichloroethylene (DDE) | 72-55-9 | | EPA 525.2 | All Results < 0.24 | 90 |
| Heptachlor | 76-44-8 | | EPA 525.2 | All Results < 0.12 | 90 |
| Hexachlorocyclopentadiene | 77-47-4 | | EPA 525.2 | All Results < 0.24 | 90 |
| Acenaphthene | 83-32-9 | | EPA 525.2 | All Results < 0.12 | 90 |
| Diethyl Phthalate | 84-66-2 | | EPA 525.2 | All Results < 1.2 | 90 |
| Di-n-butylphthalate | 84-74-2 | | EPA 525.2 | All Results < 2.1 | 90 |
| Phenanthrene | 85-01-8 | | EPA 525.2 | All Results < 0.12 | 90 |
| Butylbenzylphthalate | 85-68-7 | | EPA 525.2 | All Results < 1.2 | 90 |
| Fluorene | 86-73-7 | | EPA 525.2 | All Results < 0.12 | 90 |
| 1-Methylnaphthalene | 90-12-0 | | EPA 525.2 | All Results < 0.11 | 30 |
| Naphthalene | 91-20-3 | | EPA 525.2 | All Results < 0.24 | 90 |
| 2-Methylnaphthalene | 91-57-6 | | EPA 525.2 | All Results < 0.24 | 90 |
| Di(2-ethylhexyl)adipate | 103-23-1 | | EPA 525.2 | All Results < 1.2 | 90 |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [µg/L] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Di-n-octylphthalate | 117-84-0 | Ingestion | EPA 525.2 | All Results < 2.1 | 30 |
| Di(2-ethylhexyl)phthalate | 117-81-7 | | EPA 525.2 | All Results < 1.2 | 30 |
| Hexachlorobenzene | 118-74-1 | | EPA 525.2 | All Results < 0.12 | 90 |
| Anthracene | 120-12-7 | | EPA 525.2 | All Results < 0.24 | 90 |
| Malathion | 121-75-5 | | EPA 525.2 | All Results < 0.11 | 30 |
| Simazine | 122-34-9 | | EPA 525.2 | All Results < 0.24 | 90 |
| Pyrene | 129-00-0 | | EPA 525.2 | All Results < 0.12 | 90 |
| Dimethyl Phthalate | 131-11-3 | | EPA 525.2 | All Results < 1.2 | 90 |
| Benzo[g,h,i]perylene | 191-24-2 | | EPA 525.2 | All Results < 0.12 | 90 |
| Indeno[1,2,3-cd]pyrene | 193-39-5 | | EPA 525.2 | All Results < 0.12 | 90 |
| Benzo[b]fluoranthene | 205-99-2 | | EPA 525.2 | All Results < 0.12 | 90 |
| Fluoranthene | 206-44-0 | | EPA 525.2 | All Results < 0.24 | 90 |
| Benzo[k]fluoranthene | 207-08-9 | | EPA 525.2 | All Results < 0.12 | 90 |
| Acenaphthylene | 208-96-8 | | EPA 525.2 | All Results < 0.11 | 90 |
| Chrysene | 218-01-9 | | EPA 525.2 | All Results < 0.11 | 90 |
| Aldrin | 309-00-2 | | EPA 525.2 | All Results < 0.24 | 90 |
| Bromacil | 314-40-9 | | EPA 525.2 | All Results < 0.11 | 30 |
| Diazinon | 333-41-5 | | EPA 525.2 | All Results < 0.11 | 30 |
| Ethyl Dipropylthiocarbamate (EPTC) | 759-94-4 | | EPA 525.2 | All Results < 0.24 | 90 |
| Deisopropylatrazine | 1007-28-9 | | EPA 525.2 | All Results < 1.1 | 30 |
| Heptachlor Epoxide | 1024-57-3 | | EPA 525.2 | All Results < 0.12 | 90 |
| Total PCBs | 1336-36-3 | | EPA 505 | All Results < 0.52 | 90 |
| Trifluralin | 1582-09-8 | | EPA 525.2 | All Results < 0.24 | 90 |
