

# Medical Geology: Dust exposure and potential health risks in the Middle East.

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**Abstract.** In the Middle East, dust and sand storms are a persistent problem delivering significant amounts of particulates via inhalation into the mouth, nasal pharynx, and lungs. The health risks of this dust inhalation are not well studied nor effectively characterized. Experiments were designed to study the chemical composition, mineral content, or microbial flora of Kuwaiti and Iraqi dust for its potential to cause adverse health effects. Multiple site samples were collected and chemical and physical characterization including particle size distribution and inorganic analysis was conducted, followed by characterization of biologic flora, including bacteria, fungi and viruses. Data indicates that the mineralized dust is composed of calcium carbonate over a matrix of metallic silicate nanocrystals and compounds containing a variety of trace and heavy metals constituting ~3 % of the PM10 particles by weight, of which ~1% is bioavailable aluminum and reactive iron, each. Microbial analysis reveals a significant biodiversity of bacteria of which ~25 % are known pathogens. Of the microbes identified, several have alpha and/or beta hemolytical characteristics and show significant antibiotic resistance. Viral analysis indicates a high level of virions with RNA viruses representing a large percent. The level of total suspended particle mass at PM-10 constitutes an excessive exposure micro-particulates including PM-2.5. Cell culture and animal studies have indicated a high level of toxicity to these dust particles. These data suggest that at the level of dust exposure commonly found in the Middle East, coupled with their microbial and metal content, constitute a significant health risk, both acute and chronic, to deployed troops.

**Keywords:** *dust, health effects, heavy metals, microbes, dust exposure, dust morphology, Middle East.*

## 1. INTRODUCTION

Dust can range in both composition and particle size depending on the global location. In the Middle East, dust and sand storms are a persistent problem especially during the spring and summer months. Desert sand in the Persian Gulf region consists mostly of quartz (SiO<sub>2</sub>) but the finer dust consists primarily of clays with and without a silicate core and can be respired into the lungs due to the small size of the particle (Richards *et al.*, 1993). The dust particles predominately consist of clays (~50%) and quartz crystals (~25%). The size distribution of airborne particles can range from <1 μm to ~150+ μm depending on wind velocity.

Inhabitants of deserts can develop Desert Lung Syndrome, a benign, non-progressive fibrosis resulting from silica-containing dust depositing in the lungs. Desert Lung Syndrome generally develops after years of heavy exposure to sand particles (Nouh, 1989). An acute desert-related lung disease described as Desert Storm Pneumonitis was found to occur following inhalation of fine Saudi dust and pigeon droppings (Korenyi-Both, *et al.*, 1992). In a second paper on the subject the authors describe a novel condition triggered by exceptionally fine sand of the central and eastern Saudi Arabian peninsula (Korenyi-Both, *et al.*, 1997). They concluded that immunosuppression aggravated by opportunistic infections and other non-microbial ailments were brought on by exposure to the ubiquitous fine sand of the area causing Persian Gulf Syndrome (Korenyi-Both, *et al.*, 1997).

Recently, a pulmonary condition termed Severe Acute Pneumonitis with unknown etiology has been reported among several U.S. military personnel deployed in Southwest Asia (Shorr AF, *et al.*, 2004). Confirmed cases occurred during 2003 (March through August) and all cases have had bilateral pneumonitis requiring intubation and mechanical ventilation and elevated eosinophils in the lung or peripheral blood. Of the 19 cases, two have died. Four of the cases have had evidence of infections with a microbial agent. Sand inhaled into the lungs has been linked to Desert Lung Syndrome and Desert Storm pneumonitis however, it is not known if dust inhalation also leads to the development of severe acute pneumonitis. Following Gulf War I, obstructive bronchitis and bronchiolitis were reported in 86 autopsied casualties from Kuwait, with the reported observation of sand particles in lung parenchyma (Irey, 1994).

## 2. METHODS AND RESULTS

The physical and chemical properties of the Iraqi dust sample were unique among sand/dust samples normally encountered. These observations included: 1) a significant portion of the sample (10+%) was 20 μm or less in size; 2) these micro-particulates exhibited a charge distribution that prevented them from clumping; and 3) that particles below 20 μm in size seemed to contain a crystalline core surrounded by a non-crystalline inorganic coating.

The data collected and analysis of samples collected from this study produced the following observations and results:

- (1) At PM10 (particle with aerodynamic mass of 10 microns), the highest hourly average each day was 2.469 mg/m<sup>3</sup>

which occurred at 0800. Maximum exposures during dust storms exceeded 10.000 mg/m<sup>3</sup>. (Table 1)

- (2) Daily daytime PM 10 average for 12 consecutive hours, 0700-1900, was ~0.900 mg/m<sup>3</sup> (n=12).
- (3) At peak exposures, particle counts (0.5 to 10 μm range) exceeded 7x10<sup>8</sup> particles/ m<sup>3</sup>.

