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Director Force Health Protection
Health Services Group
Headquarters
1745 Alta Vista Drive
Ottawa, Ontario, K1A 0K6

Toxicological Review of Environmental Samples Taken in 2007 from Kandahar and FOBs in Support of OP ATHENA

Prepared by:
Reviewed by: , FRCPC.
DFHP, Occupational and Environmental Health

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ABBREVIATIONS TABLE

Abbreviation	Term/Title in Full
ACGIH	American Conference of Governmental Industrial Hygienists
AO	Aesthetic Objectives
ATSDR	Agency for Toxic Substances and Disease Registry
CCME	Canadian Council of Ministers of the Environment
CEPA	Canadian Environmental Protection Act
CEPA/FPAC	Canadian Environmental Protection Act/ Federal Provincial Advisory Committee
CNS	Camp Nathan Smith
CoPC	Chemicals of Potential Concern
DFHP	Director Force Health Protection
DHHAT	Deployable Health Hazard Assessment Team
DPS	Deployable Particle Sampler
EHSA	Environmental Health Site Assessment
FOB	Forward Operating Base
HC	Health Canada
KAF	Kandahar Air Field
PAHs	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
PM_{10}	Particulate Matter of 10 µm in diameter or smaller
PRT	Provincial Reconstruction Team
RBG	Risk-Based Guideline
TDI	Tolerable Daily Intake
TDS	Total Dissolved Solids
TLV-TWAs	Threshold Limit Values – Time Weighted Averages
USA CHPPM	Unites States Army Centre for Health Promotion and Preventive Medicine
US EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds

1. INTRODUCTION

A toxicological review was undertaken for Chemicals of Potential Concern (CoPC) in air, soil, water and rocks sampled during an Environmental Health Site Assessment (EHSA) at Kandahar and four Forward Operating Bases (FOBs) in support of OP ATHENA. This EHSA was done by the Deployable Health Hazard Assessment Team (DHHAT) lead by the Director Force Health Protection (DFHP) between September 25th and October 20th 2007. The EHSA included the FOBs Ma'sum Ghar, Sperwan Ghar, Wilson, and Spin Boldak. Updated EHSAs were also conducted at the Kandahar Air Field (KAF), Camp Nathan Smith (CNS) and Camp Mirage. More information relating to sampling procedure and field observations can be found in the OP ATHENA – DHHAT TAV 07-147 Environmental Health Site Assessment - Interim Report (Capt M.C. Lamontagne, 2008a).

The toxicological review and risk characterization of CoPC collected during the Kandahar and FOBs EHSA in ambient air, soil, water and rocks are reported in sections 2 to 5 respectively. Conclusions of the risk characterization of CoPC are found in section 6.

2. COPC MEASURED IN AMBIENT AIR

This review is based on the analytical results of the air samples collected by the DHHAT at Kandahar and four FOBs. More information relating to sampling procedure or specific sampling locations can be found in the OP ATHENA – DHHAT TAV 07-147 Environmental Health Site Assessment - Interim Report (Capt M.C. Lamontagne, 2008a).

Over 300 air samples were analyzed for close to 80 CoPC including metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), crystalline silica, asbestos and particulate matter (PM_{10}). The maximum reported concentrations of these chemicals from all air samples combined *versus* air guidelines are presented in Annex A. The risk characterization of CoPC in air are reported in the next two sections: section 2.1 for the PM_{10} results and section 2.2 for all other chemicals.

2.1. PM_{10} MEASURED IN AMBIENT AIR

Airborne particles or particulate matter (PM) vary widely in their chemical composition and can range from 0.005 μm to 100 μm in size. The respirable fraction of particulate matter is considered to be less than 10 μm in size and is known as PM_{10}. Adverse health effects related to PM exposure have been the topic of intense scientific study in recent years. PM has been associated with several cardiopulmonary health endpoints, although the exact biological mechanisms for these effects have yet to be conclusively determined (CEPA, 2000).

The Canadian Working Group on Air Quality Objectives and Guidelines has proposed a PM_{10} reference level of 25 $\mu g/m^3$, averaged over 24 hours (CEPA/FPAC, 1999). This Canadian guideline can be considered as being very conservative since it has a public health focus and is intended to protect all members of society, including all

age groups and most people with medical conditions. Moreover, this level is often exceeded in Canada. For example, the Canadian 24-hour average PM_{10} values range from 9 to 42 $\mu g/m^3$, with most urban centers in the range of 20 to 30 $\mu g/m^3$ (CEPA/FPAC, 1999). The maximum one-hour average PM_{10} level for Canadian centers are between 35 and 100 $\mu g/m^3$ but can be as high as 200 $\mu g/m^3$ (CEPA/FPAC, 1999).

CF Industrial Hygienists and Preventive Medicine Technicians collected samples at KAF in March 2002 and at both KAF and the Kandahar Provincial Reconstruction Team (PRT) site in July 2005 (http://hr.ottawa-hull.mil.ca/health/information/op_health/engraph/info_home_e.asp?Lev1=2&Lev2=6&Lev3=2). The combined results of these surveys revealed PM_{10} concentrations slightly higher than those from Kabul, with an average 24h-PM_{10} value of 225 $\mu g/m^3$ from 13 samples and values ranging from 40 - 350 $\mu g/m^3$.

The 24h average-PM_{10} measured in October 2007 in KAF as well as from several FOBs were found to be suspiciously higher. The combined results of these surveys revealed average 24h-PM_{10} concentrations at 320 $\mu g/m^3$ from 18 samples and values ranging from 100 - 570 $\mu g/m^3$. The upper range of these values approach the highest reported background 24h average-PM_{10} values in the world.

These inflated 2007 levels could be explained by the different air sampling methodology employed in 2007 as compared to the gold standard method employed in 2002 and 2005. The standard method employs an instrument called MiniVol. For operational reasons, a new PM monitoring instrument (the Deployable Particle Sampler or DPS manufactured by SKC inc.) was used for the first time by the DHHAT during the 2007 EHSA in Afghanistan. Due to unforeseen events, the air flow rate supplied to the new DSP instrument was only able to reach half of what it should have reached (5 L/min instead of 10 L/min). According to SKC inc., the DSP manufacturing company, this sub-optimal condition shifted the 50% cut-point to 14.4 µm instead of 10 µm (personal communication from Mr. Saulius Trakumas, Particle Physicist from SKC, November 21, 2007). The cut-point is the median diameter of the range of particle sizes captured by a PM monitoring equipment. The shift in the 50% cut-point from 10 µm to 14.4 µm means that bigger particles were captured in addition to the particles that would normally be included in PM_{10} sampling. Although there is no way to convert this data back to PM_{10}, it is accepted that true PM_{10} levels would be less than the PM_{14} levels that were actually captured during the 2007 EHSA.

It is the intent of the DHHAT to conduct validation testing in the field to compare the new DSP to the MiniVol (the old system that is still the gold standard for PM monitoring). Although the DSP was validated to obtain similar results compared to the MiniVol by the US Army Centre for Health Promotion and Prevention Medicine (USA CHPPM) in Kuwait and in Aberdeen Proving Ground, it has never been tested in Afghanistan by the DHHAT. The proposed DHHAT validation testing would provide confidence in the CF's PM monitoring capability.

Due to the methodological problems described above, the data gathered in 2007 with the DSP are not representative of the actual PM_{10} levels at the sampled locations. However, we have no reason to presume that the PM_{10} levels in 2007 would be significantly different than the PM_{10} levels measured in 2002 and 2005 from the same general geographic region. It is possible that CF personnel who are physically active in this environment (24h-PM_{10} concentrations of 40 - 350 $\mu g/m^3$) may experience irritation

of the eyes, nose and throat and respiratory symptoms such as cough and sputum production, and that those with pre-existing conditions such as asthma might experience a worsening of their symptoms. Although CF personnel might experience acute, transient symptoms while deployed, it is unlikely that these PM exposures would result in any chronic health effects.

2.2. COPC OTHER THAN PM_{10} MEASURED IN AMBIENT AIR

The following list of CoPC other than PM were measured in the ambient air of Kandahar and four FOBs in 2007: metals, PAHs, VOCs, crystalline silica, and asbestos. Their maximum reported ambient air concentrations were compared with standards established by the American Conference of Governmental Industrial Hygienists (ACGIH, 2007) since no such Canadian guideline exist (see the Annex A).

ACGIH provides guidelines for occupational airborne exposures. They are called Threshold Limit Values – Time Weighted Averages (TLV-TWAs) and represent airborne concentrations of substances to which nearly all workers can be repeatedly exposed over their working lifetime without adverse health effects, based on an 8-hour workday and 40-hour workweek (ACGIH, 2007). The TLV-TWA's are not directly applicable to CF Personnel since they could be exposed to CoPC for periods exceeding the standard 8-hour workday and 40-hour workweek. However, for CF personnel the duration of their deployment is much less than a working lifetime. On balance, it is believed that the TLV-TWA's provide a reasonable and conservative estimate of exposure to airborne concentrations of contaminants, which would not produce adverse health effects in CF personnel.

All compounds measured in the ambient air of Kandahar and four FOBs in 2007 were either below the analytical detection limit and/or less than the corresponding TLV-TWA (see Annex A). Therefore, the risk of adverse health effects from the inhalation of ambient airborne metals, PAHs, VOCs, crystalline silica, and asbestos for CF personnel deployed is considered to be negligible.

3. COPC MEASURED IN SOIL

In total, 35 soil samples were collected in 2007 by the DHHAT at the following locations: KAF, Spin Boldak, Sperwan Ghar, Wilson, and Ma'sum Ghar. These soil samples were analyzed for metals, organic explosive residues, and pesticides. For the 35 soil samples collected, all CoPC except arsenic had concentrations that were either below their detection limit and/or human health based soil quality criteria published by Canadian and/or American authorities (see Annex B).

Arsenic is therefore the only CoPC considered further in the toxicity evaluation.

3.1 RISK CHARACTERISATION OF ARSENIC IN SOIL

Arsenic is a naturally occurring element that is present in all environmental media. Mean concentrations of arsenic in uncontaminated soil types in Canada range from 4.8 to 13.6

μg/g (HC, 1995). It is therefore not uncommon for Canadian soils to exceed the 12 μg/g guideline derived to assure the protection of adults inadvertently ingesting arsenic-containing soil (CCME, 1999). Of the 35 soil samples taken in 2007, several were close to the 12 μg/g soil guideline and one sample was slightly above at 14 μg/g.

These results are similar to a previous EHSA conducted in the same region of Afghanistan in June 2003. During the 2003 EHSA, the highest reported arsenic level in soil was 15.6 μg/g. The conclusions of the toxicological report conducted with the 2003 soil values are therefore still relevant. It was concluded that the risk of adverse health effects from exposure to arsenic in soil for personnel serving in support of OP ATHENA was negligible. For the detailed calculations of the risk characterisation please refer to the previous OP ATHENA toxicological report (Tsekrekos and Lalonde, 2004).

4. COPC MEASURED IN WATER

Water samples were collected by the DHHAT during the EHSA survey in 2007 at KAF, Camp Nathan Smith, Ma'sum Ghar, Sperwan Ghar, Wilson, and Spin Boldak. In total, 11 water samples were analyzed for metals, potability criteria, VOCs, pesticides and herbicides, drinking water disinfectant by-products, and other organic chemicals. Although none of these water samples were used for drinking, the water was used by CF personnel for food preparation and washing.

Drinking water guidelines were applied to the ablution water sample results as a conservative way to screen out chemicals of concern since no ablution water guidelines exist. Of the 11 ablution water samples collected, only boron had maximum concentrations that exceeded human health Risk-Based Guideline (RBG) while several samples had concentrations of sulphate, chloride and Total Dissolved Solids (TDS) that exceeded their respective Aesthetic Objectives (AO) (see Table 1 and Annex C). AO are based on aesthetic considerations such as taste and odor and not based on health considerations. Also, bromate's analytical detection limit did not meet its drinking water guideline. The remainder of the analytes had concentrations that were either below their detection limit and/or human health based drinking water quality criteria published by Health Canada (Annex C).

The laboratory reporting the bromate's level in water could not meet its usual detection limit due to analytical interferences. Bromate's analytical detection limit was five times higher than is RBG. Theoretically, it could be possible for bromate levels to exceed the RBG by a factor of five or less. However, it is highly unlikely that bromate was present in the Kandahar and FOBs water samples. Bromate is not a natural component of water but rather may be formed during the disinfection of drinking water using ozone or a combination of ozone and hydrogen peroxide (HC, 1998). Such disinfection methods were not used in Kandahar nor at the FOBs where water was sampled. Chlorination was used to chemically disinfect the water in Kandahar and the FOBs (Capt M.C. Lamontagne, 2008a). Therefore, in the absence of disinfection processes necessary for the formation of bromate, it is improbable that bromate would have been present in the sampled ablution water at levels exceeding its RBG.

Table 1. CoPC in ablution water samples that exceeded their respective Canadian Drinking Water Quality Guideline published by Health Canada (HC, 2007).

Location	Sample ID and use of water	CoPC	$[CoPC]_{water}$ mg/L	CDWQG mg/L	Type of guideline
Spin Boldak	CF001305 Washing dishes and showering	Chloride	278	250	AO
		TDS	1400	500	AO
		Boron	14.6	5	RBG
	CF001313 Showering and ablution	Chloride	312	250	AO
		TDS	1400	500	AO
		Boron	14.2	5	RBG
KAF	CF001349 Showering	Chloride	479	250	AO
		Sulphate	893	500	AO
		TDS	2500	500	AO
Wilson	CF001312 Washing clothes and hands	TDS	610	500	AO
Camp Nathan Smith	CF001304 Washing hands	Sulphate	1050	500	AO
		TDS	2300	500	AO
	CF001306 Food preparation[1]	Sulphate	608	500	AO
		TDS	1600	500	AO

CoPC = Chemicals of Potential Concern
TDS = Total Dissolved Solids
CDWQG = Canadian Drinking Water Quality Guideline
AO = Aesthetic Objective
RBG = Risk-based guideline
[1]The water sample CF001306 was taken from the kitchen sink of Camp Nathan Smith. The water from that sink was used to clean fruits and vegetables and for cleaning hands and dishes but was not used to make soups, juices or coffee (Capt M.C. Lamontagne, 2008b). Approved bottled water was used to make soups, juices and coffee at Camp Nathan Smith.

Two ablution water samples collected had boron concentrations close to 15 mg/L which is three times higher than the drinking water guideline for boron (HC, 1990). Boron is the only CoPC from the water samples that have exceeded a RBG and will therefore be the only analyte considered further in this toxicity evaluation.

4.1 RISK CHARACTERISATION OF BORON IN ABLUTION WATER

Health Canada reports a boron Tolerable Daily Intake (TDI) of 0.0175 mg/kg/day (HC, 1990). By comparison, HC's boron TDI is ~10x more conservative than the more recently published US EPA boron TDI (US EPA, 2004).

Inadvertent ingestion would be the most significant exposure pathway to boron from hand washing and showering since boron in water is not volatile (inhalation would be minimal) and urinary excretion studies in humans show that very little gets absorbed through intact skin (ATSDR, 2007). By making conservative assumptions (i.e. 100% of the ingested boron would be absorbed from the GI tract), it is possible to estimate that a maximum of 0.17 L of water containing 14.6 mg/L of boron could be drunk every day for 6 months before reaching Health Canada's TDI (see Equation 1). It is unlikely that the amount of ablution water inadvertently taken in every day by personnel through showering, washing hands, and food preparation activities (eg. dish washing, washing fruits and vegetables) would have exceeded 0.17 L. Therefore, the risk of adverse health effects from exposure to boron in ablution water for personnel serving in support of OP ATHENA is negligible.

Equation 1:

$$IR_w = \frac{TDI\ (mg/kg/day) \times BW}{C_w \times AF_{GIT} \times D_1 \times D_2}$$

Where:

IR_w	*ingestion rate of water*	
C_w	*concentration of contaminant in drinking water*	*(14.6 mg/L)*
AF_{GIT}	*absorption factor from the GI tract*	*(1.0 unitless)*
D_1	*days per week exposed/7 days*	*(1.0 unitless)*
D_2	*6 months per year exposed/12 months*	*(0.5 unitless)*
BW	*body weight*	*(70 kg)*
TDI	*tolerable daily intake*	*(0.0175mg/kd/day)*

4.2 POTENTIAL IMPLICATIONS OF USING THE ABLUTION WATER FOR DRINKING

In emergency situations, the ablution water samples taken by the DHHAT in 2007 could be used for drinking as long as it is microbiologically safe. However, it is recommended that the ablution water samples that have exceeded either AOs and/or the boron drinking water guideline be further filtered to reduce exposure to boron and also to improve the water's palatability.

5. ASBESTOS MEASURED IN ROCKS

During the summer of 2007, concerns were expressed about possible asbestos exposure at FOB Ma'Sum Ghar, Afghanistan (Halton, 2007). Testing of a rock sample from a nearby location revealed high Actinolite/Tremolite content. Actinolite and Tremolite are amphibole types of asbestos known to have adverse health effects after prolonged inhalation exposure. The origin of the particular rock analyzed is not entirely clear, but it is reported to have come from a quarry some 10 km away from the base. In response to these concerns, testing was conducted by CF preventive medicine technicians in July 2007 to assess the levels of asbestos in ambient air and the asbestos content of rock found at various locations within the base perimeter. The ambient air fiber levels and rock samples at FOB Ma'Sum Ghar during the summer of 2007 were not found to be a health concern. In fact, the ambient air levels were comparable with those found in both rural and urban communities in Canada and the US (Halton, 2007).

To further investigate the potential of asbestos being present at FOB Ma'Sum Ghar and also elsewhere in Afghanistan, 44 rock samples were taken from KAF, Camp Nathan Smith, Ma'sum Ghar, Sperwan Ghar, Wilson, and Spin Boldak by the DHHAT in September and October 2007. Similar to the previous findings from Ma'Sum Ghar, asbestos fibres were not detected in any of the rock samples harvested in September and October 2007. Furthermore, the asbestos levels in ambient air were found to be very low (see Section 2.2 of this report and Annex A). No adverse health outcome is therefore expected from CF personnel due to asbestos in rock and/or ambient air.