| 2-3-7-8-Tetrachlorodibenzo-p-dioxin | 1746-01-6 | | EPA 1613B | All Results < 4.5E-6 | 30 |
| Chlorothalonil | 1897-45-6 | | EPA 525.2 | All Results < 0.11 | 30 |
| Atrazine | 1912-24-9 | | EPA 525.2 | All Results < 0.22 | 90 |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [µg/L] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Propachlor | 1918-16-7 | Ingestion | EPA 525.2 | All Results < 0.24 | 90 |
| Molinate | 2212-67-1 | | EPA 525.2 | All Results < 0.24 | 90 |
| Diquat | 2764-72-9 | | EPA 549.2 | All Results < 2 | 90 |
| Paraquat | 4685-14-7 | | EPA 549.2 | All Results < 2 | 90 |
| Chlordane (Alpha) | 5103-71-9 | | EPA 525.2 | All Results < 0.11 | 30 |
| Chlordane (Gamma) | 5103-74-2 | | EPA 525.2 | All Results < 0.11 | 30 |
| Terbacil | 5902-51-2 | | EPA 525.2 | All Results < 0.61 | 90 |
| Atrazine-Desethyl | 6190-65-4 | | EPA 525.2 | All Results < 1.1 | 30 |
| Prometryn | 7287-19-6 | | EPA 525.2 | All Results < 0.11 | 30 |
| Toxaphene | 8001-35-2 | | EPA 505 | All Results < 2.1 | 90 |
| Aroclor 1260 | 11096-82-5 | | EPA 505 | All Results < 0.52 | 90 |
| Aroclor 1254 | 11097-69-1 | | EPA 505 | All Results < 0.52 | 90 |
| Aroclor 1221 | 11104-28-2 | | EPA 505 | All Results < 0.52 | 90 |
| Aroclor 1232 | 11141-16-5 | | EPA 505 | All Results < 0.52 | 90 |
| Aroclor 1248 | 12672-29-6 | | EPA 505 | All Results < 0.52 | 90 |
| Aroclor 1016 | 12674-11-2 | | EPA 505 | All Results < 0.52 | 90 |
| Chlordane (Technical) | 12789-03-6 | | EPA 505 | All Results < 0.52 | 90 |
| Alachlor | 15972-60-8 | | EPA 525.2 | All Results < 0.24 | 90 |
| Metribuzin | 21087-64-9 | | EPA 525.2 | All Results < 0.24 | 90 |
| Cyanazine | 21725-46-2 | | EPA 525.2 | All Results < 0.11 | 30 |
| Butachlor | 23184-66-9 | | EPA 525.2 | All Results < 0.24 | 90 |
| Thiobencarb | 28249-77-6 | | EPA 525.2 | All Results < 0.11 | 30 |
| Trans-Nonachlor | 39765-80-5 | | EPA 525.2 | All Results < 0.11 | 30 |
| Metolachlor | 51218-45-2 | | EPA 525.2 | All Results < 0.24 | 30 |
| Aroclor 1242 | 53469-21-9 | | EPA 505 | All Results < 0.52 | 90 |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION* [mg/kg-dry] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Parathion | 56-38-2 | Adsorption | EPA 1699 | All Results < 0.273 | 264 |
| Methyl Parathion | 298-00-0 | | | | |
| Phorate | 298-02-2 | | | | |
| Malathion | 121-75-5 | | | | |
| Dicrotophos | 141-66-2 | | | | |
| Diazinon | 333-41-5 | | | | |
| Chlorpyrifos | 2921-88-2 | | | | |
| Methamidophos | 10265-92-6 | | | | |
| Terbufos | 13071-79-9 | | | | |
| Ethoprophos | 13194-48-4 | | | | |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 10 – MINOT AFB CHEMICALS NOT ASSESSED FOR HEALTH RISK: ALL SAMPLE RESULTS LESS THAN RL/LOQ (Continued)**