**Table 1. Particle exposure in Camp Buehring Kuwait over a 12 day period.**

<p><b>TSP (Total Suspended Particle Mass) (mg/m<sup>3</sup>) PM10</b>          = 0.001 mg/m<sup>3</sup> (NIDBR Lab, Great Lakes, IL)          = 0.137 mg/m<sup>3</sup> (Camp Virginia Clinic, Kuwait - indoors)          = 2.469 mg/m<sup>3</sup> (Highest hourly average - 0800)          = 9.114 mg/m<sup>3</sup> (Highest TSP reading)          = 2.051 mg/m<sup>3</sup> (Highest daily maximum - 18 June)          * <b>NOTE:</b> &gt;9.99 mg/m<sup>3</sup> recorded during peak dust storms</p> <p><b>Count (Total Number of Suspended PM 10 Particles /m<sup>3</sup>)</b>  <b>Size Range = 0.5 um to 10 um</b>          = 1,314,906 (Navy Lab, Great Lakes, IL - indoors)          = 12,290,917 (Camp Virginia Clinic, Kuwait - indoors)          = 107,261,167 (Highest avg. hourly maximum @1300) (SD=54,959,015)          = 588,633,693 (Highest daily maximum, 18 June)          = 127,643,273 (Highest avg. hourly daily max., 13 June@1300) (SD~34MM)          * <b>NOTE:</b> Readings during peak dust storms ≥706,293,334 particles/m<sup>3</sup></p> <p><b>Size Range = 5.0 um to 10 um</b>          = 36,515 (Navy Lab, Great Lakes, IL - indoors)          = 507,824 (Camp Virginia Clinic, Kuwait - indoors)          = 6,884,417 (Highest average hourly maximum @1300) (S =4,142,586)          = 44,571,347 (Highest hourly maximum - 18 June @1300)          = 5,244,651 (Highest average daily maximum - 13 June) (SD=3,632,501)</p>
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- (4) A total of 54 elements were screened with 37 different elements identified of which there are 15 are bioactive metals including Uranium. Of these the ones of greatest concern are: Arsenic (10 ppm), Chromium (52 ppm), Lead (138 ppm), Nickel (564 ppm), Cobalt (10 ppm), Strontium (2700 ppm), Tin (8 ppm), Vanadium (49 ppm), Zinc (206 ppm), Manganese (352 ppm), Barium (463 ppm), Aluminum (7521 ppm). [Sample particle results]
- (5) The ratio of Chromium III to Chromium VI is unknown (40 - 120 ppm = .04 - .12 μg/m<sup>3</sup> per every mg /m<sup>3</sup> of TSP mass at PM10). The US Maximum Exposure Guidelines (MEG) for Cr (III) is 12 μg /m<sup>3</sup> and 0.068 μg /m<sup>3</sup> for Cr (VI).
- (6) Microbiological analysis of these same samples identified 147+ different microbial isolates (six different Genera by 16s DNA analysis). Of these, ~30% are human pathogens, 13 are alpha and/or beta hemolytic species, and several were found to have antibiotic resistance (Figure 3). Isolates of *Acinetobacter spp.* and *Neisseria spp.* have been found inhabiting the dust.
- (7) Approximately 27 fungal isolates have been identified consisting of 7 different Genera.
- (8) Sterilization experiments have shown an exceptional ability for these organisms to survive.
- (9) Early animal studies have suggested long-term inflammation from pulmonary exposure with mild to moderate eosinophilia.

Airborne particulates are recognized the number one health risk for troops deployed to the current theaters of operations for OIF and OEF. The DoD currently employs the EPA standard of the

**Figure 1. Representative Bacteria Isolated from Dust Particles. [Colored columns indicate hemolytic characteristics.]**

Best ID thus Far	Comment
<i>Neisseria meningitidis</i>	meningitis
<i>Staphylococcus aureus</i>	cystic fibrosis
<i>Bacillus circulans</i>	gastro-enteritis
<i>Pantoea agglomerans</i>	septic arthritis
<i>Pseudomonas agrici</i>	
<i>Ralstonia paucula</i>	opportunistic-septicemia, peritonitis, abscesses
<i>Staphylococcus pasteurii</i>	various infections
<i>Arthrobacter crystallopoietes</i>	
<i>Pseudomonas balearica</i>	cystic fibrosis
<i>Paenibacillus thiaminolyticus</i>	bacteremia
<i>Bacillus vedderi</i>	obligate alkaliphile
<i>Bacillus subtilis</i>	
<i>Pantoea agglomerans</i>	epiphyte
<i>Pseudomonas pseudoalcaligenes</i>	Strains reported to carry metallo-β-lactamase
<i>Cryptococcus albidus</i>	septicemia and meningitis
<i>Bacillus clausii</i>	Oral bacteriotherapy
<i>Kurthia gibsonii</i>	Diarrhea
<i>Bacillus firmus</i>	alkaliphile; bread spoilage
<i>Staphylococcus kloosii</i>	various infections
<i>Bacillus mojavensis</i>	biosurfactant
<i>Bacillus licheniformis</i>	food poisoning
<i>Pseudomonas oryzae</i>	Hickman catheter biofilm