6. CONCLUSIONS

The results of the EHSA ambient air, soil, water and rock samples have been evaluated with regards to potential human health risks, using established Canadian and American reference values.

CF personnel deployed to Ma'sum Ghar, Sperwan Ghar, Wilson, Spin Boldak, KAF and Camp Nathan Smith in support of OP ATHENA were not likely exposed to chemicals agents in ambient air, ablution water, soil nor rock at concentrations high enough, nor for periods long enough, to present significant potential health risks.

7. REPORT LIMITATIONS

This report pertains solely to ambient air, ablution water, soil and rock sampled by the DHHAT in support of OP ATHENA between September the 25th and October 20th 2007. It has been prepared for the exclusive use of the Department of National Defence. This report is limited to the specific compounds sampled, analyzed, and reported. No comment can be made on any chemical or biological parameters of concern that have no known safety standards, or were not sampled.

It should be noted that the conclusions presented herein are based on guidelines derived from current scientific knowledge. The knowledge is believed accurate and reliable at the time of application. Should the guidelines change in the future, this could affect the conclusions reached in this report.

8. REFERENCES

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Annex A

Toxicological Evaluation - Air

Identification of chemicals of potential concern for human health in Air

[redacted]

*The lowest TLV is chosen since the source of the analyte is unknown and to assure protection.

Maximum reported concentration in air versus the air quality guideline

CAS	Analyte	Sample ID	[Max] mg/m^3	DL mg/m^3	TLV* mg/m^3
Data from file: 07101367.xls					
7429-90-5	Aluminum	AFC002362	0.019	0.0021	2
7440-36-0	Antimony	-	<DL	0.0021	0.5
7440-38-2	Arsenic	AFC004989	0.0031	0.0021	0.01
7440-39-3	Barium	-	<DL	0.0021	0.5
7440-41-7	Beryllium	-	<DL	0.0009	0.002
7440-43-9	Cadmium	-	<DL	0.0011	0.002
7440-70-2	Calcium	AFC004963	0.066	0.021	0.5
7440-47-3	Chromium	-	<DL	0.0021	0.01
7440-48-4	Cobalt	-	<DL	0.0021	0.02
7440-50-8	Copper	-	<DL	0.0021	1
7439-89-6	Iron	AFC002362	0.024	0.0021	1
7439-92-1	Lead	-	<DL	0.0021	0.05
7439-93-2	Lithium	-	<DL	0.0021	0.025
7439-95-4	Magnesium	-	<DL	0.021	10
7439-96-5	Manganese	-	<DL	0.0021	0.2
7439-98-7	Molybdenum	-	<DL	0.0021	0.5
7440-02-0	Nickel	-	<DL	0.0021	0.1
7723-14-0	Phosphorus	AFC005024	0.0028	0.0021	0.1
7440-09-7	Potassium	-	<DL	0.021	0.1
7782-49-2	Selenium	AFC002302	0.0044	0.0021	0.2
7440-22-4	Silver	-	<DL	0.00042	0.01
7440-23-5	Sodium	-	<DL	0.021	0.05
7440-24-6	Strontium	-	<DL	0.0021	-
7440-28-0	Thallium	-	<DL	0.0021	0.1
7440-31-5	Tin	-	<DL	0.0021	0.1
7440-32-6	Titanium	-	<DL	0.0023	10
7440-61-1	Uranium	-	<DL	0.00064	0.2
7440-62-2	Vanadium	-	<DL	0.0021	0.05
7440-66-6	Zinc	-	<DL	0.0021	1

CAS	Analyte	Sample ID	[Max] mg/m^3	DL mg/m^3	TLV mg/m^3
Data from file: 07101379.xls					
83-32-9	Acenaphthene	-	<DL	0.0012	-
208-96-8	Acenaphthylene	-	<DL	0.0012	-
120-12-7	Anthracene	-	<DL	0.0012	-
56-55-3	Benzo(a)anthracene	-	<DL	0.0012	- (L)
50-32-8	Benzo(a)pyrene	-	<DL	0.0012	- (L)
205-99-2	Benzo(b)fluoranthene	-	<DL	0.0012	0.2 - (L)
192-97-2	Benzo(e)pyrene	-	<DL	0.0012	-
191-24-2	Benzo(g,h,i)perylene	-	<DL	0.0012	-
207-08-9	Benzo(k)fluoranthene	-	<DL	0.0012	0.2
218-01-9	Chrysene	-	<DL	0.0012	- (L)
53-70-3	Dibenzo(a,h)anthracene	-	<DL	0.0012	-
206-44-0	Fluoranthene	-	<DL	0.0012	-

86-73-7	Fluorene	-	<DL	0.0012	-
193-39-5	Indeno(1,2,3-cd)pyrene	-	<DL	0.0012	0.2
91-20-3	Naphthalene	-	<DL	0.0012	52
85-01-8	Phenanthrene	-	<DL	0.0012	-
129-00-0	Pyrene	-	<DL	0.0012	-

CAS	Analyte	Sample ID	[Max] mg/m^3	DL mg/m^3	TLV mg/m^3
Data from file: 07101361.xls					
	Particulate, Respirable	AFC004964	0.25	0.12	3
	Cristobalite	-	<DL	0.049	0.05
	Quartz	AFC002358	0.017	0.027	0.05
	Tridymite	-	<DL	0.025	0.05

CAS	Analyte	Sample ID	[Max] mg/m^3	DL mg/m^3	CCME mg/m^3
Data from file:					
	PM10	*Data unusable - see discussion in Tox report*			0.025

CAS	Analyte	Sample ID	[Max] f/cc	DL f/cc	TLV f/cc
Data from file:					
	Asbestos	AFC002440	0.017	0.016	0.1

CAS	Analyte	Sample ID	[Max] mg/m^3	DL mg/m^3	TLV mg/m^3
Data from file: 07101374.xls					
71-55-6	1,1,1-Trichloroethane	-	<DL	0.54	-
67-64-1	Acetone	-	<DL	0.54	1188
71-43-2	Benzene	-	<DL	0.18	1.6
56-23-5	Carbon Tetrachloride	-	<DL	0.72	31
108-94-1	Cyclohexanone	-	<DL	0.18	80
64-17-5	Ethanol	-	<DL	0.89	1880
100-41-4	Ethylbenzene	-	<DL	0.36	434
142-82-5	Heptane	-	<DL	0.36	1640
67-63-0	Isopropyl Alcohol	-	<DL	0.72	490
	m-Xylene	-	<DL	0.36	434
110-43-0	Methyl Amyl Ketone	-	<DL	0.54	233
591-78-6	Methyl Butyl Ketone	-	<DL	0.54	20
78-93-3	Methyl Ethyl Ketone	-	<DL	0.54	590
110-12-3	Methyl Isoamyl Ketone	-	<DL	0.54	234
108-10-1	Methyl Isobutyl Ketone	-	<DL	0.54	205
71-36-3	n-Butanol	-	<DL	0.89	61
123-86-4	n-Butyl Acetate	-	<DL	0.54	713
110-54-3	n-Hexane	-	<DL	0.36	176
95-47-6	o-Xylene	-	<DL	0.36	434
109-66-0	Pentane	-	<DL	0.36	1770
127-18-4	Perchloroethylene	-	<DL	0.72	170
100-42-5	Styrene	-	<DL	1.8	85
108-88-3	Toluene	-	<DL	0.36	188
79-01-6	Trichloroethylene	-	<DL	0.72	269
1330-20-7	Xylene (Total)	-	<DL	0.72	434

General Notes

TLV = Threshold Limit Value from the ACGIH (American Conference of Governmental Industrial Hygienists). 2004. Threshold Limit Values for Chemical Substances and Physical Agents

& Biological Exposure Indices.

CCME = Canadian Council of Ministers of the Environment. 2000. Canada Wide Standards for Particulate Matter and Ozone. CCME, Winnipeg.

DL = Analytical Detection Limit

(L) = According to ACGIH (2004), exposure to this compound by all routes should be carefully controlled to levels as low as possible.

Toxicological Evaluation - Soil

Identification of chemicals of potential concern for human health in soil

[redacted]

Maximum reported concentration in soil versus risk-based soil guidelines

Analyte	Sample ID	[Max] mg/kg	DL mg/kg	CCME mg/kg	EPA Reg9 mg/kg
Data from file: Kandahar S1.xls					
Ag	-	<DL	2	40	1020
Al	CF001322	23700	60	-	100000
[redacted]					
B	CF001327	77.2	20	-	100000
Ba	CF001320	207	5	-	13400
Be	-	<DL	4	-	1900
Ca	CF001318	340000	100	-	-
Cd	-	<DL	1	2090	90
Co	CF001322	29	5	300	1900
Cr	CF001322	102	20	2300	450
Cu	CF001322	55.5	3	20000	8200
Fe	CF001322	56000	-	-	100000
K	CF001327	13100	-	-	-
Mg	CF001322	26800	-	-	-
Mn	CF001322	793	-	-	3800
Mo	CF001327	4.5	2	-	1020
Na	CF001327	8530	-	-	-
Ni	CF001322	124	5	-	4000
P	CF001333	4580	-	-	-
Pb	CF001344	72.8	10	8200	150
S	CF001336	21000	-	-	-
Sb	-	<DL	10	40	82
Se	-	<DL	10	4700	1020
Sn	CF001347	36.9	2	300	100000
Sr	CF001318	939	-	-	100000
Ti	CF001322	1560	-	-	-
Tl	-	<DL	1	1	13
U	CF001318	16.1	10	-	40
V	CF001322	99.6	10	130	1440
Zn	CF001322	102	15	-	100000

Analyte	Sample ID	[Max] mg/kg	DL mg/kg	CCME mg/kg	EPA Reg9 mg/kg
Data from file: Hgs17257r2.xls; Hgs17257r1.xls					
Hg	CF001331	0.1	0.1	690	62

Analyte	Sample ID	[Max] mg/kg	DL mg/kg	CCME mg/kg	EPA Reg9 mg/kg
Data from file: 75790(Cr).xls					
Cr(VI)	-	<DL	0.4	1.4	64

CAS	Analyte	Sample ID	[Max] mg/kg	DL mg/kg	EPA Reg9 mg/kg
Data from file: RMC75790(Soil)REVISED.xls					
2	2-Amino-4,6-Dinitrotoluene	-	<DL	0.1	-
0	4-Amino-2,6-Dinitrotoluene	-	<DL	0.1	-
99-35-4	1,3,5-Trinitrobenzene	-	<DL	0.5	3600
118-96-7	Trinitrotoluene	-	<DL	0.1	57

Toxicological Evaluation - Soil

99-65-0	1,3-Dinitrobenzene	-	<DL	0.1	12
121-14-2	2,4-Dinitrotoluene	-	<DL	0.1	2.5
606-20-2	2,6-Dinitrotoluene	-	<DL	0.1	2.5
99-99-0	4-Nitrotoluene	-	<DL	0.1	-
99-08-1	3-Nitrotoluene	-	<DL	0.1	-
88-72-2	2-Nitrotoluene	-	<DL	0.1	-
98-95-3	Nitrobenzene	-	<DL	0.1	20

CAS	Analyte	Sample ID	[Max] mg/kg	DL mg/kg	EPA Reg9 mg/kg
Data from file: RMC75790(Soil)REVISED.xls					
Phenoxy Herbicides					
94-75-7	2,4-D	-	<DL	2.0	1540
1689-84-5	Bromoxynil	-	<DL	2.0	2400
1918-00-9	Dicamba	-	<DL	2.0	3600
3	Diclofop-methyl	-	<DL	0.05	-
120-36-5	Dichlorprop (2,4-DP)	-	<DL	2.0	-
88-85-7	Dinoseb	-	<DL	2.0	124
94-82-6	2,4-DB	-	<DL	2.0	980
93-76-5	2,4,5-T	-	<DL	2.0	1240
93-72-1	2,4,5-TP (Silvex)	-	<DL	2.0	980
1918-02-1	Picloram	-	<DL	2.0	8600
Organochlorine Pesticides					
309-00-2	Aldrin	-	<DL	0.01	0.1
50-29-3	DDT & metabolites	-	<DL	0.01	7
57-74-9	Chlordane	-	<DL	0.10	6.5
60-57-1	Dieldrin	-	<DL	0.01	0.11
959-98-8	Endosulfan I	-	<DL	0.01	740
9	Endosulfan II	-	<DL	0.01	740
72-20-8	Endrin	-	<DL	0.01	36
7421-93-4	Endrin aldehyde	-	<DL	0.01	-
5	Endrin ketone	-	<DL	0.01	-
1031-07-8	Endosulfan sulfate	-	<DL	0.01	-
76-44-8	Heptachlor	-	<DL	0.01	0.38
1024-57-3	Heptachlor epoxide	-	<DL	0.01	0.19
72-43-5	Methoxychlor	-	<DL	0.01	620
9+319-84-	Lindane (total α,β,γ, δ or B	-	<DL	0.01	0.36
Organophosphorus and Nitrogen containing Pesticides					
834-12-8	Ametryn	-	<DL	1.0	1100
1912-24-9	Atrazine	-	<DL	1.0	7.8
2921-88-2	Chlorpyrifos	-	<DL	0.01	360
2	Cyanazine	-	<DL	1.0	2.1
333-41-5	Diazinon	-	<DL	0.8	110
60-51-5	Dimethoate	-	<DL	1.7	24
298-04-4	Disulfoton	-	<DL	1.0	5
56-38-2	Ethyl parathion	-	<DL	0.3	-
86500	methyl)	-	<DL	2.0	-
121-75-5	Malathion	-	<DL	0.1	2400
298-00-0	Methyl parathion	-	<DL	0.3	30
2	Metolachlor	-	<DL	1.0	-
9	Metribuzin	-	<DL	1.0	3000
298-02-2	Phorate	-	<DL	1.0	24

Toxicological Evaluation - Soil

732-11-6	Phosmet	-	<DL	1.0	2400
6	Phosphamidon	-	<DL	1.0	-
1610-18-0	Prometon	-	<DL	1.0	1840
7287-19-6	Prometryne	-	<DL	1.0	-
139-40-2	Propazine	-	<DL	1.0	2400
122-34-9	Simazine	-	<DL	1.0	14
3383-96-8	Temephos	-	<DL	2.0	2400
9	Terbufos	-	<DL	1.0	3
886-50-0	Terbutryn	-	<DL	1.0	120

Toxicological Evaluation - Water

Identification of chemicals of potential concern for human health in water
Exceeds AO (Aesthetic Objective) or other none risk-based guideline

[redacted]

DL exceeds the guideline

Maximum reported concentration in water versus risk-based water guidelines
Data from file: Khandahar W2.xls

Analyte	Sample ID	Sample preservation	[Max] mg/L	DL mg/L	CDWQG mg/L	EPA MCL mg/L
Al	CF001470	OK	0.16	0.1	-	0.2
As	CF001307	OK	0.006	0.003	0.025	0.01
[redacted]						
Ba	CF001311	OK	0.06	0.01	1	2
Cd	-	OK	<DL	0.001	0.005	0.005
Cr	CF001349	OK	0.020	0.005	0.05	0.1
Cu	CF001307	OK	0.02	0.005	1	1.3
Fe	-	OK	<DL	0.2	0.3	0.3
Mn	CF001304	OK	0.008	0.005	0.05	0.05
Pb	-	OK	<DL	0.01	0.01	0.015
Sb	-	OK	<DL	0.005	0.006	0.006
Se	-	OK	<DL	0.01	0.01	0.05
U	-	OK	<DL	0.01	0.02	0.03
Zn	CF001304	OK	0.24	0.01	5	5

Data from file: Hgw17257r1(Total).xls

Analyte	Sample ID	Sample preservation	[Max] mg/L	DL mg/L	CDWQG mg/L	EPA MCL mg/L
Hg	-	OK	<DL	0.0004	0.001	0.002

Data from file: VOCw17257r1.xls

CAS	Analyte	Sample ID	Sample preservation	[Max] ug/L	DL ug/L	CDWQG ug/l	EPA MCL ug/L
95-50-1	1,2-Dichlorobenzene	-	OK	<DL	2	200	600
106-46-7	1,4-Dichlorobenzene	-	OK	<DL	1	5	75
107-06-2	1,2-Dichloroethane	-	OK	<DL	2	5	5
75-35-4	1,1-Dichloroethene	-	OK	<DL	10	14	7
71-43-2	Benzene	-	OK	<DL	2	5	5
56-23-5	Carbon Tetrachloride	-	OK	<DL	2	5	5
75-09-2	Methylene chloride	-	OK	<DL	10	50	5
100-41-4	Ethylbenzene	-	OK	<DL	2	2.4	700
108-90-7	Chlorobenzene	-	OK	<DL	2	80	100
127-18-4	Tetrachloroethylene	-	OK	<DL	2	30	5
108-88-3	Toluene	-	OK	<DL	2	24	1000
79-01-6	Trichloroethene	-	OK	<DL	2	5	5
75-01-4	Vinyl chloride	-	OK	<DL	2	2	2
1634-04-4	Methyl tert-butyl ether	-	OK	<DL	2	15	4
67-66-3+75-	Total Trihalomethanes	-	OK	<DL	8	100	80
95-47-6+108	Total Xylenes	-	OK	<DL	4	300	10000

Data from files: Turbidity17257r1.xls; Kandahar W1.xls

Analyte	Sample ID	[Max]	DL	CDWQG	EPA MCL
Colour (Co/Pt Units)	-	<DL	5	15	15
pH			-	6.5-8.5	6.5-8.5
Turbidity (NTU)	CF001306	0.43	-	1	1