| CHEMICAL NAME | CAS NUMBER | ROUTE OF EXPOSURE | LABORATORY METHOD | LIMIT OF QUANTIFICATION [µg/Swipe] | TOTAL NUMBER OF SAMPLES ANALYZED** |
|---|---|---|---|---|---|
| Aroclor 1016 | 12674-11-2 | Adsorption | EPA 8082A | All Results < 1.00 | 336 |
| Aroclor 1260 | 11096-82-5 | | | | |
| Aroclor 1221 | 11104-28-2 | | | | |
| Aroclor 1232 | 11141-16-5 | | | | |
| Aroclor 1242 | 53469-21-9 | | | | |
| Aroclor 1248 | 12672-29-6 | | | | |

* Limit of Quantification (LOQ) based on maximum LOQ between Rounds 1, 2 & 3.

** Excludes Media Blanks and Trip Blanks.

**APPENDIX 11 – MINOT AFB TOTAL CONSERVATIVE, UPPER-BOUND NON-CANCER ESTIMATED HEALTH RISK DETERMINATION FOR MISSILE ALERT FACILITIES AFSCs BASED ON 8-YEARS OF EXPOSURE**

| CHEMICAL NAME | CAS NUMBER | MATRIX | ROUTE OF EXPOSURE | ESTIMATED HEALTH INHALATION RISK | ESTIMATED HEALTH INGESTION RISK | ESTIMATED HEALTH DERMAL RISK | CUMULATIVE HEALTH RISK | TOTAL NON-CANCER HEALTH RISK | EXCEEDANCE IN HEALTH RISK? | HEALTH RISK |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 71-43-2 | Air | Inhalation | 0.208 | N/A | N/A | 0.263 | 1.372 | Yes | See Appendix 8 & 9. |
| Methylene Chloride | 75-09-2 | | | 0.006 | N/A | N/A | | | | |
| Toluene | 108-88-3 | | | 0.001 | N/A | N/A | | | | |
| Radon-222 | 14859-67-7 | | | 0.048 | N/A | N/A | | | | |
| Total Nitrate/Nitrite | 14797-55-8 | Drinking Water | Ingestion | N/A | 0.140 | N/A | 0.140 | | | |
| Aroclor-1254 | 11097-69-1 | Surface | Dermal | N/A | N/A | 0.969 | 0.969 | | | |

**Acronym Table**

| | |
|---|---|
| **E-PERM** | **Trade name for a Radon measurement system** |
| **EPA** | **United States Environmental Protection Agency** |
| **EPA TO-17** | **Compendium Method TO-17 – Determination of volatile organic compounds in ambient air using active sampling onto sorbent tubes** |
| **HSV** | **Health Screening Value** |
| **IUR** | **Inhalation Unit Risk** |
| **L** | **Liters** |
| **LCC** | **Launch Control Center** |
| **LOQ** | **Limit of Quantitation** |
| **MAF** | **Missile Alert Facility** |
| **MCL** | **Maximum Contaminant Level (Drinking water)** |
| **NIOSH** | **National Institute of Occupational Safety and Health** |
| **- Method 5503** | **NIOSH Air Sampling Method for Polychlorobiphenyls** |
| **- Method 5600** | **NIOSH Air Sampling Method for Organophosphorus Pesticides** |
| **OEL** | **Occupational Exposure Limit (Air)** |
| **PCB** | **Polychlorinated Biphenyl** |
| **pH** | |
| **QA** | **Quality Assurance** |
| **QC** | **Quality Control** |
| **RL** | **Reporting Limit** |
| **SVOC** | **Semi-Volatile Organic Compound** |
| **TD** | **Thermal Desorption** |
| **USAF** | **United States Air Force** |
| **USAFSAM** | **United States Air Force School of Aerospace Medicine** |
| **VOC** | **Volatile Organic Compound** |

