Presentation 4 – Lea Steele

Fuel Combustion Products, Particulates

Exposures and Epidemiologic Findings in Gulf War Veterans

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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

- O_3, CO, CO_2, SO_2, NO, NO_2, H_2S
- 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

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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)

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Emissions from unvented tent heaters

- Results:
  - Emissions varied with type of fuel, type of heater, and temperature
  - Convection heaters emitted more NO and SO_2 then radiant heaters, less CO and particulates
  - NO_x, CO, and SO_2 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

Zhou Y, Cheng YS. Aerosol Science and Technology 33:510-524 (2000)

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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

Cheng YS, Zhou Y, et al. Aerosol Science and Technology 35: 949-957 (2001)

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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%
Kroenke, 1998	18,495 CCEP registrants	Fumes from tent heaters		73.0%
Proctor, 1998	186 Devens, 66 New Orleans Gulf War Vets	Smoke from tent heaters	Devens New Orleans	69.8% 50.0%
Unwin, 1999	3,284 U.K. 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%

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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 OR/WA vets)	CMI	diesel heater kerosene heater potbelly 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 (11,868 Seabees)	GWI	jet fuel burned in tent heaters	OR = 2.12 (1.81-2.49) (unadj) OR = 1.11 (0.83-1.39) (saturated)
Wolfe, 2002 (945 Army vets)	CMI	heater in tent	OR = 1.6 (1.0-2.5)

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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

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Particulate Exposures in the Gulf War

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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

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Particulate Exposures in the Gulf War

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

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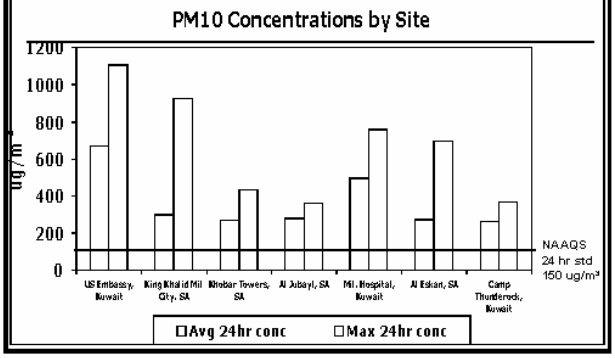
Measured Total Particulates in Theater, May-Oct 1991



Source: Particulate Matter Exposure Final Report, DoD, 2002

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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

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Health effects of particulates depend on:

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

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Health effects in relation to particle size

- PM_{10} – 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

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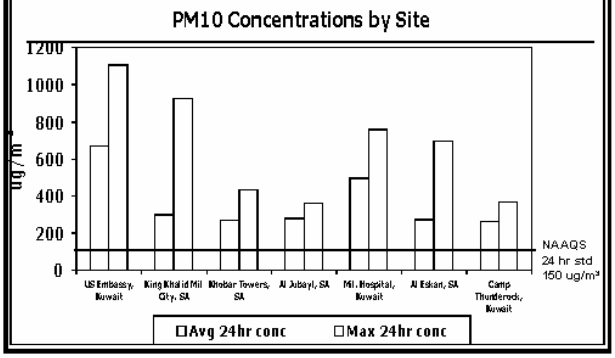
Measured Total Particulates in Theater, May-Oct 1991



Source: Particulate Matter Exposure Final Report, DoD, 2002

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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

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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.

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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

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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 (3,931 Seabees)	sandstorms	GWI	OR = 2.63 (2.09-3.31) unadj OR = 1.70 (1.28-2.25) saturated model
Kelsall, 2004 (1,456 Austr. GW vets)	dust storms	ECRHS defin. 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, $p < 0.01$

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Previous RAC Presentations Related to Sand/Particulate Exposures

- USACHPPM (2004) Measured particulates from oil well fires
- M. Sopori (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

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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

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