Data from file: Kandahar W1.xls

Analyte	Sample ID	Sample preservation	[Max]	DL	CDWQG	EPA MCL

Toxicological Evaluation - Water

Free cyanide (mg/L)	-	OK	<DL	0.10	0.2	0.2
Fluoride (mg/L)	CF001307	OK	0.88	0.10	1.5	2
Nitrate (mg/L)	CF001304	OK	18.7	0.10	45	10
Nitrite (mg/L)	-	OK	<DL	0.10	3.2	1
Sulphate (mg/L)	CF001304	OK	1050	0.10	500	250
Chloride (mg/L)	CF001349	OK	479	0.05	250	250

Data from files: TDS17257r1.xls; TDS17257r2.xls; TDS17257r3.xls

Analyte	Sample ID	Sample preservation	[Max]	DL	CDWQG	EPA MCL
TDS	CF001349	OK	2500	5	500	500

Data from file: RMC75502(Final).xls

CAS	Analyte	Sample ID	Sample preservation	[Max] ug/L	DL ug/L	CDWQG ug/L	EPA MCL ug/L
93-76-5	2,4,5-T	-	OK	<DL	2	20	72
94-75-7	2,4-D	-	OK	<DL	2	100	70
15972-60-8	Alachlor	-	OK	<DL	1	5	2
116-06-03	Aldicarb	-	OK	<DL	9	9	7
309-00-2	Aldrin	-	OK	<DL	0.1	0.7	0.2
1912-24-9	Atrazin	-	OK	<DL	5	5	3
86500	Azinphos-methyl	-	OK	<DL	20	20	-
22781-23-3	Bendiocarb	-	OK	<DL	5	40	-
1689-84-5	Bromoxynil	-	OK	<DL	2	5	150
63-25-2	Carbaryl	-	OK	<DL	1	90	720
1563-66-2	Carbofuran	-	OK	<DL	2	90	40
57-74-9	Chlordane	-	OK	<DL	0.3	7	2
2921-88-2	Chlorpyrifos	-	OK	<DL	1	90	30
21725-46-2	Cyanazine	-	OK	<DL	10	10	0.08
50-29-3	DDT and metabolites	-	OK	<DL	0.1	30	0.2
333-41-5	Diazinon	-	OK	<DL	6	20	20
1918-00-9	Dicamba	-	OK	<DL	2	120	220
51338-27-3	Dichlofop-methyl	-	OK	<DL	1	9	-
60-57-1	Dieldrin	-	OK	<DL	0.1	0.7	0.2
60-51-5	Dimethoate	-	OK	<DL	10	20	1.5
88-85-7	Dinoseb	-	OK	<DL	2	10	7
2764-72-9	Diquat	-	OK	<DL	70	70	20
330-54-1	Diuron	-	OK	<DL	5	150	15
58-89-9	Lindane	-	OK	<DL	0.1	4	0.2
1071-83-6	Glyphosate	-	OK	<DL	80	280	700
76-44-8	Heptachlor	-	OK	<DL	0.1	3	0.4
1024-57-3	Heptachlor epoxide	-	OK	<DL	0.1	3	0.2
121-75-5	Malathion	-	OK	<DL	3.5	190	100
72-43-5	Methoxychlor	-	OK	<DL	0.1	900	40
5128-45-2	Metolachlor	-	OK	<DL	3	50	-
21087-64-9	Metribuzine	-	OK	<DL	5	80	180
139-13-9	NTA	-	OK	<DL	100	400	-
4685-14-7	Paraquat dichloride	-	OK	<DL	10	10	32
56-38-2	Parathion	-	OK	<DL	2.5	50	44
298-02-2	Phorate	-	OK	<DL	2	2	1.5
1918-02-1	Picloram	-	OK	<DL	2	190	0.5
7287-19-6	Prometryn	-	OK	<DL	1	1	30
122-34-9	Simazine	-	OK	<DL	6	10	4
3383-96-8	Temephos	-	OK	<DL	200	280	146
13071-79-9	Terbufos	-	OK	<DL	1	1	0.2
2303-17-5	Triallate	-	OK	<DL	1	230	94
1582-09-8	Trifluralin	-	OK	<DL	1	45	8.7
120832	2,4-dichlorophenol	-	OK	<DL	0.5	900	22

88-06-2	2,4,6-trichlorophenol	-	OK	<DL	0.5	5	0.72
58-90-2	2,3,4,6-tetrachlorophenol	-	OK	<DL	0.5	100	220
87-86-5	pentachlorophenol	-	OK	<DL	0.5	60	1
62-75-9	NDMA	-	OK	<DL	0.009	0.009	0.0069

Data from file: Kandahar W1.xls

CAS	Analyte	Sample ID	Sample preservation	[Max] mg/L	DL mg/L	CDWQG mg/L	EPA MCL mg/L
15541-45-4	Bromate	-	OK	<DL	0.05	0.01	0.01

Data from file: PAHw17257r1.xls

CAS	Analyte	Sample ID	Sample preservation	[Max] mg/L	DL mg/L	CDWQG mg/l	EPA MCL mg/L
50-32-8	Benzo(a)pyrene	-	OK	<DL	0.00001	0.00001	0.0002

Data from file: ULPCBw17257r1.xls

Analyte	Sample ID	Sample preservation	[Max] mg/L	DL mg/L	MOE mg/L	EPA MCL mg/L
Total PCBs	-	OK	<DL	0.0001	0.003	0.0005

Data from file:* RMCC - *75502df.xls

Analyte	Sample ID	Sample preservation	[Max] pg/L	[Max] pgTEQ/L	DL pg/L	MOE pgTEQ/L
Total Dioxins and Furans	CF0001307	OK	3.1	4.0	0.7	15

Epidemiological Studies of Health Outcomes Among Troops Deployed to Burn Pit Sites Report

October 2010

FACT SHEET

Purpose of the Study

- Based on the continuing concern of Service members about the effects of exposure to burn pit smoke, the Armed Forces Health Surveillance Center (AFHSC) and the DoD Center for Deployment Health Research (part of the Naval Health Research Center), conducted a number of epidemiologic studies to look for associations of illness or other health conditions among deployed US Service member populations who were assigned to locations with burn pits.

- The health conditions examined included respiratory symptoms and diseases, cardiovascular diseases, chronic multisymptom illness (CMI), lupus erythematosus, rheumatoid arthritis, sleep apnea, and birth outcomes for infants of parents who had deployed.

Key Findings

- The main preliminary finding was that, for nearly all health outcomes measured, the incidence for those health outcomes studied among personnel assigned to locations with documented burn pits and who had returned from deployment, was either lower than, or about the same as, those who had never deployed.

- Similar findings occurred in comparisons between those who had deployed near a documented burn pit and those who had deployed outside the area of a burn pit, with one exception: A small, but measurable, increase in the rate of signs, symptoms, and ill-defined conditions was noted for personnel deployed to a site (Arifjan, Kuwait) without a burn pit.

- For health outcomes measured in theater, Air Force members at Joint Base Balad had a higher proportion of respiratory encounters, although Army members at the same location and Service members at the other burn pit sites studied did not.

- In general, using deployment location as a proxy for burn pit smoke exposure at various times before and during pregnancy, and for differing durations, there was no association with an increase in birth defects or pre-term birth in infants of active-duty military personnel. A very small, but measureable increased risk of birth defects was seen, however, among infants of male Service members who were deployed to a burn pit region more than 280 days prior to their infant's date of conception.

- For those who had deployed to Joint Base Balad, there was a higher risk of self-reported, newly diagnosed lupus following deployment, but it was not associated with proximity or length of time of possible exposure to smoke from a documented burn pit.

Study Strengths and Limitations

- Each of the studies had a number of strengths and some limitations. Depending on the individual studies, the strengths include:
  - The use of comprehensive electronic medical records;
  - The ability to control for health related behaviors such as smoking and physical activity;
  - The inclusion of Reserve and National Guard members;
  - The ability to follow individuals after they had left military service;
  - A large population size;
  - The robust statistical methods used for investigations.

- As with many epidemiological studies, limitations are also recognized. They include:
  - The lack of measures of individual exposure to smoke or hazardous chemicals, which is extremely difficult in the deployed setting;
  - The potential for exposure misclassification with regard to who was or was not exposed and to what extent;
  - The lack of information regarding job duties where additional exposures may have occurred; and
  - For some studies, a lack of information regarding smoking and other potential confounders.

Conclusions

- The overall preliminary findings indicate, at this time, no substantial or consistent health effects in personnel assigned to locations with burn pits at the bases examined, on a population-wide basis, compared to other deployers.

- These findings are consistent with the earlier Joint Base Balad Burn Pit Health Risk Assessment accomplished in 2008 and with the Department's position over the past year.

- Because of the likelihood of some exposure misclassification, and other limitations inherent to the data, the Department will continue to examine the possibility that there may be some Service members who may have developed chronic health conditions, or experienced aggravation or worsening of preexisting conditions, as a result of exposure to burn pit smoke.

- While concern over exposure to burn pit smoke during deployment remains, the report offers reassurance that at this time and for the health outcomes and deployment locations studied, the health of deployers appear to be better or about the same for the conditions studied as other deployers, those who had never deployed, and those who had deployed to an area without a documented burn pit.

Next Steps

- The Department of Defense will continue to work to identify any factors that place personnel at risk for smoke-related illness, eliminate burn pits in theater wherever feasible, and ensure all who experience any adverse health conditions, whatever the cause, receive the treatment they need and deserve.

- US Central Command is working to reduce the amount of waste, maximize the use of incinerators, minimize exposure to burn pit smoke, and ultimately, reduce the number of burn pits in the theater of operations.

    - Currently, there are 42 burn pits remaining in Iraq. The plan calls for most to be closed by August, and all by December 2010.

    - There are 184 burn pit locations in Afghanistan, and a plan is in place to replace many with incinerators.

    - Section 317 of the 2010 NDAA prohibits the disposal of hazardous waste, medical waste, and solid waste containing plastic in an open-air burn pit during a contingency operation lasting longer than one year except when the Secretary determines that no alternative disposal method is feasible.

    - On March 30, 2010, Directive Type Memorandum 09-032, "Use of Open Air Burn Pits in Contingency Operations," was issued. It prohibits the disposal of covered waste in open-air burn pits during contingency operations except when no alternative disposal method is feasible and limits the materials that can be burned.

- Health surveillance of both deployed and returning Services members is ongoing and will continue for the full range of health outcomes and to identify any concerning trends.

- Environmental monitoring will continue, as will exposure-related research by both the Department of Defense and the Military Services.

- This preliminary report has been sent to the Defense Health Board for its review, and its findings will be used to improve subsequent studies.

- The Institute of Medicine, under contract with the VA, is engaged in an 18-month study to examine the risks of inhaling burn pit smoke, and the DoD looks forward to its assessment and recommendations.

- A Pulmonary Health Working Group, comprised of DoD and non-DoD clinicians and researchers, will recommend research regarding deployment respiratory disease concerns, including the need to medically assess respiratory function in deployed personnel.

- The Department of Defense will continue to work with the Department of Veterans Affairs to identify any health conditions that may be linked to burn pit smoke exposures in their patient population.

Epidemiological Studies of Health Outcomes among Troops Deployed to Burn Pit Sites

MAY 2010

JOINTLY PREPARED BY:

THE ARMED FORCES HEALTH SURVEILLANCE CENTER,
Silver Spring, MD
THE NAVAL HEALTH RESEARCH CENTER,
San Diego, CA
THE U.S. ARMY PUBLIC HEALTH COMMAND (PROVISIONAL)
Edgewood, MD

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DEPARTMENT OF DEFENSE
ARMED FORCES HEALTH SURVEILLANCE CENTER
503 ROBERT GRANT AVENUE
SILVER SPRING MD 20910-7500

REPLY TO ATTENTION OF

MCHB-CG-AFH 27 May 2010

MEMORANDUM FOR: ACTING DEPUTY ASSISTANT SECRETARY OF DEFENSE (FORCE HEALTH PROTECTION AND READINESS)

SUBJECT: Epidemiologic Studies of Health Outcomes among Troops Deployed to Burn Pit Sites

1. REFERENCE: OASD memorandum, subject; Evaluation of potential health effects of exposure to smoke from open pit burning during deployment in the U.S. Central Command Area of Responsibility, 30 October 2009

2. PURPOSE: The enclosed report, subject as above, has been prepared in response to the reference OASD memorandum. The Armed Forces Health Surveillance Center, Naval Health Research Center, and the US Army Public Health Command (Provisional) have collaborated in this endeavor.

3. BACKGROUND: This summary report reflects background studies, environmental air sampling, and epidemiologic and analytic studies of short- and long-term health effects among troops deployed to several locations in the US Central Command Area of Responsibility where open burn pit operations were conducted.

4. Questions and comments should be directed to the undersigned, 301-319-3240, DSN 285-3240.

Robert F. DeFraites
COL, US Army
Director

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Summary of Findings

There has been concern over the possibility that, as a result of exposure to smoke produced by burn pit operations in USCENTCOM, deployed Service members are at increased risk for acute and long term health effects[1-4]. The Armed Forces Health Surveillance Center (AFHSC) and the Naval Health Research Center (NHRC) were tasked to conduct expedient epidemiologic studies using readily available data to determine any associations between exposure to burn pit smoke and illness or other health events. These studies assessed whether a range of health outcomes (i.e. respiratory diseases, cardiovascular diseases, chronic multisymptom illness (CMI), lupus erythematosus, rheumatoid arthritis, and birth outcomes for infants whose parents had been deployed) were more likely to occur among troops who were deployed to one or more USCENTCOM sites with a documented burn pit. Since specific individual exposure levels are not available, the studies described herein assumed that troops deployed to selected USCENTCOM locations with active burn pits were exposed to products of combustion in smoke.

AFHSC conducted a retrospective cohort study to: (1) compare the incidence rates among deployers and non-deployers for respiratory diseases, circulatory diseases, cardiovascular diseases, ill-defined conditions, and sleep apnea, (2) compare the responses on the post-deployment health assessment forms among the individuals deployed to one of several USCENTCOM locations, (two with burn pits and two without), and (3) compare the rates and proportions of medical encounters for respiratory outcomes while assigned to the various USCENTCOM locations. In these studies, active component Army and Air Force Service members who were deployed to any one of four USCENTCOM locations (Balad, Buehring, Arifjan, or Taji) or to the Republic of Korea from 1 January 2005 to 30 June 2007 were compared to a never-deployed CONUS-based active component population as of 15 April 2006. For all outcomes measured upon redeployment, Service members from the USCENTCOM locations and the Korea cohort had either similar or significantly lower incidence rates compared to the CONUS-based cohort, with the exception of "signs, symptoms, ill-defined conditions" among the Arifjan cohort (a location with no burn pit). Comparisons of medical encounters in theater between the USCENTCOM camps did show a higher proportion of medical encounters to be respiratory-related for Balad (a location with a burn pit) compared to the three other camps, possibly indicating increased acute respiratory effects of being at Balad; however, as noted above, these effects did not persist upon redeployment. Additionally, the Balad cohort was more likely to self-report exposure to smoke from burning trash or feces, and Air Force personnel from Balad were more likely to report persistent health problems following the deployment compared to Air Force personnel at Arifjan.

NHRC independently conducted studies to evaluate: (1) birth outcomes in infants whose mothers or fathers had been exposed before and during pregnancy, (2) newly reported and recurring respiratory illness, (3) CMI, and (4) newly reported lupus and rheumatoid arthritis. These studies included active-duty, Reserve, and National Guard personnel of all Services and included three USCENTCOM burn pit sites: Joint Base Balad (JBB), Contingency Operating Base (COB) Speicher, and Camp Taji. The primary analysis results showed that possible burn pit exposure was not associated with an increase in birth defects or preterm birth in infants of male and female active-duty military personnel. A number of secondary analyses were conducted to assess whether the timing of burn pit exposure in relation to last menstrual period (LMP) or estimated date of conception (EDC) were related to birth defects. While the vast majority of the secondary analyses showed no association with exposure immediately prior to LMP or EDC, an increased odds of birth defects was found among a subset of infants whose fathers were exposed more than 280 days prior to the EDC. This unexpected finding may be attributed to chance alone and should be considered for further investigation. Exposure within a 5-mile radius of a burn pit was not associated with an increased risk for newly reported or recurring respiratory outcomes, CMI, or newly reported rheumatoid arthritis. While newly reported lupus was not found to be elevated at Camp Taji or COB Speicher, Joint Base Balad was associated with a statistically significant risk of newly reported lupus and this should also be considered a subject for additional study.

While concern over possible exposure to burn pits in Service members during deployment remains, these analyses should offer some reassurance. The epidemiological approach used in these studies found no evidence that Service members at burn pit locations are at an increased risk for most of the health outcomes examined. While each of these well designed and comprehensive studies has limitations, their results taken collectively generally show no impact of burn pit exposure several years post-deployment. Future analyses should focus on improving the quality of individual-level exposure data, include data from additional burn pit sites, and further investigate possible long term health effects related to burn pit exposure.

Introduction

There is concern over health risks to deployed Service members resulting from exposure to smoke emitted during the combustion of waste burned in burn pits. Anecdotal reports of complaints by Service members of eye and respiratory symptoms have been attributed to exposure to burn pit smoke, and news outlets and Members of Congress have expressed concern that exposure to burn pit smoke in certain deployed settings is causing adverse health effects[1, 2]. The Office of the Assistant Secretary of Defense for Health Affairs (OASD HA) - Force Health Protection & Readiness tasked the AFHSC to

support a collaborative multi-agency effort to comprehensively evaluate health effects potentially related to burn pit exposures at deployment locations by conducting rapid epidemiologic studies using existing longitudinal data.