## Table 1 - Sampling of Air for VOCs, Pesticides, PCBs

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Mitigating Step |
|---|---|---|
| 1. Air sampling not sufficiently sensitive to detect concentrations that are less than the Inhalation Unit Risk (IUR) level for cancer and the Health Screening Value for non-cancer. | Overall Directionality if True:<br><br>Overestimate.<br><br>Note: The Reporting Limit (RL) or Limit of Quantification (LOQ) was the same for all EPA TO -17 analytes at 10 µg/m3 and varied for NIOSH Method 5600 for organophosphorus pesticides and for PCBs via NIOSH Method 5503. | + Validated, current, comprehensive NIOSH and EPA air sampling & analytical methods utilized.<br>+ These methods were developed to have Reporting Limits (RLs) or Limits of Quantification (LOQs) that are 10 times below the occupational exposure limits (OELs) and Health Screening Values (HSVs).<br>+ Cancer risk factors such as Inhalation Unit Risk (IUR) or non-cancer risk factors such as health screening values (HSVs) are geared towards sensitive individuals such as children. Thus, they are set at much lower concentrations than OELs.<br>+ Even if all results for a contaminant were less than the RL/LOQ, if the RL or LOQ were higher than the IUR or HSV, there is a region of uncertainty between RL or LOQ and the IUR or HSV.<br>+ The uncertainty was accounted for in the cancer and non-cancer risk estimates given the cancer estimate was based on 70-year exposures and HSVs were many times more conservative than the chemicals' corresponding OEL. |

| | | |
|---|---|---|
| 2. Point in time sample collection versus potential environmental variability in concentrations over time. | Overall Directionality if True:<br><br>Unknown – depends on environmental factor that could lead to overestimation or underestimation. | + A sampling strategy that incorporates randomness and sampling at different times of the year can compensate for environmental variability.<br>+ Three rounds of sampling occurred during different seasons on random days within each season. |
| 3. Insufficient air volume collected versus specified range for method. | Overall Directionality if True:<br><br>Overestimate | + Validated NIOSH and EPA sampling and analytical methods were used.<br>+ Air volumes collected via Method 5503 were within the minimum and maximum allowed volumes. |
| 4. Greater air volume collected versus typical range for method. | Overall Directionality if True:<br><br>Potentially underestimate ambient concentration if tube had no backup section.<br><br>Underestimate if analyte found on backup section of media. | + Air volumes collected via Method 5600 were at the maximum allowed volume of 60L for Malathion & 240L for other Organophosphorus pesticides<br>+ Air volumes collected via TO-17 were greater than the 4L maximum volume. Per EPA documents, the method allows for one tube to screen sample locations and collection of volumes greater than 4L is allowed to fit target lists and monitoring objectives. |
| 5. Sample flow rate above specified range for method. | Overall Directionality if True:<br><br>Potentially Underestimate ambient concentration.<br><br>“Potentially” because a higher flow rate could strip the higher volatility VOCs off the sample media. | + NIOSH and EPA sampling and analytical methods were followed.<br>+ The methods specify the acceptable flow rate or range of flow rates.<br>+ Sample pumps that drew air through the sample media were calibrated before and after sampling to verify flow rates were intended to be within the specified ranges. |

| | | |
|---|---|---|
| 6. Sample flow rate below specified range for method. | Overall Directionality if True:<br><br>Potentially underestimate ambient concentration.<br><br>"Potentially" because the flow rate does not effectively capture the VOCs. | + NIOSH and EPA sampling and analytical methods were followed. The methods specify the acceptable flow rate or range of flow rates.<br>+ Sample pumps that drew air through the sample media were calibrated before and after sampling to verify flow rates were intended to be within the specified ranges. |
| 7. <u>Applicable to EPA TO-17</u>: Sampling for volatile and semi-volatile organic compounds with thermal desorption (TD) tubes: inadequate purge of TD tubes obtained from contract laboratory. | Overall Directionality if True:<br><br>Likely overestimation of actual ambient concentration. | + Carbotrap 300 tubes were used and VOCs detected on field and media (Lab) sample blanks when there should have been no VOCs present.<br>+ Carbotrap 300 tubes can be reused and there is a protocol for purging them.<br>+ When the issue was discovered, the USAFSAM lab was informed, and the contract laboratory was notified the QC control media (i.e. lab and field blanks) had positive results.<br>+ LCC and Topside sample results were not adjusted. |
| 8. Media, because of manufacturing process, contains residual chemical constituents. | Overall Directionality if True:<br><br>Overestimate. | + Lab blanks (not unsealed or opened sample media) and field blanks (unsealed and resealed media with no air drawn through) submitted for each Missile Alert Facility.<br>+ The lab and field blanks were analyzed as part of the QC process to determine if residual chemicals were present on the unsampled media. |

