

Presentation 4 – Lea Steele

Fuel Combustion Products, Particulates

Exposures and Epidemiologic Findings
in Gulf War Veterans

Lea Steele, Ph.D.

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Exposure to Hydrocarbon Fuel Combustion Products

Sources of Exposure:

- Oil well fires (partially combusted crude oil)
- Tent heaters, cooking stoves (combusted gasoline, kerosene, diesel, jet fuel)
- Exhaust emissions from military vehicles and aircraft
- Emissions from generators
- Open burning of trash, wastes

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Hydrocarbon Fuel Combustion: Primary Compounds of Concern

Complex mixtures of gaseous compounds and particulates

- O₃, CO, CO₂, SO₂, NO, NO₂, H₂S
- VOCs, PAHs
- Particles of varying chemical composition and size

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Hydrocarbon Fuel Combustion

IOM Report on Fuel Combustion Products and Propellants (2005):

Sufficient evidence to conclude that there is an association between combustion products and lung cancer

Limited/suggestive evidence of an association between combustion products and cancers of nasal and oral cavities, bladder cancer, and low birthweight/pre-term births

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Tent Heater Emissions

- Exposures varied seasonally; in cold weather, tent heater exposures could have been continuous for 8 or more hours, over days – months
- Mumford et al (J Toxicol Env Health 1992;36:151) reported that organic emissions from unvented kerosene heaters are mutagenic

Emissions from unvented tent heaters

- 2 studies from Lovelace Respiratory Research Institute
 - Zhou Y, Cheng YS. Aerosol Science and Technology 33:510-524 (2000)
 - Cheng YS, Zhou Y, et al. Aerosol Science and Technology 35: 949-957 (2001)
- Experiments simulated and characterized emissions from heaters used inside of Army tent
- Tested 3 types of heaters, 3 types of fuels (kerosene, JA-1, JP-8)

Emissions from unvented tent heaters

- Results:
 - > Emissions varied with type of fuel, type of heater, and temperature
 - > Convection heaters emitted more NO and SO₂ than radiant heaters, less CO and particulates
 - > NO_x, CO, and SO₂ exceeded air quality standards when tent doors were closed; but did not exceed 24-hour exposure standards
 - > Most particulates were in the fine range (peak ~0.2 - 0.3 microns), with some in the ~10 micron range. Levels exceeded 24-hour standards when door closed, close to standards when door open

Emissions from unvented tent heaters

- Chemical Analyses of Particulates:
 - > Large amounts of sulfur (most as sulfates); mostly confined to smaller particles
 - > High amount of ammonium
 - > Elemental and organic carbons
 - > Also silica, aluminum, iron, lead

**Emissions from Tent Heaters: Epidemiologic Studies
 How many Were Exposed?**

Study	Population	Exposure	
Gray, 1999	527 Seabees	Airplane fuel burned in tent heaters	20.7%
Kronke, 1998	18,495 CCEP registrants	Fumes from tent heaters	73.0%
Proctor, 1998	186 Devers, 66 New Orleans Gulf War Vets	Smoke from tent heaters	Devers 69.8% New Orleans 50.0%
Unwin, 1999	3,284 UK Gulf War Vets	Exhaust from heaters or generators	78.2%
Vasterling, 2003	72 LA reservists	Smoke from tent heaters	56.9%
Wolfe, 2002	945 Army Gulf War Vets	Heater in tent	61.6%

**Emissions from Tent Heaters:
 Association with Health Outcomes**

Study	Outcome	Exposure	Findings
Proctor, 1998 (220 Army vets)	symptoms (groups)	smoke from tent heaters	Sign. correlated with cardiac, neurological, and pulmonary symptoms (p<0.001)
Unwin, 1999 (3,284 UK vets)	CMI	exhaust from heaters	OR = 1.9 (1.6-2.2)
Spencer, 2001 (1,119 ORNA vets)	CMI	diesel heater kerosene heater pothelly heater cleaned heaters	OR = 1.78 (0.93-3.42) OR = 1.92 (0.93-4.00) OR = 2.31 (1.14-4.66) OR = 2.41 (1.29-4.52)
Gray, 2002 (11,368 Seabees)	GWV	jet fuel burned in tent heaters	OR = 2.12 (1.81-2.49) (unadj) OR = 1.11 (0.88-1.38) (adjusted)
Wolfe, 2002 (945 Army vets)	CMI	heater in tent	OR = 1.6 (1.0-2.5)

Summary: Tent Heaters

- > 50% of troops report exposure to fumes from tent heaters (lower in Navy personnel)
- Exposure to tent heaters in theater associated with:
 - > Cardiac, neurological, and pulmonary symptoms
 - > Chronic multisymptom illness (ORs ~ 2.0)
- Compounds of potential concern include CO, SO_x, NO_x
- Particulate levels inside tents exceeded NAAQS standards

**Particulate Exposures in the
 Gulf War**



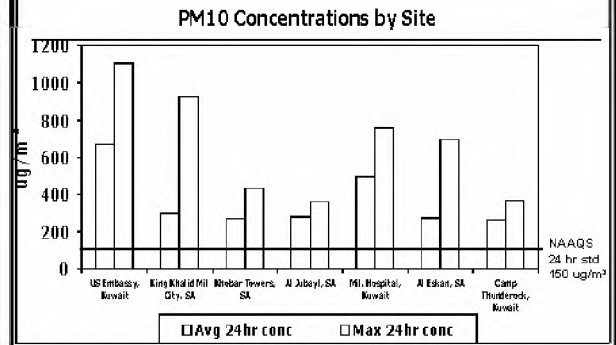
Particulate Exposure in the Gulf War

- Primary source of particulates in theater was the natural environment – blowing sand and dust (*USAEHA est: 75%*)
- Naturally occurring particulate levels in the region are among the highest in the world
- Respiratory illnesses, “Kuwaiti Crud” common among troops first entering the region