Environmental/occupational physicians, environmental scientists and epidemiologists at the Services' public health centers and at the AFHSC held a number of meetings and teleconferences to determine goals and methodology. During these meetings the participants discussed and debated the health effects most likely to occur during or soon after deployment and potential methods to evaluate these health outcomes. Outcomes of the teleconferences and meetings included development of consensus analysis plans, identification of locations with potentially exposed personnel, and, based on the expertise of personnel who had conducted environmental sampling in-theater, identification of comparison locations that were thought to have similar environmental conditions with the exception of proximity to a burn pit.

Service members in the vicinity of burn pits during deployment have the potential to be exposed to combustibles either directly through inhalation or ingestion, or indirectly through dermal deposition. Potential acute health effects of exposure to combustible pollutants include eye, throat and sinus irritation, cough, headache, chest pain and fever, acute bronchitis, bronchiolitis, dermatitis, and allergic rhinitis, as well as acute exacerbation of pre-existing medical conditions such as asthma[3-11]. Some potential long-term health effects include chronic obstructive pulmonary disease (COPD), emphysema, reproductive health, and cancers[4, 12-18].

Background of Burn Pits

In general, burn pit operations are conducted until incinerators (or alternate waste disposal) become available. Waste segregation for reuse/recycling and the use of incinerators is currently the preferred method of solid waste disposal. Many base camps in USCENTCOM now use incinerators in lieu of burn pits[19].

Unlike municipal combustors, which operate under highly controlled conditions designed to reduce the formation of emissions, open burning of trash is uncontrolled and is generally characterized by low temperature burning and smoldering[20]. The chemicals emitted by burn pits contribute to the total concentration of environmental pollutants that may have harmful health effects. Smoke emitted by burning waste that has the potential to cause the largest health effects include respirable particulate matter of 10 micrometers in diameter or less (PM_{10}), fine particulate matter of 2.5 micrometers in diameter or less ($PM_{2.5}$), lead, mercury, dioxins, furans, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and irritant gases[20]. The contribution of burning waste to the environmental

concentrations of those contaminants varies widely and is based on a number of factors; among these are the composition of the materials being burned and meteorological conditions.

Characterization of Locations of Interest

The Office of the ASD HA-Force Health Protection & Readiness specifically asked the AFHSC and NHRC to address the impact of burn pits at JBB and Camp Taji. Two other USCENTCOM locations, Camp Buehring and Camp Arifjan, were selected for comparison in the AFHSC studies because they are USCENTCOM locations thought to have similar environmental conditions to JBB and Camp Taji with the exception of proximity to a burn pit. The Republic of Korea was used as an additional comparison location in the AFHSC studies because of the meteorological phenomenon found there known as 'yellow dust'. The NHRC studies also included COB Speicher, a third USCENTCOM location with a burn pit.

Joint Base Balad, Iraq

Joint Base Balad, formerly known as Balad Air Base and Camp Anaconda, is located in North Central Iraq, and is surrounded by land primarily used for agriculture[20]. The JBB burn pit was the largest burn pit located in the USCENTCOM AOR[21]. The amount of solid waste initially burned was estimated at about 2 tons of material per day and during the beginning of 2007 was as much as several hundred tons per day. This burn pit, which is now inactive, was located at the northeast corner of the base property and occupied the same site as a former Iraqi army base camp burn pit. Smoke from the burn pit frequently blew over the base and into living areas of a housing area about 1.5 km south of the burn pit. Solid wastes, which were generated and dumped into the burn pit, included plastics, metals (to include aluminum cans), rubber, paints, solvents, petroleum, oil, and lubricants, munitions and wood waste. Incomplete combustion by-products from jet fuel (JP-8) that was used as an accelerant also contributed to emissions.

Waste segregation practices, such as inspecting waste prior to depositing it into the burn pit to prevent unapproved items from being burned, separating out the plastics, and diverting food waste to the incinerators, were adopted as base operations matured and alternatives to burning became available and enforceable. In July 2007, two incinerators were put into operation at JBB, and in April 2008 a third incinerator began operation. By October 2009 the fourth incinerator began operation in JBB, resulting in 100% of solid waste disposal via incineration or off-site recycling, and ending burn pit operations in JBB. At one time, medical waste was also burned in a separate on-base burn pit. In 2005, a medical waste incinerator was built on JBB. The incinerator, located on the southern corner of the base, is now the sole disposal method for medical waste. Hazardous wastes are now removed from the base via a Defense Reutilization and Marketing Service (DRMS) contract managed at JBB and/or Al Asad [20].

Contingency Operating Base Speicher, Iraq

COB Speicher is located in Northern Iraq in the Tigris River Valley near the city of Tikrit. It occupies an airfield site formerly used by the Iraqi military. The surrounding area is primarily agricultural fields. In the vicinity, there is one large industrial facility which is an oil and gas production plant. The prevailing wind direction is from northwest to southeast in this area. A burn pit area containing a series of 7 open pits approximately 20 feet deep are available for solid waste disposal. The pits are located along the southern camp perimeter, reportedly away from the majority of the camp population. The population appears to be predominantly downwind of the burn pit area based on surface wind rose data. Burning operations are nearly continuous. Waste segregation has been in place since 2005 and has grown over time as means of segregation and alternate disposal have become available. Hazardous materials, hazardous waste, tires, medical waste, military energetics, metal, plastics, and other recyclables are segregated from the waste stream and not burned. Medical waste is incinerated in of the 2 medical waste incinerators on base. A 20-ton per day solid waste incinerator is planned for installation and operation in 2010.

Other contributors to overall air quality on COB Speicher include flight operations, vehicle traffic, convoy operations, fueling, power generation, and suspended dust from natural sources as well as local resuspension of particulate matter. The suspended particulate matter is typically present at concentrations higher than normally experienced in most areas of the US.

Camp Taji, Iraq

Camp Taji is located at a former Iraqi airfield in central Iraq north of the city of Baghdad. The surrounding area is primarily used for agriculture and has a few small villages. There is a large industrial complex, the Al Samud Plant, about 3 km to the north of the camp. Two 30-ton municipal waste incinerators are located adjacent to the west edge of the base. A brick factory which is typically operated one day per month is located adjacent to the north side of the base. The predominant wind direction is from northwest to the southeast. Flight operations, vehicle traffic, convoy operations, fueling, and power generation produce exhaust across the Camp. Other contributors to air quality beyond smoke from the burn pit include the regional dust and locally resuspended dust. These are typically present at concentrations higher than normally experienced in most areas of the US.

A large burn pit area located along the north perimeter of the base that consists of approximately 20 individual burn pits. Burning operations are on-going 24 hours per day, 7 days per week, but rotate among the various pits. Typically 2 pits are in use at any given time. The pits are used for burning

municipal solid waste generated on the camp. One pit is designated for burning mattresses and electrical equipment and can be in use at the same time as 2 other pits. Hazardous materials, hazardous waste, tires, medical waste, and military energetics are segregated from the waste stream and not burned. The daily tonnage burned was estimated to be around 50 tons per day. A small percentage of the camp population is located within 1.5 km of the burn pit area, while the majority is 3-5 km from the burn pit area.

Camp Arifjan, Kuwait

Camp Arifjan is a fully functional U.S. military base established in southern Kuwait near the Persian Gulf coast in December 2002. Most of the personnel at the base are support and headquarters elements. During the summer, frequent sandstorms caused by arid shamal winds blow across the Persian Gulf region. The surrounding area is lightly populated desert, with petroleum refining and chemical manufacturing factories located approximately 15 km to the north, south, and west. Hazardous waste storage on the camp is limited to waste POL products and small spill cleanup residue. Burn pits are not used to dispose of solid waste at Camp Arifjan. Trash and garbage are containerized and routinely removed by contractors to off-base municipal landfills. The primary sources of airborne emissions from outside the camp are wind-blown particulate matter and the nearby petroleum industry; on-site sources include vehicle operations and generators.

Camp Buehring, Kuwait

Camp Buehring, formerly known as Camp Udairi, is located in northern Kuwait near the border of Iraq. The surrounding area is largely uninhabited open desert with no industry. Similarly to Camp Arifjan, this location also experiences frequent arid shamal sandstorms during the summer. Burn pits are not used to dispose of solid waste at this camp; instead, waste is disposed via local contractors. The primary sources of airborne emissions are wind-blown particulate matter, vehicle operations, generators, and aviation operations.

Republic of Korea

Air quality at base camp locations in the Republic of Korea can vary widely due to the range of settings that the camps are located. Some Camps are in rural locations where air quality could be affected by local agriculture, and on-base light industrial and vehicular emissions. Most Camps however, are in or adjacent to medium-sized urban areas (Uijongbu, Tongducheon, Osan) or large population dense cities

(Seoul, Taegu, Pusan). These urban base camps are affected by combustion derived (automobile, power generation, etc.) airborne emissions and local industry. A meteorological phenomenon known as 'yellow dust' occurs annually in the springtime throughout the republic of Korea resulting in clouds of yellow particulate matter. This material originates in the Gobi desert in Mongolia and the Taklamakan desert in China and is transported by strong springtime winds across China, North and South Korea, and Japan.

Summary of Environmental Sampling

Ambient air sampling has been conducted throughout the USCENTCOM AOR to evaluate emission hazards that may impact the health of deployed personnel. The environmental sampling description here is a synopsis of the results of the comprehensive sampling effort found in the Department of Defense Enhanced Particulate Matter Surveillance Program (EPMSP) Final Report[22]. This is a summary of the environmental sampling done to characterize the ambient environment at Balad, Taji, Tikrit, Arifjan, and Buehring.

Table 1. Summary of Enhanced Particulate Matter Surveillance 2006-2007.

				Average Ambient Concentration ($\mu g/m^3$)*			Ratio	
Camp	Country	Sampling Days	Analyzed Days	TSP	PM_{10}	$PM_{2.5}$	TSP/ PM10	$PM_{2.5}$/ PM_{10}
Balad	Iraq	60	60	242	184	56*	1.31	0.30
Taji	Iraq	60	60	348	213	81*$^{+}$	1.63	0.38
Speicher	Iraq	60	60	628	300	114*$^{+}$	2.09	0.38
Arifjan	Kuwait	60	60	290	199	62*	1.45	0.31
Buehring	Kuwait	60	59	416	211	67*$^{+}$	1.98	0.32

$^{+}$Concentrations that exceeded the 24-hour military exposure guidelines (MEG)
*Concentrations that exceeded the 1-year MEG
**Ambient sampling was conducted for 24 hours every 6 days
Results are site specific averages.
The standard for PM_{10} (formerly 50 $\mu g/m^3$ was revoked in December, 2006).
There is no standard for total suspended particulates (TSP).

In 2006/2007, the USACHPPM coordinated enhanced surveillance of ambient particulate matter at several US bases in Southwest Asia which included the USCENTCOM area. The purpose of the assessment was to provide information on the chemical and physical properties of particulate matter collected over a period of approximately 1 year and did not focus on burn pit emissions. The study found the three main ambient air particulate matter types to be geological material, smoke from burn pits, and heavy metal condensates (possibly from metals smelting and battery manufacturing facilities)[23]. The study's ability to determine or discriminate particulate matter sources was severely limited for

methodological reasons. Data from this surveillance effort demonstrates that ambient levels of particulate matter (all size fractions) were high at all five locations considered by the present summary, relative to average concentrations found in the US. Average concentrations of $PM_{2.5}$ at all camps were above the 1 year military exposure guideline (MEG) level of 15 μg/m^3. The highest average particulates levels were observed at Tikrit in COB Speicher ; the lowest average levels were observed at Balad (Table 1). MEGs are published in the USACHPPM Technical Guide 230, *Chemical Exposure Guidelines for Deployed Military Personnel*[24]. These MEGs represent chemical concentrations above which certain types of health effects may begin to occur in individuals within an exposed population after a continuous, single exposure of specified duration. The MEGs are conservative estimates to be used as preventive guidelines and are not designed for determining casualty estimates.

The $PM_{2.5}$/ PM_{10} ratios for the five sites are similar to each other, and approximately the same as that seen in the rural southwestern area of the US (0.36). This signifies that, on average, the $PM_{2.5}$: PM_{10} particulate mass distribution of sampled areas in the Middle East is similar to that of the drier parts of the southwestern US. This low value is typical of regions dominated by geological dust, in contrast to urban areas, where combustion processes such as coal or wood burning dominate, and where $PM_{2.5}$/ PM_{10} ratios are on average as high as 0.85 [22].

It is expected that some personnel exposed to the levels of $PM_{2.5}$ and PM_{10} found in the USCENTCOM AOR may experience notable mild eye, nose, or throat irritation, and pre-existing health conditions (e.g., asthma, or cardiovascular diseases) may be exacerbated. Over a year period, repeated exposures of $PM_{2.5}$ from any source above an ambient average concentration of 65 μg/m^3 may increase the risk for developing chronic health conditions such as reduced lung function or exacerbated chronic bronchitis, COPD, asthma, atherosclerosis, or other cardiopulmonary diseases in some personnel [4]. Those with a history of asthma or cardiopulmonary disease are considered to be at a higher risk for developing these health conditions.

AFHSC: Report on Health Effects among Active Component U.S. Service Members who Deployed to Select Deployment Locations

1. Overall Summary

To investigate the health effects of deployment to USCENTCOM locations with burn pit operations, we conducted a retrospective cohort study to: (1) compare the incidence rates among deployers and non-deployers for respiratory diseases, circulatory diseases, cardiovascular diseases, ill-

defined conditions, and sleep apnea, (2) compare the responses on the post-deployment health assessment forms among the individuals deployed to each USCENTCOM location, and (3) compare the rates and proportion of medical encounter for respiratory outcomes while in-theater between the USCENTCOM locations. Active component Service members who deployed to any one of four USCENTCOM locations (Balad, Buehring, Arifjan, or Taji) or Korea from 1 January 2005 to 30 June 2007 were compared to a never-deployed CONUS-based active component population as of 15 April 2006. For all outcomes, the USCENTCOM locations and the Korea cohort had either similar or significantly lower incidence rates compared to the CONUS-based cohort, with the exception of "signs, symptoms, ill-defined conditions" among the Arifjan cohort. Comparisons of medical encounters in theater between the USCENTCOM camps did show a higher proportion of medical encounters to be respiratory-related for Balad compared to the other camps, possibly indicating increased acute respiratory effects some factor associated with location at Balad. Additionally, the Balad cohort was more likely to self-report exposure to smoke from burning trash or feces, and Air Force personnel from Balad were more likely to report persistent health problems following the deployment compared to Air Force personnel at Arifjan. Given these findings and the significant limitations to this study, further investigation to better understand these possible associations may be warranted.

2. Introduction

Measurements of airborne particulates at deployed locations in USCENTCOM have been found to regularly exceed maximum exposure guideline levels for military operations[21]. To evaluate health effects potentially related to burn pit exposures, the AFHSC looked at base camps located in Balad, Taji, Buehring, and Arifjan. The peer-reviewed literature was reviewed to further elucidate potential methods, and International Classification of Diseases, 9th Revision, Clinical Modification medical diagnostic (ICD-9) code groupings for conditions of interest were developed. In addition to the acute conditions that AFHSC investigators judged most likely to be influenced or caused by particulate matter, investigators decided to also examine the occurrence of sleep apnea due to specific interest in this condition by Members of Congress. Reservations about the lack of individual exposure data to environmental particulates and the lack of information about smoking status were expressed during meetings and teleconferences held by environmental/occupational physicians and epidemiologists at the Services' public health hubs and at the AFHSC; however this approach was determined to be the best that could be conducted given the available data. The Defense Manpower Data Center (DMDC) de-classified and provided rosters of personnel who had been in the deployment camps of interest in USCENTCOM during the period under study.

Outcomes of the teleconferences included development of a consensus analysis plan and, based on the expertise of personnel who had access to particulate matter sampling in-theater, identification of comparison locations that were thought to have similar environmental conditions with the exception of proximity to a burn pit.

3. Overall Methods for all sub-studies

A retrospective cohort study was conducted to compare acute and long-term health care utilization during and immediately after return from deployment for active component Service members who had spent at least 31 days deployed and were in one of four USCENTCOM deployment locations or in the Republic of Korea during the period 1 January 2005 to 30 June 2007, or who were never deployed and stationed only in the continental United States (CONUS) as of 15 April 2006.

3.1. Study populations

3.1.1. *Camp cohorts*

The DMDC queried its deployment roster and provided declassified data on the active component Service members who were located within a 3 mile radius of one of the three USCENTCOM camps (Balad, Buehring, and Taji) and just over a 3 mile radius of Arifjan. This slightly larger radius for Arifjan served to provide a larger and more appropriate population size for this location. Personnel who spent time in more than one of the camps or who had multiple, non-continuous segments in a specific camp during the deployment were excluded. Also, all individuals with a total deployment time less than 31 days (regardless of time spent at a specific camp) or whose date of departure from the camp was >30 days from their end date of deployment according to the DMDC Contingency Tracking System (CTS) roster were excluded. Individuals were required to be at the specific camp at the end of their deployment so that any effects of the location resulting in medical encounters could be accurately captured immediately following the deployment. This requirement strengthens the study assumption placing the Service member at one of the camps of interest immediately prior to redeployment, and allowed for the reasonable attribution of medical encounters captured at redeployment to the Service members' location at the camp of interest.

3.1.2. *Korea-based comparison group*

The AFHSC queried the Defense Medical Surveillance System (DMSS) personnel records to identify active component personnel with a stationing in Korea for more than 30 days that began during

the period of interest. Personnel who had a previous deployment according to the CTS roster or were already selected for the camp cohorts were excluded.

3.1.3. *CONUS-based comparison group*

For the CONUS comparison group, all active component Service members who were stationed in the US as of April 15, 2006 were included. Personnel who had a previous deployment according to the DMDC deployment roster or personnel who appeared in the USCENTCOM camp or Korea-based comparison groups were excluded.

3.1.4. *Additional exclusions*

Due to the small number of Marines (less than 2% of the total camp population) and no Navy personnel identified at the camp locations, the study population for the camps, Korea, and CONUS-based cohorts were restricted to Service members from the Army and Air Force.