respirable fraction (<10 μm) to estimate the risk of exposure to airborne particulates. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) reported that PM10 exceeded the 1-year MEG (70 μg/m<sup>3</sup>) for PM10 (particulate matter <10 μm) over 97+% of the time.

The scientific studies conducted supplied substantial data as to the composition of dust particles within the Kuwaiti/Iraqi sample area as well as environmental conditions and exposure potential for troops operating under these conditions. For example, during June 2004, environmental conditions were monitored from 0700 till 1900 for 12-days at Camp Buehring, Udairi, Kuwait on the Iraqi/Kuwaiti border. The average daytime temperature was 106.2 °F with maximums in excess of 135 °F. However, surface sand temperatures elevated to 155-160 °F due to the infrared (IR) radiation absorption. The average UV exposure index was 10 (>360 mW / m<sup>2</sup>) and is one of the highest in the world. Average humidity was <10 % but was probably elevated over that previously reported for that region (<3%) because of the presence of humans and other sources of water. Average daily wind velocity was approximately 14 MPH (1267 ft/min) with maximum wind gusts in excess of 33 MPH (2800 ft/min). This is significant because it physically relates not only to the amount of total suspended particle mass in the breathable air at standing height (~ 2 m vertical), but also to the size fraction of particles being suspended (>150 μm). Airborne particle dynamics determine the size of the particle airborne and the height off the deck based primarily on wind velocity and 'roughness' (drag) of the particle. Simply put, at any given wind velocity, the lower one gets to the ground the greater the mass of particles one is subjected to with an increase in particle size. Particle sizes <44 μm constituted from 5% to 11% of the total mass for samples collected outdoors versus indoors (tent dust) respectively. Approximately 98% of the indoor dust samples were <150 μm in diameter, while upwards of 60% of the terrestrial soil samples were 150 μm or smaller in size. Under relatively low humidity conditions, these micro-particulates resist clumping and thus can remain suspended in the air for long periods.

Therefore, normal human activity and natural wind can keep these dust particles airborne for indefinite periods of time.

### 3. CONCLUSIONS

The findings are most notable for a thorough description of the soil and particulate dust samples collected in this theater. The chemical and biological composition of the particles expands our current data. Presently, a potentially significant amount of dust is inhaled and ingested daily within the military exposure area especially during dust storms and troop movements through the desert. Most of these micro-particulates are composed of a porous silica core (crystalline metallic silicate and amorphous silica dioxide) surrounded by a type of clay (inorganic) consisting of, primarily, calcium carbonate ( $\text{CaCO}_3$ ) and magnesium sulfate ( $\text{MgSO}_4$ ), and metallic compounds and silicates. This inorganic coating offers varying degrees of protection to microbes from UV radiation, heat, alcohol, and oxidizing agents, and bactericidal agents. The chemistry of these particles displays a unique potential for trace metal exposure. Due to their extreme small size, these particles readily become airborne and are easily inhaled nasally ( $<40 \mu\text{m}$ ) and orally ( $<150 \mu\text{m}$ ) and can be deposited in deepest regions of the lungs ( $<10 \mu\text{m}$ ).

The data indicates that the mineralized dust is composed of  $\text{CaCO}_3$  in a coating over a matrix of metallic silica crystals containing a variety of trace metals constituting ~1% of the PM10 by weight. The particles also consist of ~1% by weight each (10,000 ppm) of bioavailable Aluminum and reactive Iron with another 1% by weight a combination of trace and heavy metals. This finding is of specific concern due to the recent implication of Aluminum in Multiple Sclerosis and other neurological diseases. Microbial analysis reveals a significant biodiversity of bacterial, fungi, and viruses of which ~30% are pathogens. The level of total suspended particle mass along with environmental & physiological conditions present constitute an excessive exposure to micro-particulates including PM 2.5 & the potential for long-term adverse health effects. These data suggest that the level of dust exposure coupled with the microbial & bioavailable metal content could constitute a significant health risk. When taken with other existing work suggest that further immediate research is warranted to provide insight into potential human health risks both acute and chronic.

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## 5. ADDENDUM

**Bioavailable Elements in Dust Particles from Camp Buehring, Kuwait. [NOTE: Strontium at 2436 PPM, Lead is 138 PPM, Nickel is 564 PPM, and Aluminum 7521 PPM.]**