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| 9. Outdoor air samples not collected while indoor samples were collected. | Overall Directionality if True:<br><br>Overestimate. | + Some VOCs, (e.g. toluene, benzene, and others) are ubiquitous in the outdoor environment or present because of local industry or agricultural practices.<br>+Buildings exchange air with the outdoors, VOCs from outdoors could be present in the indoor environment.<br>+ Outdoor samples are typically collected for indoor air quality assessments when TO-17 sampling occurs, and positive outdoor results are accounted for since VOCs present outdoors can influence indoor levels. |
| 10. Samples were tampered with between the time they were shipped to when they arrived at the lab. | Overall Directionality if True:<br><br>Unknown. | + Chain of custody forms were used and physical custody maintained until shipped.<br>+ Each lab report contains a copy of the chain of custody and any notes as to condition of the samples as received. |
| 11. Inadequate quality control (QC) steps. | Overall Directionality if True:<br><br>Depends on quality control results.<br><br>Unable to determine if no quality control. | + Laboratories utilized had accreditations by independent entities.<br>+ Operating procedures, quality assurance/control, personnel qualifications, and analytical proficiency typically evaluated as part of accreditation process.<br>+ Sample blanks (field and lab) submitted.<br>+ Each lab conducted its own QC analysis to check instrument performance. Any anomalies regarding instrument performance or analysis were noted in the report. |

## Table 2 - Sampling of Air for Radon

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Mitigating Step |
|---|---|---|
| 1. Radon sampling strategy not sufficient to quantify cancer risk. | Overall Directionality if True:<br><br>Underestimate. | + Uranium 238 is found in soil at varying concentrations. Radon 222 (a radioisotope of Radon) is a gas that has short-lived decay products such as Polonium-218 and -214, which emit alpha particles. In the lung the alpha particles can damage the lining, potentially leading to lung cancer.<br>+ E-PERM Electrets were used to detect alpha particle decay.<br>+ Sampling was consistent with where Radon could partition within the indoor environment.<br>+ Sampling occurred Topside and in the LCC and repeated with each round.<br>+ To compensate for environmental variability, three rounds of sampling occurred during different seasons on random days within each season. |
| 2. Sampling strategy in MAFs not sufficient. | Overall Directionality if True:<br><br>Underestimate. | + E-PERM Electret devices were deployed to locations within each MAF where personnel spend significant time: A) Topside Facility Manager Bedroom; B) Topside Common Area; C) Topside Security Forces Room; D) Launch Control Center (LCC); and E) Hallway Corridor outside LCC. |
| 3. High humidity (steam). | Overall Directionality if True:<br><br>Overestimate. | + E-PERM Electrets were not placed in areas where steam could be present such as bathrooms, shower facilities, and Topside Kitchen. |

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| 4. Inadequate ventilation resulting in high humidity or not enough air flow to mitigate gaseous concentrations of Radon 222 and Radon daughters. | Overall Directionality if True:<br><br>Overestimate. | + Radon levels detected were well below the Annual Working Level Months – suggesting adequate ventilation.<br>+ Radon concentrations within each MAF were similar and suggests consistent airflow throughout each MAF. |
| 5. The number of days for sampling not sufficient | Overall Directionality if True:<br><br>Unknown/Unclear. | + Per Federal and USAF requirements, duration >90 days for all samples. Total 24-hr sample days for each sample location exceeded 270 days (3 x 90 days). |
| 6. Variation in sample duration between MAFs | Overall Directionality if True:<br><br>Unknown/Unclear. | + While all E-PERMs deployed met Federal requirements to sample the air for >90 days, logistics prevented deploying all or collecting all on the same day.<br>+ Because they were not deployed or collected on the same day, there were differences in the overall number of sampling days for each electret. For Round 1, the maximum difference was 9 days, 6 days for Round 2, and 8 days for Round 3.<br>+ When they were collected, they were read on the same at that time. |
| 7. Inadequate quality control steps. | Overall Directionality if True:<br><br>Unknown/Unclear. | + Personnel from the Bioenvironmental Shop familiar with the E-PERM electrets and consequences of dropping them; deployed the electrets for Round 1.<br>+ Local Bioenvironmental shop personnel conducted the radon reading Topside because the reader was not allowed in the LCC. Results were recorded in a logbook<br>+ When the E-PERM electrets were redeployed back to the sample locations, the serial number and voltage recorded. |