Particulate Exposures in the Gulf War

- Other Sources:
 - > Oil well fires (*USAEHA est 23%*)
 - > Tent heater emissions
 - > Industrial pollution
 - > Engine exhaust

Measured Total Particulates in Theater, May-Oct 1991



Source: Particulate Matter Exposure Final Report, DoD, 2002

Health effects of particulates

Numerous studies have linked particulate exposure to:

- ER visits for respiratory and cardiovascular conditions
- Increased death rates during acute elevation of particulates
- Aggravation of chronic respiratory conditions

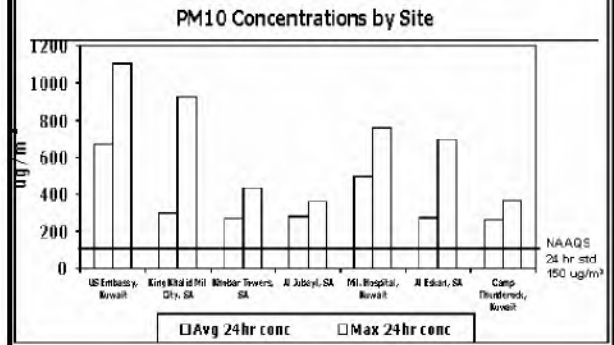
Health effects of particulates depend on:

- > Concentration of exposure
- > Duration of exposure
- > Physical and chemical properties of particle
 - Particle size
 - Chemical composition
 - Surface characteristics

Health effects in relation to particle size

- **PM₁₀** - Particles, diameter < 10 microns, > 2.5 microns
 Can be inhaled into and accumulate in the lungs
- **PM_{2.5}** - Fine particles, diameter 0.1 – 2.5 microns
 Can lodge more deeply into alveoli
- **Ultrafine particles** – Diameter < 0.1 microns
 Can cross pulmonary epithelium and enter circulatory system
 Recent studies indicate potential for systemic inflammatory effects, direct entry into brain

Measured Total Particulates in Theater, May-Oct 1991



Source: Particulate Matter Exposure Final Report, DoD, 2002

Health Effects of Sand/Particulates in Gulf War Veterans?

Al Eskan Disease: Desert Storm Pneumonitis and Dirty Dust

- In 1992, COL (Dr.) Andreas Korenyi-Both described an illness among troops housed in Al Eskan village (SA) apartment buildings that had been uninhabited for previous decade
- Approximately 2/3 of soldiers ill with symptoms of respiratory infection within 48-72 hours of arrival
- Most recovered with antibiotic treatment; 1% relapsed 5-6 weeks after initial onset and were unresponsive to treatment
- Dr. Korenyi-Both hypothesized that soldiers' exposure to mix of fine dusts and pigeon droppings triggered immunopathologic reactions resulting in a unique illness, Al Eskan disease

Al Eskan Disease:

Desert Storm Pneumonitis and Dirty Dust

- Dr. Korenyi-Both's analyses of Al Eskan sand indicated a very fine grain structure (0.1 – 0.25 microns), high CA levels. Bacteria and fungi species were isolated from the particles.
- In later publications, Dr. Korenyi-Both hypothesized that this fine sand could have acted as a carrier of chemical agents (or other exposures, including biological agents).
- The fine sand "carrier" would have enhanced the effects of the agents, increasing toxicity and delivered dosage.

**Al Eskan Disease:
 Desert Storm Pneumonitis and Dirty Dust**

- Dr. Korenyi-Both's hypotheses have not been formally studied
- Government officials have criticized his theories for their reliance on speculation rather than data
- Recent government research on properties of sand in the region and its potential to act as a carrier of environmental contaminants

**Epidemiologic Studies:
 Association of Health Outcomes with Sand Exposure**

Study	Exposure	Outcome	Findings
Gray, 1999 (527 Seabees)	sandstorms	fatigue forgetfulness sleepy all time rash muscle pain night sweats PTSD	OR = 2.7 OR = 2.1 OR = 2.3 OR = 2.7 OR = 2.7 OR = 2.5 OR = 4.1
Gray, 2002 (3831 Seabees)	sandstorms	GWV	OR = 2.63 (2.09-3.34) unadj OR = 1.70 (1.26-2.25) saturated model
Kelsall, 2004 (1,456 Austr. GW vets)	dust storms	ECRHS defn. suggesting asthma	OR = 1.1 (0.8-1.7)
Suadicani, 1999 (667 Danish GW vets)	sand or dust storm	Neuropsych symptoms	Sign bivariate association with number of symptoms, p < 0.01

**Previous RAC Presentations Related to
 Sand/Particulate Exposures**

- USACHPPM (2004) Measured particulates from oil well fires
- M. Soperi (2004) Lovelace Respiratory Research Institute: Inhalation of crystalline silica activates the immune system; silicosis results from second phase of response that does not require sustained immune activation
- J. Lewis (2004) University of New Mexico: Penetration of inhaled DU into the brain is enhanced when occurs with inflammation in the nasal cavities

**Summary:
 Particulate Exposures in the Gulf War**

- Multiple sources of particulate exposure during the Gulf War
- Ambient particulate levels in the region among the highest in the world
- Kuwaiti sand is unique: fine "dust", highly mineralized
- Little epi information: some indication of association of chronic symptoms with s/r sandstorm exposure
- Recent research evaluates relationship of particulates to systemic and neuro inflammation