4. Sub-Study Methodologies and Results

4.1. Sub-Study 1: Comparison of incidence rates of select outcomes of interest following deployment to select locations.

Sub-study 1 utilized the cohorts defined previously for the overall study.

4.1.1. Methods

4.1.1.1. *Outcomes of interest*

Military treatment facility or purchased care hospitalizations and ambulatory medical encounters with an ICD-9 code of interest (regardless of diagnostic position) within the surveillance period were captured. The ICD-9 code groupings of interest were:

1. Diseases of the Respiratory System (460-519)
    a. Acute respiratory infections (460-466)
    b. Chronic obstructive pulmonary disease (COPD) and allied conditions (490-492, 494-496)
    c. Asthma (493)
2. Diseases of the Circulatory System (390-459)
3. Signs, symptoms, ill-defined conditions (SSIC) (780-799)
    a. SSIC involving cardiovascular system (785)
    b. SSIC involving respiratory system and other chest symptoms (786)
    c. A secondary analysis also evaluated each 3-digit ICD code between 780-799

4. Organic sleep disorders (327)
    a. Organic sleep apnea (327.2)

4.1.1.2. *Surveillance period and person time calculation*

Person-time was calculated beginning on the date of return from a deployment or Korea assignment, or (for the CONUS-based population) from April 15, 2006. Person-time was censored at the earliest occurring date among the following events per individual: first encounter for an ICD-9 code of interest, separation from active service, the start of a subsequent deployment, departure for a change of station to Korea, or the end of the 36-month follow-up period.

4.1.1.3. *Analytic Methods*

Incidence and 95% confidence intervals for first diagnoses (number of incident diagnoses per 1000 person-years [PY]) were calculated for each condition for each population. Incidence rate ratios and 95% confidence intervals were calculated to compare the deployed populations to the CONUS-based population. Incidence rate ratios (IRR) were adjusted for covariates of importance, specifically age (defined at start of follow-up), sex, race, grade (defined at start of follow-up), and Service, using Poisson regression models. Negative binomial and zero-inflated negative binomial models were also explored, but provided similar estimates as the Poisson models and are therefore not reported.

A Service stratified analysis was also conducted, but the results were similar to the overall cohort. Therefore, only the overall results are presented in the report. Stratification by time in location was also conducted; however this did not yield meaningfully different results from the overall analysis (data not shown).

4.1.2. Results

4.1.2.1. *Comparison of Cohorts*

Table 2 displays a comparison of the demographic and Service related covariates between the five cohorts. There were significant demographic differences in the deployed populations compared to the CONUS based population. Specifically, the age makeup of the deployed population differed from the CONUS-based cohort and the gender makeup of the deployed cohorts was different than the Korea and CONUS-based cohorts. Balad has a higher percentage of Air Force personnel, while Arifjan and Korea had a higher percentage of Army personnel. The Buehring and Taji cohorts were almost exclusively Army.

4.1.2.2. *Incidence Analysis*

Crude/unadjusted and adjusted IRR varied depending on the camp and the outcome of interest (Table 3). For all outcomes, subjects from at least one of the camps or Korea had significantly lower incidence rates (highlighted in peach) compared to the CONUS-based cohort. The only outcome and camp with a significantly higher adjusted incidence rate (highlighted in green) compared to the CONUS-based cohort was "signs, symptoms, ill-defined conditions" (SSIC) among the Arifjan cohort (IRR=1.07, 95% CI=1.03, 1.12). Specifically for Balad, adjusted incidence rates compared to the CONUS-based cohort were significantly lower for all outcomes except SSIC involving respiratory system and chest, which showed no significant difference from the CONUS-based rate.

4.2. Sub-Study 2: Comparison of health status and exposure concern responses on the DD2795, DD2796, and DD2900 among the Balad, Arifjan, Buehring, and Taji cohorts.

Sub-study 2 utilized the cohorts defined previously for the overall study.

4.2.1. Methods

4.2.1.1. *Selection of deployment forms*

Among the camp cohorts, individuals were identified who had completed a DD2795 (pre-deployment health assessment form), DD2796 (post-deployment health assessment form, PDHA), and/or DD2900 (post-deployment health re-assessment form, PDHRA) for the deployment of interest. The start and end dates of the full deployment were obtained from the DMDC CTS roster. The DD2795 had to be completed within the 1 year prior to or the 30 days after the start of the deployment. The DD2796 has to be completed within the 30 days prior to or the 60 days after the end of the deployment. The DD2900 had to be completed within the 60 to 210 days following the end of the deployment.

The "health assessment" question, "Would you say your health in general is excellent, very good, good, fair, or poor" (DD2795) or "Overall, how would you rate your health during the past month?", was pulled from all forms (DD2795, DD2796 (20080103 version), DD2900 (JUN 2005 version), DD2900 (20080103 version): question 1; DD2796 (APR 2003 version): question 1 of the health care provider section). Question 2, addressing whether the Service member's health changed after the deployment compared to prior to the deployment, from all versions of the DD2796 and DD2900 was assessed. Additional, the questions on the DD2796 and DD2900 pertaining to exposure-related concerns were assessed; specifically exposure to "smoke from oil fire", "smoke from burning trash or feces", "vehicle or truck exhaust fumes", and "JP8 or other fuels". On the DD2900, the question on whether the Service member had persistent major concerns regarding health effects related to something they believe they were exposed to during deployment was also investigated.

4.2.1.2. *Statistical analysis*

The camps were stratified by Service. The number and percent of individuals who completed each form was calculated for each camp and Service. Of those who completed each form of interest, the number and percent who reported "fair" or "poor" health, "health got worse" during the deployment, exposure to each of the exposure categories listed above, and "persistent major concerns due to deployment exposures" were calculated.

4.2.2. Results

Regardless of Service or camp, the percentage of Service members from each cohort who completed each of the three forms was relatively similar, with the exception of the DD2796 and DD2900 forms for the Buehring cohort and DD2900 forms among the Army Arifjan cohort, which had much lower completion percents (Table 4). Overall, the Army personnel compared to the Air Force personnel were more likely to report "poor" or "fair" health on all three forms and that their "health got worse during the deployment" on the DD2796 and DD2900. However, the Air Force personnel from Balad compared to the Army Balad cohort and the other camps, reported higher exposure to smoke from burning trash or feces on both the DD2796 and the DD2900. Although lower than the Air Force, the Army personnel at Balad were also more likely to report exposure to smoke from burning trash or feces on both the DD2796 and the DD2900 compared to the other camps.

4.3. Sub-Study 3: Comparison of the rates and proportion of medical encounter for respiratory outcomes while in-theater between the USCENTCOM locations.

Sub-study 3 utilized the cohorts defined previously for the overall study.

4.3.1. Methods

4.3.1.1. *Outcomes of Interest*

Inpatient and outpatient medical encounters recorded in the Theater Medical Data System (TMDS) were examined for all individuals from each of the four camp cohorts. Encounters were classified as respiratory and non-respiratory using the primary ICD-9 code associated with an encounter (Table 5). Due to incomplete capture of medical encounters and differential reporting by location in TMDS, rates of respiratory encounters were normalized between the four camps to the respective non-respiratory rates (expressed as a ratio of the non-respiratory to respiratory rates). The normalization category included all medical events except those classified as "respiratory", headache, migraine, or dry/red eyes (Table 5).

4.3.1.2. Statistical Analysis

The camps were stratified by Service. Individual person-time was calculated as the amount of time in days spent in the camp. Aggregate person time for each camp was then calculated and converted to person years. Encounter rates were expressed as the number of encounters per 100 PY. Individuals could have multiple encounters during the surveillance period. The ratio of the non-respiratory to respiratory rates was calculated for each camp. In addition, the proportions of respiratory and non-respiratory conditions among all theater encounters were calculated to compare the distribution of encounters for specific respiratory conditions across the cohorts and Services.

4.3.2. Results

4.3.2.1. *Encounter rates*

Total person-time contributed for this analysis was 4575 and 923 person-years for Air Force personnel at Balad and Arifjan, respectively, and 1252, 330, 732, and 1163 person-years for Army personnel at Balad, Buehring, Arifjan, and Taji, respectively (Table 6). For non-respiratory conditions, the counts and rates of encounters were lowest at Balad (Air Force: 90.9 per 100 PY; Army: 55.7 per 100 PY) and highest at Arifjan (Air Force: 185.1 per 100 PY; Army: 519.7 per 100 PY). For respiratory conditions, Air Force rates were similar between Balad and Arifjan, but were over 9 times higher for Arifjan (40.2 per 100 PY) compared to Balad (4.4 per 100 PY) for the Army. The ratio of non-respiratory to respiratory encounter rates were over twice as high for Arifjan compared to Balad for the Air Force, however they were remarkably consistent across all cohorts for the Army.

4.3.2.2. *Proportion of all encounters coded as respiratory*

The distribution of encounter types for respiratory and non-respiratory conditions was examined for each camp (Table 7). Overall, the proportion of all TMDS encounters accounted for by respiratory conditions were lower among the Army cohorts (range: 6-7%) compared to the Air Force cohorts (range: 10-20%). Air Force personnel from the Balad camp had the highest proportion of TMDS encounters that were respiratory (20%).

5. Discussion

The purpose of this analysis was to evaluate post-deployment healthcare encounters among personnel stationed at different in-theater locations in USCENTCOM, two known to have a burn pit and two locations without burn pits, and compare them to a similarly healthy group which may have been

exposed to particulate levels higher than in the U.S. (personnel assigned to Korea), and to a CONUS-based group. Additionally, comparisons between the USCENTCOM cohorts were performed to evaluate pre- and post-deployment health assessment form responses and respiratory healthcare encounters while in-theater.

For the analysis of post-deployment healthcare encounters, only one outcome (signs, symptoms, and ill-defined conditions) at one location (Camp Arifjan) had a slightly elevated risk compared to the CONUS-based cohort. All other outcomes had adjusted IRR that appeared lower or similar for the USCENTCOM camps and Korea compared to the CONUS-based population. In general, a collection of Service members that deploy is healthier at baseline than a group of personnel that do not deploy since the latter group includes personnel with health issues that prevent them from deploying or being stationed in an area where the standard of health care quality or resources are lower than in the U.S. Lower rates in the USCENTCOM cohorts compared to the CONUS-based population were not unexpected given this "healthy deployer" effect. To remove this "healthy deployer effect", rates among the USCENTCOM cohorts can be compared. The comparison shows similar rates between the deployed cohorts, regardless of whether or not the location had a burn pit. Although we were not able to identify any increased risk of the outcomes investigated for the burn pit locations, these findings are only applicable on a population level. These results do not rule out the possibility that certain individuals exposed to smoke from a burn pit may subsequently develop adverse health conditions. Additionally, all individuals at a location were assumed to have been exposed to the conditions of that location equally, as it was not possible to identify individual exposures.

The results of the TMDS analysis of medical encounters while in theater indicate possible elevated risks of acute respiratory outcomes during the deployments for some, but not all personnel stationed at a burn pit location. Air Force personnel from Balad had the highest percent of encounters for respiratory conditions, but Army personnel had proportions similar to other non-burn pit camps. These Service specific differences could be due to different exposures; e.g. different occupations or location of housing that resulted in higher exposure to burn pit smoke for the Air Force, increases or decreases in the other conditions used to create the proportion at one location versus another, or simply different health care seeking behaviors. Due to limitations of the TMDS data, such as its incomplete capture of events and the lack of individual level data on housing and occupations while in the camp, it is difficult to adequately address this issue. Additionally, normalization of the rates of respiratory conditions for comparison, rather than comparing rates directly may be misleading if for some reason the rates of the other conditions at any camp are unusually high or low.

The findings from the analysis of the PDHA and PDHRA forms support the hypothesis that Service members who were located in Balad were more likely to report being exposed to potentially

hazardous environmental conditions such as smoke from burning trash and feces. This observation also correlates well with the findings of the TMDS analysis, since the Air Force personnel at Balad had the highest proportion of Service members reporting exposure to smoke from burning trash and feces and also had the highest percent of medical encounters for a respiratory outcome while deployed. However, the deployment form data should be interpreted cautiously due to the fact that these are self-reported exposures and health outcomes and may be subject to a reporting or recall bias. From these data alone, it is not known if results are reflective of actual health problems and exposures or simply a reflection of personal differences in how the form was completing the forms.

The findings from this study should be balanced by the understanding that, as mentioned throughout this report, there are limitations to this study. First, data were not available on individual environmental exposures over time. Deployment duties (apart from or in addition to job classification) and specific locations would likely have had a major impact on the environmental exposures within the camp; however these data are not available. Additionally, there were no data on where individuals were located prior to being at the camps of interest. If individuals did not spend their entire deployment at one of the specific camps, they may have been exposed to other environmental conditions while at different locations. The analysis of post-deployment healthcare encounters is impacted by the fact that all personnel following redeployment are required to have at least one healthcare encounter to complete post-deployment health assessment processing around the time of return, and another visit 3-6 months later to complete post-deployment health reassessment processing. This type of mandatory health care encounter is not counted as a condition but may introduce an opportunity to identify a diagnosis. This situation introduces a surveillance bias that might exaggerate any effects seen in deployers when comparing them to non-deployers. Also, since healthcare in theater is limited, catch-up on requirements such as well woman exams, immunizations and other mandatory visits must also occur. It is important to bear this in mind when viewing and drawing conclusions from these results. In addition, despite efforts to choose cohorts that would be similar to each other, there were significant demographic differences between the study groups necessitating adjustment when comparing results. The question remains if there are unknown/unmeasured determinants of health status which vary between the comparison groups and which may therefore confound the results. Most notable of these would be smoking status. For the in-theater healthcare encounter analysis, interpretation of these findings should also be approached with caution as capture of healthcare encounter information in-theater is highly variable by site. The pre- and post-deployment health assessment forms are primarily self-reported and therefore subject to recall bias. Another limitation is the lack of information on individual tobacco smoking behavior, which has significant impacts on respiratory illness. A substantial difference in smoking prevalence between deployers and non-deployers might confound the findings presented here.

The strengths of this study include the following aspects. Documentation of post-deployment health care encounters in Service members' electronic health records allows for more complete determination of post-deployment health encounters and diagnoses. The size of the observed population also strengthens these studies by allowing for precise estimation of rates.

6. Conclusion

With the exception of one outcome among the Arifjan cohort, all outcomes of interest following deployment were found to occur at similar or lower rates for the camps and Korea cohorts compared to the CONUS-based cohort. However, in-theater respiratory encounters made up a larger proportion of all Air Force encounters at Balad compared to the other deployed settings, a possible indication of increased acute respiratory effects of being at Balad. In addition, individuals from the Balad cohort were more likely to self-report higher environmental exposures compared to the other deployed locations. These findings may warrant further investigation to better understand the association and to confirm these findings, especially given the significant limitations to the current study.

Table 2. Demographic characteristics of the study cohorts

	Balad		Arifjan		Buehring		Taji		Korea		CONUS	
	n	%	n	%	n	%	n	%	n	%	n	%
Total	15,908	100.0	4,431	100.0	1,906	100.0	2,522	100.0	44,962	100.0	237,714	100.0
Age												
<20	46	0.3	14	0.3	37	1.9	32	1.3	581	1.3	17,175	7.2
20-29	9,635	60.6	2,600	58.7	1,334	70.0	1,695	67.2	33,086	73.6	141,731	59.6
30-39	4,588	28.8	1,291	29.1	441	23.1	625	24.8	8,574	19.1	50,937	21.4
40+	1,639	10.3	526	11.9	94	4.9	170	6.7	2,721	6.1	27,871	11.7
Sex												
Female	2,478	15.6	554	12.5	205	10.8	317	12.6	9,094	20.2	55,720	23.4
Male	13,430	84.4	3,877	87.5	1,701	89.2	2,205	87.4	35,868	79.8	181,994	76.6
Race												
White	10,967	68.9	2,732	61.7	1,218	63.9	1,555	61.7	25,812	57.4	162,417	68.3
Black	2,388	15.0	971	21.9	345	18.1	581	23.0	10,022	22.3	37,583	15.8
Other	2,553	16.0	728	16.4	343	18.0	386	15.3	9,128	20.3	37,714	15.9
Rank												
E00-E04	6,354	39.9	1,707	38.5	988	51.8	1,256	49.8	26,828	59.7	126,564	53.2
E05-E09	7,092	44.6	2,028	45.8	693	36.4	1,004	39.8	13,546	30.1	62,466	26.3
O01-O10 (including warrant)	2,462	15.5	696	15.7	225	11.8	262	10.4	4,588	10.2	48,684	20.5
Service												
Army	3,989	25.1	2,873	64.8	1,904	99.9	2,522	100.0	32,553	72.4	100,726	42.4
Air Force	11,919	74.9	1,558	35.2	2	0.1	0	0.0	12,409	27.6	136,988	57.6

Table 3. Incidence rate ratios of outcomes of interest by cohort.