## Table 3 - Sampling of Drinking Water for SVOCs, Diquat/Paraquat, PCBs, Dioxin, Total Nitrate/Nitrite

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Mitigating Step |
|---|---|---|
| 1. Drinking water sampling not sufficiently sensitive to detect concentrations that are less than the Inhalation Unit Risk (IUR) level for cancer and the Health Screening Value for non-cancer. | Overall Directionality if True:<br><br>Overestimate.<br><br>Note: The RL or LOQ varied for the contaminants, except for Nitrate/Nitrite. | + Validated, current, comprehensive EPA drinking water sampling & analytical methods utilized.<br>+ These methods were developed to have Reporting Limits (RLs) or Limits of Quantification (LOQs) that are below local, state or federal maximum contaminant levels (MCLs).<br>+ Cancer risk factors such as cancer slopes for ingestion or non-cancer risk factors such as health screening values (HSVs) are geared towards sensitive individuals such as children. Thus, they are set at much lower concentrations than OELs and HSVs.<br>+ Even if all results for a contaminant were less than the RL/LOQ, if the RL or LOQ were higher than the IUR or HSV, there is a region of uncertainty between RL or LOQ and the IUR or HSV.<br>+ The uncertainty was accounted for in the cancer and non-cancer risk estimates. |
| 2. Differing drinking water sources between MAFs: 1) Wells in different aquifers; 2) Small local municipal facilities; 3) Wholesale water trucked in (under limited circumstances) resulting in localized differences. | Overall Directionality if True:<br><br>Uncertain/Unclear. | + Cancer risk estimates apply to all 15 MAFs at the installation regardless of drinking water source. |

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| 3. Reverse Osmosis filters not changed within the serviceable timeframe. | Overall Directionality if True:<br><br>No bias. | + Not determined.<br>+ The results associated with the sample would indicate the current state of the water quality. |
| 4. Reverse Osmosis system disconnected. | Overall Directionality if True:<br><br>No bias. | The results associated with the sample would indicate the current state of the water quality. |
| 5. Cross-contamination between samples by collector. | Overall Directionality if True:<br><br>Overestimate. | + Standard protocol is to wear disposable gloves when collecting samples at a sample location and changing to new gloves when sampling at a subsequent location. |
| 6. Timing of sample collection not first draw but after running the water for 5 minutes. | Overall Directionality if True:<br><br>Unknown/Unclear. | + MAFs are remotely located and manned 24/7, meaning first draw is meaningless.<br>+ Overall directionality of uncertainty mostly influenced by water source.<br>+Timing of draw standardized. |
| 7. Samples were tampered with between the time they were shipped to when they arrived at the lab. | Overall Directionality if True:<br><br>Unknown/Unclear. | + Chain of custody forms were used and physical custody maintained until shipped.<br>+ Each lab report contains a copy of the chain of custody and any notes as to condition of the samples as received (e.g. when sample containers broke during shipping, it is noted in reports). |
| 8. Water samples not at required temperature parameter upon arrival to the laboratory. | Overall Directionality if True:<br><br>Underestimate due to potential degradation of sample constituents. | + Laboratories provided instructions for the collection and shipping of samples. All exceptions were documented in laboratory reports. |

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| 9. Inadequate quality control (QC) steps. | Overall Directionality if True:<br><br>Depends on quality control results.<br><br>Unable to determine if no quality control. | + Laboratories utilized had accreditations by independent entities.<br>+ Operating procedures, quality assurance/control, personnel qualifications, and analytical proficiency typically evaluated as part of accreditation process.<br>+ Collection of Matrix Spike (MS) and Matrix Spike Duplicate (MSD) samples at each sample location.<br>+ Laboratories prepared Laboratory Control Samples and compared against each contaminant in the MS and MSD samples to determine if analytical bias for contaminants in the water sources was high, neutral, or low.<br>+ Results not adjusted. |

## Table 4 - Sampling of Soil for Organophosphate Pesticides

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Mitigating Step |
|---|---|---|
| 1. Analytical instrument capability to detect contaminants in soil samples (e.g. RL, or LOQ) is not sufficiently sensitive compared to health screening values. | Overall Directionality if True:<br><br>None. | + The purpose of soil samples was to inform the air samples and indicate whether organophosphorus pesticides were present due to overspray from adjacent farmland.<br>+ Ingestion of soil or dermal exposure unlikely for adults in occupational settings<br>+ Utilized validated sampling and analytical methods. |
| 2. Analysis for Organophosphate pesticides not comprehensive enough. | Overall Directionality if True:<br><br>Underestimate. | + Analytical scan utilized. The scan consisted of 10 common crop organophosphate pesticides. |
| 3. Laboratory qualification. | Overall Directionality if True:<br><br>Unknown/Unclear. | + Selected laboratory had accreditations based upon proficiency testing by independent entities.<br>+ Operating procedures, quality assurance/control, personnel qualifications, and analytical proficiency are evaluated as part of certification process. |
| 4. Samples were tampered with between the time they were shipped to when they arrived at the lab. | Overall Directionality if True:<br><br>Unknown/Unclear. | + Chain of custody forms used.<br>+ Physical custody of samples maintained until shipped to laboratory.<br>+ Each lab report contains a copy of the chain of custody and any notes as to condition of the samples as received. |

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| 5. Inadequate quality control (QC) steps. | Overall Directionality if True:<br><br>Depends on Quality Control results. | + Collection of background soil sample outside the fenceline at each MAF.<br>+ The depth of the sample was according to a protocol. A shovel was used to remove the top layer of soil and individual trowels were used at each sample location to prevent cross-contamination.<br>+ Laboratory prepared Method Blank, Matrix Spike, Matrix Spike Duplicate, and LCS samples and compared against each contaminant in each sample to determine if bias was high, neutral, or low. |
| 6. Inadequate depth of samples. Depth not randomized. | Overall Directionality if True:<br><br>Unknown/Unclear. | + Soil samples were collected according to a sample strategy at a depth of 8 to 12 inches.<br>+ Sample strategy was for presence/absence of organophosphate pesticides.<br>+ Moisture levels were detected. |
| 7. Sample locations not sufficient to characterize presence of organophosphate pesticides. | Overall Directionality if True:<br><br>Underestimate. | + Samples collected at each corner of the MAF within the fenceline, at the location of the ventilation air intake, and at a random location within the fenceline.<br>+ Background soil sample collected outside of the fenceline, which include MAFs situated within agricultural areas where pesticides are reportedly used. |

## Table 5 - Collection of Surface Swipe Samples for Polychlorinated Biphenyls (PCBs)

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Mitigating Step |
|---|---|---|
| 1. Surface swipe sampling not sufficiently sensitive to detect concentrations that are less than the Cancer Slope Factor for dermal exposure. | Overall Directionality if True:<br><br>Overestimate.<br><br>Note: The RL (expressed at Practical Quantification Limit (PQL)) did not vary. | + Validated, current, comprehensive EPA sampling & analytical method utilized.<br>+ The method was developed to have a Reporting Limit (RL) that is less than the EPA surface limit for PCBs.<br>+ Cancer risk factors such as Cancer Slope for dermal exposure or non-cancer risk factors such as health screening values (HSVs) are geared towards sensitive individuals such as children – in this case, workers dermally exposed to PCBs in water. Thus, they are set at a lower concentration than the EPA surface limits.<br>+ The determination of risk was artificially elevated as 100% of the detected PCB was transferred to the skin and 100% was absorbed through skin and not washed or wiped off. |
| 2. Analytical instrument capability to detect contaminants in swipe samples (e.g. RL, or LOQ) is not sufficiently sensitive compared to EPA limit for PCB surface concentrations. | Overall Directionality if True:<br><br>Underestimate. | + Validated EPA sampling and analytical methods specific to detect concentrations at a 1 microgram per wipe, which is 10x below the EPA limit. |