A. Incidence rate ratios for respiratory diseases (ICD-9: 460-519)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	18132	6477	357	0.89	0.87	0.91	0.91	0.88	0.93
Arifjan	4950	1847	373	0.93	0.89	0.97	1.00	0.96	1.05
Buehring	1364	340	249	0.62	0.56	0.69	0.68	0.61	0.75
Taji	2866	900	314	0.78	0.73	0.84	0.86	0.81	0.92
Korea	49355	16661	338	0.84	0.83	0.85	0.83	0.82	0.84
CONUS	272903	109563	401	REF			REF		

B. Incidence rate ratios of acute respiratory infections (ICD-9: 460-466)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	20446	4859	238	0.87	0.84	0.89	0.90	0.88	0.93
Arifjan	5698	1333	234	0.85	0.81	0.90	0.95	0.90	1.00
Buehring	1498	231	154	0.56	0.49	0.64	0.62	0.54	0.70
Taji	3128	686	219	0.80	0.74	0.86	0.90	0.83	0.97
Korea	54703	12615	231	0.84	0.83	0.86	0.82	0.81	0.84
CONUS	311221	85382	274	REF			REF		

C. Incidence rate ratios of chronic obstructive pulmonary disease (ICD-9: 490-492 or 494-496)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	25923	564	22	0.84	0.77	0.92	0.91	0.84	0.99
Arifjan	7174	186	26	1.00	0.87	1.16	0.98	0.85	1.13
Buehring	1733	31	18	0.69	0.49	0.98	0.62	0.44	0.88
Taji	3802	93	24	0.95	0.77	1.16	0.83	0.68	1.02
Korea	67591	1556	23	0.89	0.84	0.94	0.83	0.78	0.88
CONUS	415659	10749	26	REF			REF		

D. Incidence rate ratios of asthma (ICD-9: 493)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	26164	332	13	0.66	0.59	0.73	0.81	0.73	0.91
Arifjan	7211	149	21	1.07	0.91	1.26	0.95	0.80	1.11
Buehring	1720	32	19	0.96	0.68	1.36	0.76	0.53	1.07
Taji	3815	83	22	1.13	0.91	1.40	0.97	0.78	1.21
Korea	67638	1386	20	1.06	1.00	1.12	0.91	0.86	0.96
CONUS	417579	8062	19		REF			REF	

E. Incidence rate ratios for circulatory system diseases (ICD-9: 390-459)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	23927	2225	93	0.98	0.93	1.02	0.94	0.90	0.98
Arifjan	6539	710	109	1.14	1.06	1.23	1.05	0.98	1.13
Buehring	1590	146	92	0.96	0.82	1.13	1.04	0.89	1.23
Taji	3539	321	91	0.95	0.85	1.06	1.03	0.92	1.15
Korea	63071	5374	85	0.89	0.87	0.92	0.95	0.92	0.98
CONUS	381302	36361	95		REF			REF	

F. Incidence rate ratios of signs, symptoms, ill-defined conditions (ICD-9: 780-799)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	17036	7460	438	0.92	0.90	0.95	0.97	0.94	0.99
Arifjan	4472	2249	503	1.06	1.02	1.11	1.07	1.03	1.12
Buehring	1111	528	475	1.00	0.92	1.09	0.97	0.89	1.06
Taji	2433	1231	506	1.07	1.01	1.13	1.03	0.97	1.09
Korea	43910	21504	490	1.03	1.02	1.05	0.94	0.93	0.95
CONUS	260160	123320	474		REF			REF	

G. Incidence rate ratios of SSIC - Cardiovascular (ICD-9: 785)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	25990	493	19	0.75	0.68	0.82	0.81	0.74	0.88
Arifjan	7234	152	21	0.83	0.70	0.97	0.93	0.79	1.09
Buehring	1732	30	17	0.68	0.48	0.97	0.79	0.55	1.13
Taji	3823	74	19	0.76	0.61	0.96	0.90	0.71	1.13
Korea	67677	1428	21	0.83	0.79	0.88	0.87	0.82	0.92
CONUS	415500	10567	25		REF			REF	

H. Incidence rate ratios of SSIC - Respiratory symptoms and other chest (ICD-9: 786)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	24036	2205	92	0.93	0.89	0.97	0.97	0.93	1.01
Arifjan	6548	712	109	1.10	1.02	1.19	1.07	0.99	1.15
Buehring	1617	129	80	0.81	0.68	0.96	0.79	0.67	0.94
Taji	3517	348	99	1.00	0.90	1.11	0.99	0.89	1.10
Korea	62919	5931	94	0.95	0.93	0.98	0.91	0.89	0.94
CONUS	382505	37772	99		REF			REF	

I. Incidence rate ratios of sleep apnea (ICD-9: 327.2)

				Unadjusted			Poisson Model		
	Person-years	Incidences	IR*1000	IRR	95% lower	95% upper	IRR	95% lower	95% upper
Balad	26253	386	15	0.95	0.85	1.05	0.81	0.73	0.89
Arifjan	7268	153	21	1.35	1.15	1.59	1.08	0.92	1.26
Buehring	1753	19	11	0.70	0.44	1.09	0.63	0.40	0.99
Taji	3855	56	15	0.93	0.72	1.22	0.89	0.68	1.16
Korea	68539	839	12	0.79	0.73	0.85	0.87	0.81	0.93
CONUS	422239	6565	16		REF			REF	

Table 4. Responses to health and exposure questions on the DD2795, DD2796, and DD2900 deployment forms by Service and camp.

		Army				Air Force	
	Form Type	**Balad**	**Arifjan**	**Buehring**	**Taji**	**Balad**	**Arifjan**
Total cohort, n		3,989	2,873	1,904	2,522	11,919	1,558
Individuals who completed form, n (%)	DD2795	3607 (90%)	2319 (81%)	1744 (92%)	2319 (92%)	11021 (92%)	1393 (89%)
	DD2796	3168 (79%)	2190 (76%)	680 (36%)	2144 (85%)	9953 (84%)	1218 (78%)
	DD2900	1835 (46%)	661 (23%)	282 (15%)	1210 (48%)	6736 (57%)	906 (58%)
Reported general health to be "fair" or "poor", %	DD2795	2.7	2.8	3.1	3.7	0.6	0.7
	DD2796	8.4	7.1	10.3	9.0	2.1	3.3
	DD2900	17.7	17.3	16.3	15.0	6.4	6.8
Reported "health got worse" during deployment, %†	DD2796	18.2	16.5	18.5	17.7	9.1	7.3
	DD2900	25.8	26.8	24.8	22.2	13.9	20.2
Reported exposure to smoke from oil fires, %†	DD2796	23.8	17.9	18.8	26.3	19.3	31.7
	DD2900	8.3	8.3	9.2	8.8	7.2	6.7
Reported exposure to smoke from burning trash or feces, %†	DD2796	68.6	38.0	46.0	59.6	92.2	42.8
	DD2900	17.8	10.4	14.2	14.1	26.8	10.3
Reported exposure to vehicle or truck exhaust fumes, %†	DD2796	65.7	58.2	56.8	68.7	68.7	65.4
	DD2900	11.1	12.0	9.9	13.1	7.8	11.7
Reported exposure to JP8 or other fuels, %†	DD2796	58.0	50.2	54.7	63.2	41.3	49.8
	DD2900	10.0	9.4	11.4	13.2	6.6	6.6
Reported persistent major health concerns due to deployment exposures	DD2900	25.8	24.5	23.1	22.5	29.2	19.0

†Question on the DD2900 requires responder to have a persistent major concern regarding the health effects of something they believe they were exposed while deployed.

Table 5. ICD-9 codes used to define respiratory and non-respiratory medical encounters.

Category	Sub-category	ICD-9 Codes
Respiratory encounter	Acute respiratory infections	460-466
	Other diseases of the upper respiratory tract	470-478
	Pneumonia and influenza	480-488
	Chronic Obstructive Pulmonary Disease and allied conditions	490-496
	Pneumoconiosis and other lung diseases due to external agents	500-508
	Other diseases of respiratory system	510-519
	Symptoms involving respiratory system and other chest symptoms	786
	Nonspecific abnormal results on pulmonary function studies	794.2
Excluded non-respiratory encounter	Other headache syndromes	339
	Migraine	346
	Headache	784
	Redness of Eyes	379.93
	Dry Eyes	375.15

Table 6. Rates of theater medical encounters for respiratory and non-respiratory outcomes by Service and camp.

			Primary ICD-9				
			Non-respiratory encounters		Respiratory encounters		Ratio of non-respiratory to respiratory encounter rates
Service	Camp	PY	N	Rate (per 100 PY)	N	Rate (per 100 PY)	
Army	Balad	1252	697	55.7	55	4.4	12.7
	Buehring	330	1,013	307.2	68	20.6	14.9
	Arifjan	732	3,804	519.7	294	40.2	12.9
	Taji	1163	2,512	216.1	200	17.2	12.6
Air Force	Balad	4575	4,157	90.9	1197	26.2	3.5
	Arifjan	923	1,709	185.1	194	21.0	8.8

PY=person-years

Table 7. Proportion of theater medical encounters for respiratory and non-respiratory outcomes by Service and camp.

		TMDS Encounters											
		Army								Air Force			
		Balad		Arifjan		Buehring		Taji		Balad		Arifjan	
Category	Sub-category	N	%	N	%	N	%	N	%	N	%	N	%
Respiratory encounter	Acute respiratory infections	35	4.6	139	3.3	33	2.9	122	4.4	768	12.7	114	5.8
	Other diseases of the upper respiratory tract	4	0.5	58	1.4	10	0.9	36	1.3	248	4.1	50	2.5
	Pneumonia and influenza	2	0.3	3	0.1	1	0.1	6	0.2	10	0.2	7	0.4
	Chronic obstructive pulmonary disease and allied conditions	5	0.7	36	0.9	12	1.1	8	0.3	129	2.1	6	0.3
	Other diseases of respiratory system	0	0.0	2	0.0	0	0.0	5	0.2	1	0.0	1	0.1
	Symptoms involving respiratory system and other chest symptoms	9	1.2	56	1.3	12	1.1	23	0.8	41	0.7	16	0.8
Excluded non-respiratory encounter	Migraine	2	0.3	17	0.4	18	1.6	24	0.9	11	0.2	8	0.4
	Headache	9	1.2	12	0.3	6	0.5	24	0.9	48	0.8	3	0.2
	Redness of eyes	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0	1	0.1
	Dry eyes	0	0.0	1	0.0	1	0.1	0	0.0	0	0.0	0	0.0
Non-respiratory encounters		697	90.6	3,804	91.5	1,015	90.5	2,512	90.8	4,157	69.0	1,709	86.9
Missing		6	0.8	29	0.7	13	1.2	7	0.3	613	10.2	51	2.6
Total		769	0.0	4,157	0.0	1,121		2,768		6,027	0.0	1,966	0.0

NHRC: Epidemiologic Studies on Health Effects among Active Component U.S. Service Members who Deployed to Select Deployment Locations

7. Overall Summary

Concerns have been raised that individuals exposed to airborne particulates in the deployed setting, specifically those produced by burn pits, may be at increased risk for adverse health outcomes[1-3]. Studies were initiated to evaluate the effects of possible exposure within a 5-mile radius to a documented burn pit compared with no exposure to a documented burn pit, for the following outcomes: (1) birth outcomes in infants born to military men and women exposed before and during pregnancy, (2) newly reported and recurring respiratory illness, (3) CMI, and (4) newly reported lupus and rheumatoid arthritis.

Data from the Department of Defense (DoD) Birth and Infant Health Registry were used to identify birth outcomes among live born infants with birth dates between January 1, 2004 and December 31, 2007, born to active-duty military men and women. For all other outcomes, data from consenting participants who completed the Millennium Cohort Study questionnaires during the 2004-2006 and 2007-2008 survey cycles, which includes active-duty, Reserve, and National Guard Armed Forces members were used. These data sources were linked with electronic military deployment data to identify possible exposure within a 5-mile radius of a documented burn pit at three camp sites. Service members exposed to multiple burn pit sites were grouped into the location with the longest duration of possible exposure, and multivariable models were created to examine associations between burn pit exposure and specific health outcomes.

Possible burn pit exposure at various times in relation to pregnancy and for differing durations was not significantly associated with an increase in birth defects or preterm birth in infants of active-duty military personnel. However, a statistically significant increase risk of birth defects among infants born to a subset of men who were exposed more than 280 days prior to the EDC was found and should be considered for further investigation. Possible exposure to a documented burn pit within a 5-mile radius was not significantly associated with an increased risk for newly reported and recurring respiratory outcomes, CMI, or newly reported rheumatoid arthritis. Though possible burn pit exposure in general was not found to be associated with an increased risk, the burn pit located in Balad was associated with a statistically significant risk of newly reported lupus and should be considered for further investigation. All results were adjusted for demographic, military, and other covariates.

7.1. Data Sources

For the birth outcomes study, the DoD Birth and Infant Health Registry (Registry) was used. This registry was established in 1998 and uses comprehensive health care data to define live births and infant health outcomes based on ICD-9 coding, including birth defects and preterm birth, through the first year of life among infants born to DoD beneficiaries.

For other outcomes, data were collected as part of the Millennium Cohort Study. The Millennium Cohort Study, launched in 2001, was developed to conduct coordinated strategic research to determine any potential effects of military occupational and deployment-related exposures on long-term health.[25-27] Over 27,000 Millennium Cohort participants who deployed in support the operations in Iraq and Afghanistan, including over 3,000 participants with at least one deployment within a 5-mile radius of a burn pit at JBB, COB Speicher, or Camp Taji, were included in these analyses. Information collected and used in these studies includes data on respiratory health, smoking status (nonsmoker, past smoker, current smoker, and resumed or new smoker), mental and physical health, and physical activity among other demographic, behavioral, and military characteristics. Specific questions on respiratory health included self-reported provider-diagnosed asthma, chronic bronchitis, emphysema, and persistent or recurrent cough and shortness of breath and were utilized for the sub-study on respiratory health. General fatigue, mood and cognition, and musculoskeletal self-reported symptoms were utilized for assessment of CMI. For the lupus and rheumatoid arthritis sub-study, outcomes were assessed using self-reported provider-diagnosed lupus and rheumatoid arthritis.

The DMDC provided data on demographic and military characteristics, deployment data in support of the operations in Iraq and Afghanistan, as well as data on deployment within a 5-mile radius of a documented burn pit from the three camp sites.

8. Sub-Study Methodologies and Results

8.1. Sub-Study 1: Birth outcomes following exposures to documented burn pits before and during pregnancy

8.1.1. Methods

The primary data source for this study was the DoD Birth and Infant Health Registry. This registry was established in 1998 and uses comprehensive health care data to define live births and infant health outcomes based on ICD-9 coding, including birth defects and preterm birth, through the first year of life among infants born to DoD beneficiaries[28]. Live born infants of active-duty military men and

women born between January 1, 2004 and December 31, 2007, were identified using the Registry. Parental demographic and deployment information was obtained from DMDC.

The primary analyses compared infants born to military men and women deployed to a region within a 5-mile radius of a documented burn pit, with infants born to all others deployers in support of the operations in Iraq and Afghanistan. Infants born to spouses of active-duty military men (paternal model, N = 88,074) were considered possibly exposed if the father deployed to a burn pit region prior to the infant's EDC, n = 6,763. Infants born to active-duty military women (maternal model, N = 13,129) were considered possibly exposed if the mother deployed to a burn pit region any time prior to or during pregnancy, with the onset of pregnancy defined by the first day of the LMP, n = 1,172. Both EDC and LMP were calculated using the infant's date of birth and estimated gestational age at birth. Additional analyses included variables for the temporality (or proximity in time) of the parents' exposure to the conception (paternal model) or onset of pregnancy (maternal model), and cumulative days of exposure to a burn pit region (both models).

Analyses included descriptive investigations of parental demographic and occupational characteristics stratified by deployment status. Analyses were restricted to Army and Air Force personnel because of the low number of Navy and Marine Corps personnel located within a 5-mile radius of the documented burn pits in the sample. Preliminary univariate analyses, including chi-square tests and odds ratios, were performed to assess the significance of associations between the outcomes of interest (birth defects and preterm birth) and possible burn pit exposure. An exploratory model analysis was completed to assess regression diagnostics, significant associations, and collinearity, while simultaneously adjusting for all other variables in the model.

Multivariable logistic regression models were used to estimate the adjusted odds ratios and 95% confidence intervals of birth defects and preterm birth among infants with the exposure of concern. All models were adjusted for multiple birth, infant sex, maternal age, and military sponsor demographics, including race/ethnicity, branch of military Service, rank, military occupation, and duty status. Additionally, maternal models were adjusted for marital status.

8.1.2. Results

In the primary paternal model, possible exposure to a burn pit was not significantly associated with an increase in birth defects or preterm birth (data not shown) when controlling for all other variables in the model (Table 8). There were also no significant differences between the various burn pit sites included in these analyses. When timing of exposure in relation to EDC was analyzed, a significantly increased risk of birth defects was found among infants born to men who were exposed more than 280

days prior to EDC (Table 9). Analyses of cumulative exposed time showed no significant association with either adverse outcome (Table 10, preterm birth data not shown).

For the primary paternal model, infants born to spouses of active-duty military men were more likely to be diagnosed with a birth defect if they were part of a multiple birth, male sex, or if their mother was 35 years of age or older. They were less likely to be diagnosed with a birth defect if their active-duty father was black or Hispanic, or if his military specialty was in the area of health care. These infants were more likely to be born preterm if they were part of a multiple birth, male sex, if their mother was 35 years of age or older, or if their father was black, or in a Reserve/other duty status compared with regular active duty. They were less likely to be born preterm if their father was Hispanic or an officer.

In the primary maternal model, infants born to active-duty military women with burn pit exposure before or during pregnancy were not at increased odds of being born preterm or being diagnosed with a birth defect in the first year of life, and there were no significant differences between the various burn pit regions. Likewise, there was no statistical significance when investigating temporal proximity of exposure to pregnancy (Table 12) or cumulative exposure time (Table 13).

As previously reported in other registry studies, infants of active-duty military women were more likely to be diagnosed with a birth defect if they were male, or if their mother was in the Air Force compared to the Army. They were less likely to be diagnosed with a birth defect if their mother was of an unknown or other race compared with those of white race [29]. These infants were more likely to be born preterm if they were part of a multiple birth, or if their mother was 35 years of age or older or black, and less likely to be born preterm if their active-duty mother was an officer.

Table 8. Odds of Birth Defects among Infants of Male Deployers in Relation to Burn Pit Exposure, 2004–2007

	OR	95% CI	*p*	AOR*	95% CI	*p*
Deployment			0.85			0.81
Other deployment‡	1.00§			1.00§		
Exposed deployment	0.99	0.87–1.13		0.98	0.86–1.12	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*Model is adjusted for multiple birth, infant sex, maternal age, sponsor race/ethnicity, sponsor branch of military Service, sponsor rank, sponsor military occupation, and sponsor duty status.

‡Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

Table 9. Odds of Birth Defects among Infants of Male Deployers: Timing of Burn Pit Exposure in Relation to Estimated Date of Conception, 2004–2007

	OR	95% CI	*p*	AOR*	95% CI	*p*
Temporal proximity‡			0.06			0.04
Other deployed¶	1.00§			1.00§		
≥281 days	1.29	1.03–1.62		1.31	1.04–1.64	
126–280 days	0.99	0.77–1.28		1.00	0.77–1.28	
34–125 days	0.75	0.56–1.00		0.75	0.56–1.00	
<34 days	0.92	0.71–1.20		0.90	0.69–1.17	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*Model is adjusted for multiple birth, infant sex, maternal age, sponsor race/ethnicity, sponsor branch of military Service, sponsor rank, sponsor military occupation, and sponsor duty status.

‡Days from the end of the most recent deployment within a 5-mile radius of a burn pit to the estimated date of conception, grouped by quartile.

¶Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

Table 10. Odds of Birth Defects among Infants of Male Deployers: Cumulative Days of Burn Pit Exposure Prior to Estimated Date of Conception, 2004–2007

	OR	95% CI	*p*	AOR*	95% CI	*p*
Cumulative deployment			0.47			0.37
Other deployed‡	1.00§			1.00§		
<73 days¶	0.87	0.66–1.14		0.85	0.65–1.11	
73–130 days	1.00	0.77–1.29		1.01	0.78–1.30	
131–201 days	1.18	0.93–1.48		1.19	0.94–1.50	
≥202 days	0.91	0.70–1.18		0.90	0.69–1.17	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*Model is adjusted for multiple birth, infant sex, maternal age, sponsor race/ethnicity, sponsor branch of military Service, sponsor rank, sponsor military occupation, and sponsor duty status.

‡Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

¶Cumulative days of deployment, within a 5-mile radius of a burn pit, prior to the estimated date of conception, grouped by quartile.

Table 11. Odds of Birth Defects among Infants of Female Deployers in Relation to Burn Pit Exposure, 2004–2007

	OR	95% CI	*p*	AOR*	95% CI	*p*
Deployment			0.44			0.30
Other deployment‡	1.00§			1.00§		
Exposed deployment	1.13	0.82–1.57		1.19	0.86–1.64	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*Model is adjusted for multiple birth, infant sex, maternal age, marital status, sponsor race/ethnicity, sponsor branch of military Service, sponsor rank, sponsor military occupation, and sponsor duty status.

‡Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

Table 12. Odds of Birth Defects among Infants of Female Deployers: Timing of Burn Pit Exposure in Relation to Pregnancy, 2004–2007

	OR	95% CI	*p*	AOR*	95% CI	*p*
Temporal proximity‡			0.63			0.47
Other deployed¶	1.00§			1.00§		
≥290 days	0.99	0.49–1.97		1.02	0.51–2.03	
108–289 days	0.98	0.49–1.97		1.02	0.51–2.03	
1–107 days	1.12	0.58–2.16		1.18	0.61–2.27	
In pregnancy	1.48	0.91–2.42		1.59	0.97–2.61	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*Model is adjusted for multiple birth, infant sex, maternal age, marital status, sponsor race/ethnicity, sponsor branch of military Service, sponsor rank, sponsor military occupation, and sponsor duty status.

‡Days from the end of the most recent deployment within a 5-mile radius of a burn pit, to the estimated last menstrual period. The number of days prior to pregnancy was grouped by tertile.

¶Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

Table 13. Odds of Birth Defects among Infants of Female Deployers: Cumulative Days of Burn Pit Exposure Prior to Infant's Date of Birth, 2004–2007

	OR	95% CI	*p*	AOR	95% CI	*p*
Cumulative deployment			0.54			0.54
Other deployed‡	1.00§			1.00§		
<78 days¶	1.12	0.60–2.10		1.22	0.65–2.29	
78–132 days	1.58	0.92–2.71		1.57	0.92–2.69	
133–193 days	1.11	0.60–2.08		1.13	0.60–2.10	
≥194 days	0.89	0.45–1.77		0.98	0.49–1.95	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*Model is adjusted for multiple birth, infant sex, maternal age, marital status, sponsor race/ethnicity, sponsor branch of military Service, sponsor rank, sponsor military occupation, and sponsor duty status.

‡Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

¶Cumulative days of deployment, within a 5-mile radius of a burn pit, prior to the infant's date of birth, grouped by quartile.

8.2. Sub-Study 2: The Effects of Exposure to Documented Burn Pits on Respiratory Health among Deployers of the Millennium Cohort Study

8.2.1. Methods

For this preliminary study, the population included deployed personnel who completed a Millennium Cohort questionnaire during the June 2004 to February 2006 (baseline) and June 2007 to December 2008 (follow-up) survey cycles. The Millennium Cohort survey collected information on respiratory health, smoking status (nonsmoker, past smoker, current smoker, and resumed or new smoker), and physical activity among other demographic, behavioral, and military characteristics. Specific questions on respiratory health included self-reported asthma, chronic bronchitis, emphysema, and persistent or recurrent cough and shortness of breath. The DMDC provided data on demographic and military characteristics, and deployment dates within a 5-mile radius of a documented burn pit at three camp sites and other operational locations in regions of Iraq or Afghanistan. This study explored three self-reported respiratory outcomes: (1) newly reported asthma, (2) newly reported chronic bronchitis or emphysema, and (3) self-reported respiratory symptoms of persistent or recurring cough or shortness of breath. Newly reported outcomes were defined as presence of the condition at follow-up without indication of the condition at baseline, while prevalence of self-reported respiratory symptoms was measured at both time points.

Data were prospectively examined between the survey periods of June 2004 to February 2006 and June 2007 to December 2008. Descriptive statistical analyses were performed. Separate models were developed for each respiratory outcome. Multivariable logistic regression analyses were performed to compare the adjusted odds of association for respiratory outcomes in relation to three metrics of exposure within a 5-mile radius of the documented burn pits: (1) deployment near the documented burn pits (yes/no), (2) cumulative days exposed to the burn pits, and (3) exposure to the burn pits at three different camp sites (JBB, Taji, or Speicher). Cumulative days exposed within a 5-mile radius of the documented burn pits were summed prior to and across the 2004–2008 observation period, categorized into quartiles (1–56 days, 57-132 days, 133- 210 days, and >210 days), and compared to those with no exposure to these burn pit sites. For analyses evaluating each outcome in relation to burn pit exposure at JBB, Camp Taji, or COB Speicher, participants with deployments to multiple sites between the observation period were categorized based on the camp with the greatest exposure, as measured by deployment length (in days). All analyses adjusted for the following covariates: sex, birth year, marital status, race/ethnicity, education, smoking status, physical activity, Service branch, military rank, pay grade, and occupation. Analyses examining respiratory symptoms also included adjustment of respiratory symptom prevalence at baseline in addition to the covariates. All covariates were measured at baseline, however, smoking status

was prospectively assessed using the 2004 and 2007 survey instruments, while physical activity was measured using the 2007 survey instrument. Analyses for the newly reported respiratory outcomes excluded personnel who reported the respective condition at baseline.

8.2.2. Results

Incidence of newly reported asthma in those not exposed and exposed were 1.63% and 1.62%, respectively, while incidence of newly reported chronic bronchitis or emphysema was 1.54% and 1.46%, respectively. Across the observation period, prevalence of self-reported respiratory symptoms in nonexposed and exposed personnel ranged from 16.1% to 19.8% and 15.4% to 21.5%, respectively. After adjusting for smoking status, physical activity, and other covariates measured at baseline, deployment within 5-miles of the documented burn pits was not significantly associated with increased risk for newly reported asthma ($p = 0.44$), newly reported chronic bronchitis or emphysema ($p = 0.36$), or self-reported respiratory symptoms ($p = 0.38$) compared with those not exposed (Table 14). When examining the effect of cumulative days exposed in association with the respiratory outcomes, no increased risk was observed with newly reported asthma ($p = 0.54$), newly reported chronic bronchitis or emphysema ($p = 0.65$) and self-reported respiratory symptoms ($p = 0.85$) (Table 15). Furthermore, there was no significant elevated risk for the three outcomes associated with exposure at specific camp sites (newly reported asthma, $p = 0.59$; newly reported chronic bronchitis or emphysema , $p = 0.33$), or self-reported respiratory symptoms ($p = 0.51$) (Table 16).

Table 14. Odds of Reported Respiratory Outcomes among Deployers in Relation to Burn Pit Exposure, the Millennium Cohort Study, 2004-2008.

	Chronic Bronchitis or Emphysema[*†]		Asthma[*†]		Respiratory Symptoms[*‡]	
	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)
Deployment	$p = 0.71$	$p = 0.36$	$p = 0.89$	$p = 0.44$	$p = 0.01$	$p = 0.38$
Other deployment[§]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]
Exposed deployment	0.95 (0.70–1.27)	0.87 (0.64–1.18)	1.01 (0.75–1.33)	0.89 (0.66–1.19)	1.11 (1.02–1.21)	1.04 (0.95–1.14)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

[*]All models adjusted for sex, birth year, marital status, race/ethnicity, education, smoking status, aerobic activity, Service branch, Service component, military rank, time, and occupation. For respiratory symptoms outcome, model also adjusted for prevalence of respiratory symptoms at baseline.

[†]All participants in respective models were disease free at baseline.

[‡]Respiratory symptoms were defined as self-reported persistent or recurring cough or shortness of breath.

[§]Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of the documented burn pit sites.

[‖]Indicates reference category.

Table 15. Odds of Respiratory Outcomes among Deployers in Relation to Cumulative Days Exposed to a Burn Pit, the Millennium Cohort Study, 2004–2008.

	Chronic Bronchitis or Emphysema[*†]		Asthma[*†]		Respiratory Symptoms[*‡]	
	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)
Exposed days[§]	$p = 0.66$	$p = 0.65$	$p = 0.50$	$p = 0.54$	$p = 0.02$	$p = 0.85$
0	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]
1–56	1.11 (0.66–1.87)	0.95 (0.56–1.61)	0.79 (0.43–1.44)	0.67 (0.37–1.24)	1.16 (0.99–1.35)	0.99 (0.83–1.17)
57–132	0.60 (0.29–1.21)	0.59 (0.29–1.19)	0.73 (0.39–1.37)	0.70 (0.37–1.33)	1.02 (0.87–1.20)	1.05 (0.88–1.25)
133–210	1.10 (0.64–1.89)	1.06 (0.61–1.82)	1.14 (0.68–1.93)	1.09 (0.64–1.84)	1.01 (0.86–1.19)	1.07 (0.89–1.27)
>210	0.98 (0.56–1.72)	0.86 (0.49–1.51)	1.34 (0.83–2.16)	1.10 (0.68–1.79)	1.26 (1.08–1.48)	1.07 (0.90–1.27)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

[*]All models adjusted for sex, birth year, marital status, race/ethnicity, education, smoking status, aerobic activity, Service branch, Service component, military rank, time, and occupation. For respiratory symptoms outcome, model also adjusted for prevalence of respiratory symptoms at baseline.

[†]All participants in respective models were disease free at baseline.

[‡]Respiratory symptoms were defined as self-reported persistent or recurring cough or shortness of breath.

[§]Categories found by computing quartiles of days exposed to the burn pits of only those identified with deployments within a 5-mile radius of the burn pit sites.

[‖]Indicates reference category.

Table 16. Odds of Respiratory Outcomes among Personnel Deployed Within 5-miles of Burn Pits, by Camp Site, the Millennium Cohort Study, 2004–2008.

	Chronic Bronchitis or Emphysema[*†]		Asthma[*†]		Respiratory Symptoms[*‡]	
	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)
Camp site	$p = 0.67$	$p = 0.33$	$p = 0.67$	$p = 0.59$	$p < 0.0001$	$p = 0.51$
Other deployed[§]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]	1.00[‖]
JBB	1.02 (0.70–1.47)	0.96 (0.66–1.40)	0.90 (0.61–1.33)	0.85 (0.57–1.26)	0.96 (0.85–1.08)	0.97 (0.85-1.10)
Taji	0.93 (0.46–1.88)	0.81 (0.40–1.66)	1.37 (0.77–2.45)	1.14 (0.63–2.06)	1.41 (1.18–1.69)	1.15 (0.94–1.40)
Speicher	0.63 (0.30–1.33)	0.50 (0.23–1.07)	0.96 (0.53–1.77)	0.72 (0.39–1.34)	1.27 (1.08–1.49)	1.02 (0.85–1.22)

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; JBB, Joint Base Balad; OR, unadjusted odds ratio.

[*]All models adjusted for sex, birth year, marital status, race/ethnicity, education, smoking status, aerobic activity, Service branch, Service component, military rank, time, and occupation. For respiratory symptoms outcome, model also adjusted for prevalence of respiratory symptoms at baseline.

[†]All participants in respective models were disease free at baseline.

[‡]Respiratory symptoms were defined as self-reported persistent or recurring cough or shortness of breath.

[§]Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of the documented burn pit sites.

[‖]Indicates reference category.

8.3. Sub-Study 3: Chronic Multisymptom Illness and Deployment Within a 5-Mile Radius of a Documented Burn Pit

8.3.1. Methods

This sub-study used data from the 2004–2006 and 2007–2008 survey cycles of the Millennium Cohort Study. Deployment related data including Service members' proximity to a documented burn pit at JBB, Camp Taji, or COB Speicher between 2003 and 2008 was obtained from the DMDC. Self-reported symptoms were assessed both at baseline (2004-2006) and follow-up (2007-2008) to identify CMI in participants who deployed in support of the operations in Iraq or Afghanistan. The case definition for CMI was based on the Centers for Disease Control and Prevention (CDC) definition of an individual reporting at least one symptom in at least two of the following symptom constructs: general fatigue, mood and cognition, and musculoskeletal[30, 31]. General fatigue was considered present when participants reported they had "unusual fatigue." Mood and cognition was assessed through the presence of any of the following symptoms: "feeling down, depressed, or hopeless," "problems with forgetfulness" or "difficulty concentrating," "feeling irritable or having angry outbursts," "feeling nervous, anxious, on edge, or worrying about a lot of different things," "confusion," and "trouble falling or staying asleep." The musculoskeletal construct had the following two symptoms: "pain in your arms, legs, or joints (eg, knees, hips)" and "unusual muscle pain." CMI was assessed at follow-up in relation to three types of deployment exposures. First, deployment status was dichotomized as deployed within a 5-mile radius of a documented burn pit, and deployed to all other locations in support of the operations in Iraq or Afghanistan. Exposure was assumed if deployment was to a location within 5-miles of a documented burn pit. Second, deployment was assessed by the cumulative days exposed within the 5-mile radius surrounding a documented burn pit. Cumulative days exposed to the burn pit site was measured prior to baseline through the follow-up survey assessment and categorized into quartiles in reference to those not exposed. Finally, exposure proximal (within a 5-mile radius) to JBB, Taji, or Speicher was also assessed. Participants who were deployed to multiple camps were categorized by the camp they were deployed to for the longest period of time. Multivariable logistic regression was performed for all three analyses while adjusting for baseline covariates, including CMI status at baseline, and burn pit exposure. Using a backward statistical modeling strategy, variables that were not significant nor confounders were manually removed to establish the final model.

8.3.2. Results

After adjusting for sex, birth year, education, Service component, Service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status, deployment within a 5-mile radius of a documented burn pit was not significantly associated with CMI ($p = 0.16$) (Table 17). While cumulative days exposed within 5 miles was not significant overall after adjusting for the variables listed above, those exposed for more than 210 days had higher odds of CMI (Table 18). Proximity to a burn pit by camp (Table 19) was also not significantly associated with CMI after adjusting for the same variables described above ($p = 0.32$).

Table 17. Odds of Chronic Multisymptom Illness (CMI) among Deployers in Relation to Proximity to a Burn Pit, 2004–2008.

	CMI					
	OR	95% CI	*p*	AOR*	95% CI	*p*
Deployment			<0.01			0.16
Other deployment‡	1.00§			1.00§		
Exposed deployment	1.13	1.04–1.22		1.07	0.98–1.17	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*CMI model is adjusted for sex, birth year, education, Service component, Service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status.

‡Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit.

§Indicates reference category.

Table 18. Odds of Chronic Multisymptom Illness (CMI) among Deployers in Relation to Cumulative Days within 5-miles of a Documented Burn Pit, 2004–2008.

	CMI					
	OR	95% CI	*p*	AOR*	95% CI	*p*
Exposed days‡			<0.001			0.18
0	1.00¶			1.00¶		
1–56	1.16	1.00–1.34		0.98	0.83–1.16	
57–132	1.02	0.88–1.19		1.05	0.88–1.24	
133–210	0.93	0.80–1.09		1.02	0.86–1.22	
>210	1.42	1.23–1.64		1.22	1.04–1.44	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*CMI model is adjusted for sex, birth year, education, Service component, Service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status.

‡Categories found by computing quartiles of days exposed to the burn pits among deployers exposed from 2003–2008.

¶Indicates reference category.

Table 19. Odds of Chronic Multisymptom Illness (CMI) among Deployers in Relation to Burn Pit Proximity by Camp, 2004–2008.

	CMI					
	OR	95% CI	*p*	AOR*	95% CI	*p*
Camp site‡			<0.001			0.32
Other deployed	1.00¶			1.00¶		
JBB	0.99	0.89–1.10		1.07	0.95–1.20	
Taji	1.50	1.27–1.77		1.16	0.95–1.40	
Speicher	1.28	1.10–1.48		0.96	0.81–1.14	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; JBB, Joint Base Balad; OR, unadjusted odds ratio.

*CMI model is adjusted for sex, birth year, education, Service component, Service branch, pay grade, smoking status, alcohol-related problems, mental health symptoms, and baseline CMI status.

‡Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of a camp with a documented burn pit.

¶Indicates reference category.