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| 3. Analysis for PCBs not comprehensive enough. | Overall Directionality if True:<br><br>Underestimate. | + Analytical scan utilized. The scan consisted of 7 of the most common PCBs.<br>+ Total PCBs also included in the sampling and analytical method. |
| 4. Laboratory qualification. | Overall Directionality if True:<br><br>Unknown/Unclear. | + Selected Laboratory utilized has certifications based upon proficiency testing by independent entities.<br>+ Operating procedures, quality assurance/control, personnel qualifications, and analytical proficiency are evaluated as part of certification process. |
| 5. Inadequate quality control (QC) steps. | Overall Directionality if True:<br><br>Depends on Quality Control results. | + Round 1 supplies procured from a source not associated with the lab that performed the analysis. No media blanks submitted for analysis.<br>+ Round 2 supplies procured from the lab that performed the analysis. No media blanks submitted for analysis.<br>+ Laboratory prepared Method Blank, Matrix Spike, Matrix Spike Duplicate, and LCS samples and compared against each contaminant in each sample to determine if bias was high, neutral, or low. |

## Table 6 – Overall Uncertainty

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Mitigating Step |
|---|---|---|
| 1. Sampling results indicate the current environmental conditions within (outside in the case of soil samples) the 15 Missile Alert Facilities. Past environmental conditions could be similar or dissimilar to current conditions. | Overall Directionality if True:<br><br>Unknown/Unclear.<br><br>Facilities have undergone upgrades/changes. | + Sampling represents current conditions, but environmentally persistent compounds that could represent past environmental conditions were sampled such as PCBs, dioxins, and other persistent semi-volatile compounds.<br>+ Rapid response when concerns were raised. |
| 2. Laboratory Limit of Quantification (LOQ) was less than the applicable Health Screening Value (HSV) and concentrations reported were less than the LOQ. | Overall Directionality if True:<br><br>Potential to artificially inflate/ overestimate risk when added together. | + Results statistically treated according to USEPA policy/protocols/guidance. |
| 3. Laboratory RL, LOQ, or PQL were greater than the Cancer Slope Factor or HSV and concentrations reported were less than the RL, LOQ, or PQL. | Overall Directionality if True:<br><br>Potential to artificially inflate/ overestimate risk when added together. | + Situations where the RL, LOQ, or PQL were greater than the IUR, Cancer Slope Factor, or HSV were areas of uncertainty that were accounted for in the cancer and non-cancer risk estimates. |

## Table 7 - Computation of Risk

| Uncertainty | Direction of Bias in Exposure and Risk Estimates | Notes |
|---|---|---|
| 1. Duration of exposure to airborne and waterborne chemicals at a MAF would not be equal to a residential, 24-hr, 365 day, lifetime exposure | Overall Directionality:<br><br>Overestimate risk. | 13N AFSC typically serve two, three-year terms at operational missile wings with broadening assignments afterwards within 6 to 12-year time-in-service thresholds. While at operational missile wings, schedule is 24 hrs at MAF followed by 48-hours away, or 1 week at MAF followed by 2-weeks away. During broadening assignments, time in LCC reduced to a non-routine, non-consistent tempo.<br><br>Upon consultation with AFGSC, 13Ns would work 1/3-year (2,290 hours/year) in a MAF for an upper bound of 8-years. |
| 2. Dermal cancer risk based on assumptions maximizing the potential for risk | Overall Directionality (Overestimate risk) | Based on highest detected concentration on frequent, high likelihood of contact to contaminated surface for each installation.<br><br>Assumptions:<br>+ whole surface area of hand (100 cm2) exposed.<br>+ Entire concentration transferred to skin.<br>+ Not washed off.<br>+ 100% of PCB on skin was absorbed<br>+ Frequency and duration of exposure aligned to a residential exposure (24-hrs/day, 350 days/year) |

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