8.4. Sub-Study 4: Newly reported Lupus and Rheumatoid Arthritis in Relation to Deployment within a 5-Mile Radius of a Documented Burn Pit

8.4.1. Methods

This sub-study used data from the 2004–2006 and 2007–2008 survey assessments of the Millennium Cohort Study. DMDC provided demographic and deployment-related data, including Service members' proximity to a documented burn pit at three different camp sites between 2003 and 2008.

The occurrence of newly reported provider-diagnosed lupus and rheumatoid arthritis and potential risk factors were estimated among those deployed in support of the operations in Iraq and Afghanistan. To define newly reported disease for the first enrollment, the participant had to affirmatively self-report a physician diagnosis of lupus or rheumatoid arthritis at follow-up (2007–2008) among those with no report of the condition ever at baseline (2001–2003) and no condition within the last 3 years at follow-up (2004–2006). The second enrollment participants had to affirmatively self-report a physician diagnosis of lupus or rheumatoid arthritis at follow-up (2007–2008) while also reporting no condition ever at baseline (2004–2006). Newly reported lupus and rheumatoid arthritis were assessed in relation to deployment status categorized as deployed within a 5-mile radius of a documented burn pit, and all other locations during deployments in support of the operations in Iraq and Afghanistan. Exposure was assumed if deployment was to a location within a 5-mile radius of a burn pit. Additionally, a second analysis assessed newly reported lupus and rheumatoid arthritis in relation to cumulative days of exposure within a 5-mile radius of a burn pit. Cumulative days exposed to a burn pit site was measured from 2003 through the follow-up survey assessment and categorized into quartiles in reference to those not exposed. Lastly, a third analysis evaluated each outcome in association with participants being deployed within a 5-mile radius of a documented burn pit in three different camp sites. If participants were deployed to multiple camp sites, they were categorized based on the camp to which they were deployed with the longest exposure time. An electronic medical records review was performed for the current study but could only be conducted for active-duty members diagnosed while in service. Multivariable logistic regression was performed for all analyses, while adjusting for factors reported in the 2004–2006 survey that were potentially associated with lupus or rheumatoid arthritis and burn pit exposure. Model diagnostic tests were performed to assess multicollinearity, and potential confounders were evaluated. Variables that were not confounders and were not significant in the model at $p < 0.05$ were removed using a backward manual reduction strategy to establish the final models.

8.4.2. Results

The cumulative incidence over the average 2.8 years of follow-up for lupus and rheumatoid arthritis was 0.1% and 1.4%, respectively. After adjustment, the final lupus model revealed proximity to a burn pit ($p = 0.14$), and cumulative days exposed within a 5-mile radius of a burn pit ($p = 0.58$) were not significantly associated with newly reported lupus compared with those not exposed (Tables 20 and 21). However, those deployed to JBB were more than three times as likely to newly report lupus compared with those not within proximity to a burn pit (95% confidence interval: 1.59–7.79) (Table 22). After adjustment, the final rheumatoid arthritis model revealed none of the following: proximity to a burn pit ($p = 0.08$), cumulative days within a 5-mile radius of a burn pit ($p = 0.09$), nor proximity by burn pit site ($p = 0.49$) to be significantly associated with newly reported rheumatoid arthritis when compared with deployers not exposed within a 5-mile radius of a burn pit (Tables 23-25).

The electronic medical records review confirmed 33% of self-reported lupus and 17% of self-reported rheumatoid arthritis diagnoses among deployers. Low confirmation is likely due to the limitation of diagnosis verification among active-duty personnel only, since Reservists and those who have separated likely received care outside the military health care system. Additionally, verification would not capture active-duty individuals who sought treatment outside the military health care system. Among confirmed cases, burn pit exposure was not significantly associated with self-reported lupus or rheumatoid arthritis.

Table 20. Odds of Newly Reported Lupus among Deployers in Relation to Proximity to a Documented Burn Pit, 2004–2008

	All Cohort Cases*						Confirmed Cases*†		
	OR	95% CI	*p*	AOR	95% CI	*p*	AOR	95% CI	*p*
Deployment			0.12			0.14			0.36
Other deployment‡	1.00§			1.00§			1.00§		
Exposed deployment	1.94	0.84–4.49		1.89	0.82–4.39		2.14	0.42–10.79	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*All Millennium Cohort cases and confirmed cases models are adjusted for race/ethnicity, and exposure to chemical or biological warfare agents.

†Confirmed cases model is among active-duty, nonseparated participants; Firth's method was used.

‡Deployment in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a documented burn pit.

§Indicates reference category.

Table 21. Odds of Newly Reported Lupus among Deployers in Relation to Cumulative Days Within a 5-Mile Radius of a Documented Burn Pit, 2004–2008

	All Cohort Cases*						Confirmed Cases*†		
	OR	95% CI	*p*	AOR	95% CI	*p*	AOR	95% CI	*p*
Exposed days			0.55			0.58			0.17
0‡	1.00§			1.00§			1.00§		
1–56	2.17	0.51–9.16		2.15	0.51–9.11		8.67	1.59–47.47	
57–132	1.11	0.15–8.21		1.08	0.15–8.01		3.00	0.23–40.12	
133–212	2.27	0.54–9.58		2.21	0.52–9.37		2.69	0.20–36.47	
>212	2.22	0.53–9.39		2.12	0.50–9.01		2.77	0.21–36.12	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*All Millennium Cohort cases and confirmed cases models are adjusted for race/ethnicity, and exposure to chemical or biological warfare agents.

†Confirmed cases model is among active-duty, nonseparated participants; Firth's method was used.

‡Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of a documented burn pit.

§Indicates reference category.

Table 22. Odds of Newly Reported Lupus among Deployers in Relation to Burn Pit Proximity by Camp Site, 2004–2008

	All Cohort Cases*						Confirmed Cases*†		
	OR	95% CI	*p*	AOR	95% CI	*p*	AOR	95% CI	*p*
Camp site			0.02			0.02			0.35
Other deployed‡	1.00§			1.00§			1.00§		
JBB	3.47	1.53–7.83		3.52	1.59–7.79		4.25	0.80–22.49	
Taji	0.75	0.05–12.39		0.68	0.05–10.25		2.92	0.22–37.96	
Speicher	0.59	0.04–9.67		0.55	0.04–8.31		2.73	0.21–36.20	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; JBB, Joint Base Balad; OR, unadjusted odds ratio.

*All Millennium Cohort cases and confirmed cases models are adjusted for race/ethnicity, and exposure to chemical or biological warfare agents.

†Confirmed cases model is among active-duty, nonseparated participants; Firth's method was used.

‡Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of a documented burn pit.

§Indicates reference category.

Table 23. Odds of Newly Reported Rheumatoid Arthritis among Deployers in Relation to Proximity to a Documented Burn Pit, 2004–2008

	All Cohort Cases*						Confirmed Cases*†		
	OR	95% CI	*p*	AOR	95% CI	*p*	AOR	95% CI	*p*
Deployment			0.53			0.08			0.55
Other deployment‡	1.00§			1.00§			1.00§		
Exposed deployment	1.11	0.81–1.51		1.37	0.97–1.93		1.40	0.47–4.15	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*All Millennium Cohort cases and confirmed cases models are adjusted for sex, birth year, marital status, Service component, military pay grade, Service branch, occupation, mental and physical component scores, exposure to chemical or biological warfare agents, and exposure to microwaves.

†Confirmed cases model is among active-duty, nonseparated participants; Firth's method was used.

‡Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of a documented burn pit.

§Indicates reference category.

Table 24. Odds of Newly Reported Rheumatoid Arthritis among Deployers in Relation to Cumulative Days Within a 5-Mile Radius of a Burn Pit (2004–2008)

	All Cohort Cases*						Confirmed Cases*†		
	OR	95% CI	*p*	AOR	95% CI	*p*	AOR	95% CI	*p*
Exposed days			0.36			0.09			0.42
0‡	1.00§			1.00§			1.00§		
1–56	0.85	0.43–1.65		1.09	0.55–2.15		1.53	0.16–14.28	
57–131	1.28	0.73–2.23		1.54	0.82–2.86		1.01	0.11–9.34	
132–211	1.54	0.93–2.56		2.03	1.18–3.49		3.00	0.76–11.83	
>211	0.77	0.38–1.56		0.87	0.40–1.89		2.89	0.67–12.50	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; OR, unadjusted odds ratio.

*All Millennium Cohort cases and confirmed cases models are adjusted for sex, birth year, marital status, Service component, military pay grade, service branch, occupation, mental and physical component scores, exposure to chemical or biological warfare agents, and exposure to microwaves.

†Confirmed cases model is among active-duty, nonseparated participants; Firth's method was used.

‡Deployment in support of operations in Iraq and Afghanistan outside a 5-mile radius of a documented burn pit.

§Indicates reference category.

Table 25. Odds of Newly Reported Rheumatoid Arthritis among Deployers in Relation to Burn Pit Proximity by Camp Site, 2004–2008

	All Cohort Cases*						Confirmed Cases*†		
	OR	95% CI	*p*	AOR	95% CI	*p*	AOR	95% CI	*p*
Camp site			0.57			0.49			0.43
Other deployed‡	1.00§			1.00§			1.00§		
JBB	1.10	0.74–1.64		1.21	0.80–1.83		2.06	0.65–6.47	
Taji	1.46	0.80–2.68		1.34	0.72–2.50		2.59	0.57–11.68	
Speicher	0.83	0.41–1.69		0.72	0.34–1.55		0.87	0.08–9.35	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; JBB, Joint Base Balad; OR, unadjusted odds ratio.

*All Millennium Cohort cases and confirmed cases models are adjusted for sex, birth year, marital status, Service component, Service branch, mental and physical component scores, exposure to chemical or biological warfare agents, and exposure to microwaves.

§Indicates reference category.

9. Discussion

The purpose of these analyses was to evaluate potential health effects for Service members that were deployed to locations where they may have been exposed to burn pits while in theater compared with individuals deployed to other locations in theater. Possible burn pit exposure was not found to be associated with birth defects or preterm birth in infants of active-duty military personnel in general. However, a statistically significant increase risk of birth defects among infants born to a subset of men who were exposed more than 280 days prior to the EDC was found and should be considered for further investigation. Possible burn pit exposure was not associated with an increased risk for newly reported and recurring respiratory outcomes, CMI, or newly reported rheumatoid arthritis. Though possible burn pit exposure in general was not found to be associated with an increased risk in these outcomes, the burn pit located in JBB was associated with a statistically significant risk of newly reported lupus and should be considered for further investigation.

In general, there are several limitations to these studies. Despite ongoing attempts to improve individual-level exposure data, there remains the potential for misclassification of exposure status. In these studies, a military member is considered possibly exposed if they were deployed to a region located within a 5-mile radius of a documented burn pit. Within this exposed group, it is likely there were different levels of exposure that these analyses were unable to differentiate. Additionally, these analyses were limited in the ability to evaluate other potentially confounding occupational and environmental exposures occurring in theater or around burn pit sites.

Data on particulate matter characteristics and levels of exposure, beyond number of days deployed, were not available. This study used data from documented burn pits at three camps only, limiting the ability to assess burn pit exposure over the entire theater of operations.

A specific limitation for the birth outcomes analysis is the inability to adjust for late recognition of pregnancy. Late recognition of pregnancy has been associated with an increased risk for birth defects[32]. Also, these analyses were not able to investigate pregnancy terminations, miscarriages, or stillbirths, all of which are important outcomes that may be associated with exposure to environmental pollutants.

Specific limitations to the studies of respiratory outcomes, CMI, lupus and rheumatoid arthritis are that the study populations consist of a sample of Millennium Cohort participants and may not be representative of the military population in general. These outcomes relied on self report and may be subject to reporting bias; however, possible biases in these data were previously investigated, suggesting a representative cohort of US military personnel who report reliable data with responses unaffected by the participant's health status prior to enrollment[26, 33-42]. Due to the large sample size and population-based

design, conducting clinical examinations to confirm self-reported symptoms and conditions was not feasible. Another important limitation is that chronic bronchitis, emphysema, lupus, and rheumatoid arthritis are rare outcomes, resulting in few newly reported cases over the average 2.8 years of follow-up causing low precision of the estimates. The CDC requires CMI symptoms to be present for at least 6 months. The Millennium Cohort questionnaires, however, assess these symptoms over a shorter time frame, which may overestimate CMI in this population, though misclassification would be expected to be nondifferential[44].

Despite limitations, these studies have a number of important strengths including the use of other deployers in support of the operations in Iraq and Afghanistan outside a 5-mile radius of a burn pit site as the most appropriate referent population rather than non-deployers who are potentially less healthy. The DoD Birth and Infant Health Registry is the most comprehensive registry of birth defects in infants born to military personnel, capturing health care data through the first year of life. It contains nearly all diagnosed birth defects, since approximately 95% are diagnosed before the end of infancy[45]. Linked with electronic data from DMDC, which provides objective measures of demographic variables and deployment dates of all military personnel, this study provides an important look at the prevalence of birth defects and preterm birth in infants of military personnel with burn pit exposure. The Millennium Cohort consists of participants from all military Services and includes active-duty, Reserve, and National Guard members. It also includes Service members while in service and follows individuals even after separation from the military. The longitudinal study design of the Millennium Cohort Study allows for behavioral and health assessment prior to deployment. Importantly, symptoms like persistent and recurring cough and shortness of breath, and symptom complexes, such as CMI, may be better assessed through self-report than through medical encounter data, making the Millennium Cohort Study well positioned to address this vital issue for our active-duty, Reserve and National Guard military, and veterans.

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APPENDIX A

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, DC 20301-1200

OCT 30 2009

HEALTH AFFAIRS

MEMORANDUM FOR DIRECTOR, ARMED FORCES HEALTH SURVEILLANCE CENTER

SUBJECT: Evaluation of Potential Health Effects of Exposure to Smoke from Open Pit Burning During Deployment in the U.S. Central Command Area of Responsibility

Members of Congress, the Department of Veterans Affairs (VA), Service Members, Department of Defense (DoD) leadership, and others have expressed concerns associated with the inhalation of smoke from open burn pit operations in Iraq and Afghanistan. While much useful information has been provided by preliminary investigations, more work is needed. Additional epidemiologic and analytic support is needed to assess the health effects that might be associated with this exposure.

We are requesting that the AFHSC support a comprehensive assessment of the problem by conducting additional rapid epidemiologic studies using existing longitudinal data in the Defense Medical Surveillance System. These studies will serve to expeditiously refine potential health risks and generate hypotheses that may drive more comprehensive and complex studies of acute and chronic smoke-related health outcomes.

Several lines of simultaneous investigation are indicated, and a collaborative, multi-agency effort should be the most effective approach. Agencies/groups with environmental health expertise vital to this effort include the U.S. Army Center for Health Promotion and Preventive Medicine and the DoD/VA Deployment Health Working Group. Cross-sectional and longitudinal research is needed to more accurately characterize the risks associated with the exposure to burn pit smoke, including chronic or delayed health outcomes such as cancer. Those agencies instrumental in this effort would include the Naval Health Research Center, the Navy Marine Corps Public Health Center, other agencies within the DoD, and other Federal Agencies, such as the VA. AFHSC should take advantage of these agencies efforts and findings to provide an initial health outcome summary followed by a more comprehensive report at the completion of the rapid epidemiological studies.

The AFHSC should schedule and lead meetings, as required, with the organizations specified above to develop and direct a comprehensive study plan, with emphasis on rapid low cost studies. Identify any study components, deemed necessary, that cannot be carried out with existing funding and resources to my point of contact.

The AFHSC should provide an initial report summarizing current health outcome findings to FHP&R by December 30, 2009, with a final report submitted at the conclusion of your analyses of the rapid epidemiological studies (i.e., non-cancer studies). My point of contact is Col Michael Butel, who can be reached at 703-578-8524, or Michael.Butel@tma.osd.mil.

Donald L. Noah, Col, USAF, BSC
Acting Deputy Assistant Secretary of Defense
(Force Health Protection and Readiness)

cc: Commander, USACHPPM
Director, Joint Staff
U.S. Central Command
Army Surgeon General
Navy Surgeon General
Air Force Surgeon General
Director, Naval Health Research Center

APPENDIX B
Glossary of Acronyms

$\mu g/m^3$: micrograms per cubic meter
AFHSC: Armed Forces Health Surveillance Center
AOR: adjusted odds ratio
AOR: area of responsibility
CI: confidence interval
CMI: chronic multisymptom illness
COB: contingency operating base
CONUS: continental United States
COPD: chronic obstructive pulmonary disease
CTS: contingency tracking system
DD2795: pre-deployment health assessment form
DD2796: post-deployment health assessment form
DD2900: post-deployment health re-assessment form
DMSS: Defense Medical Surveillance System
DoD: Department of Defense
DRMS: Defense Reutilization and Marketing Service
EDC: estimated date of conception
EPMSP: Enhanced Particulate Matter Surveillance Program
ICD-9: International Classification of Diseases 9th Revision
IRR: incidence rate ratios
JBB: Joint Base Balad
LMP: last menstrual period
MEGs: military exposure guidelines
NHRC: Naval Health Research Center
OASD HA: Office of the Assistant Secretary of Defense for Health Affairs
OR: unadjusted odds ratio
PAHs: polycyclic aromatic hydrocarbons
PDHA: post-deployment health assessment
PDHRA: post-deployment health re-assessment
PM_{10}: particulate matter of 10 micrometers in diameter or less
$PM_{2.5}$: particulate matter of 2.5 micrometers in diameter or less
POL: petrol, oils and lubricants
PY: person-years
Registry: Department of Defense Birth and Infant Health Registry
SSIC: signs symptoms ill-defined conditions
TMDS: Theater Medical Data System
TSP: total suspended particulates
USACHPPM: US Army Center for Health Promotion and Preventive Medicine
USAPHC: US Army Public Health Command
USCENTCOM: US Central Command
VOCs: volatile organic compounds