

Extreme Dust Events and Potential Impacts to Human Health

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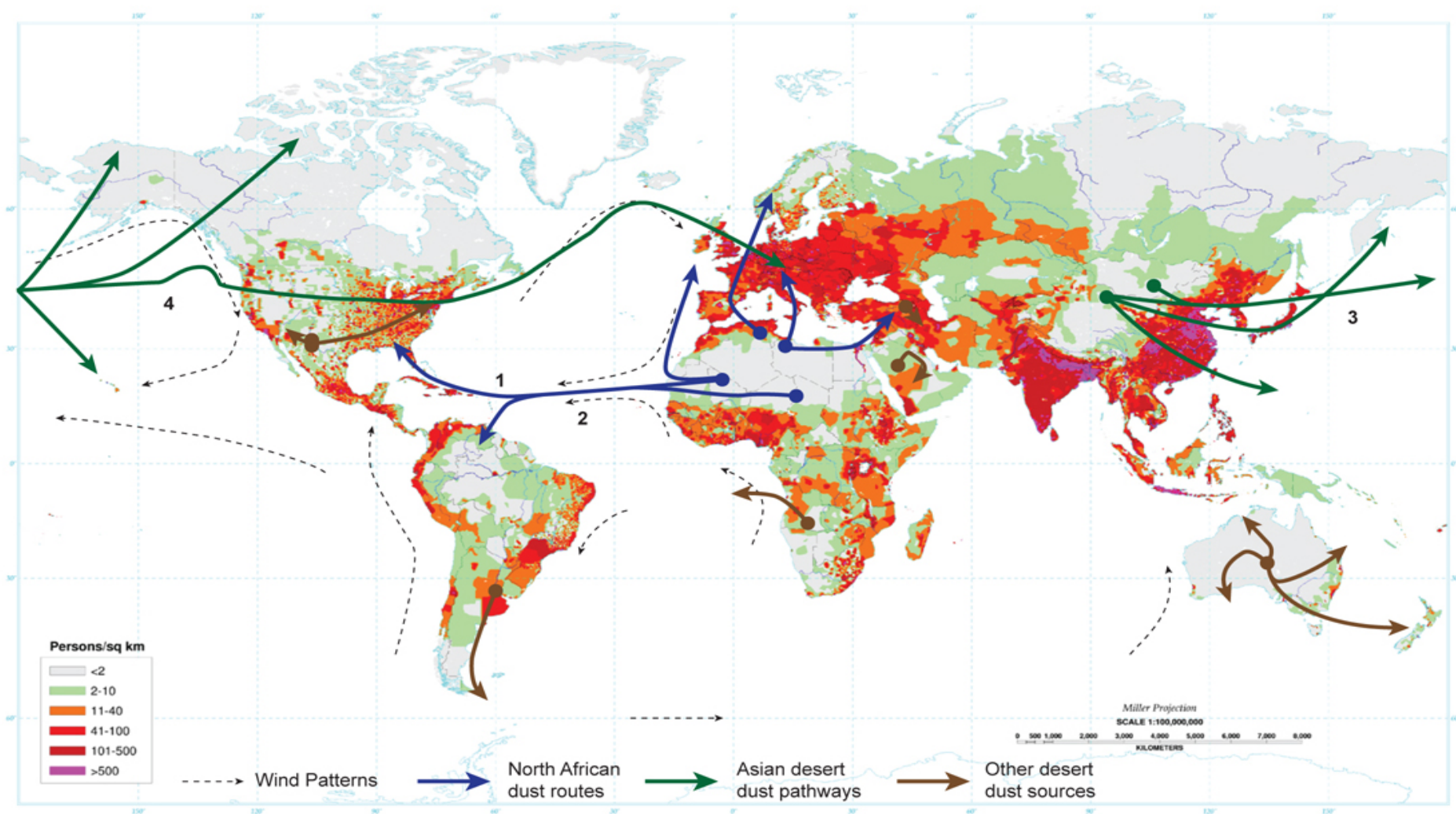
The Joint Pathology Center
Silver Spring, MD

International Medical Geology Association
<http://www.medicalgeology.org>



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- 1 - Northern Hemisphere summer (approximately June - October), African desert dust crosses the Atlantic to northern Caribbean and North America.
- 2 - Northern Hemisphere winter (approximately November - May), African desert dust crosses the Atlantic to southern Caribbean and South America.
- 3 - Asian dust season typically lasts from late February to late April.
- 4 - Large Asian dust events can travel significant distances in the Northern Hemisphere, including a full circuit.

Primary sources of mineral dust and their generalized atmospheric pathways (modified after Griffin, 2007), and world population density 1994 (United States Department of Agriculture).

SOURCES

Including:

- **Volcanoes**
- **Dust storms (regional storms)**
- **Long-range transport episodes of desert dust (intercontinental dust)**
- **Displacement through natural processes such as landslides and earthquakes**
- **Mine tailings spills**
- **Chemical or industrial spills**
- **Terrorist attacks**

Dominant dust source regions around the world (in brown) .

Courtesy of Prof. Dr. Edward Dervishire, UK and Dr. Geoffrey Plumlee, USGS

The Health Effects of Dusts

- Some aspects have been well known for decades
 - General effects of industrial / commercial asbestos
 - Silicosis (hard rock mining), pneumoconiosis
 - Black lung (coal mining)
- New issues and problems are arising:
 - Regional desert storms, trans-oceanic dust transport
 - Airborne dust composition (ie, toxic metals) ,
 - Microbiological, infectious disease agents and pathogens (ie, Valley fever)



Crocidolite (Blue Asbestos)

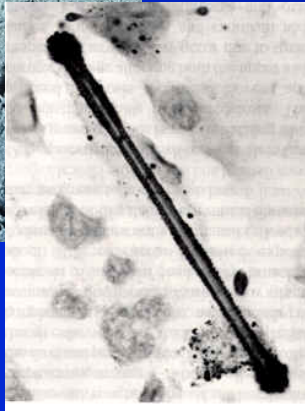


Photo courtesy of Dr. Tony Ladson, Civil Engineering,
Monash University, Clayton, Victoria, Australia

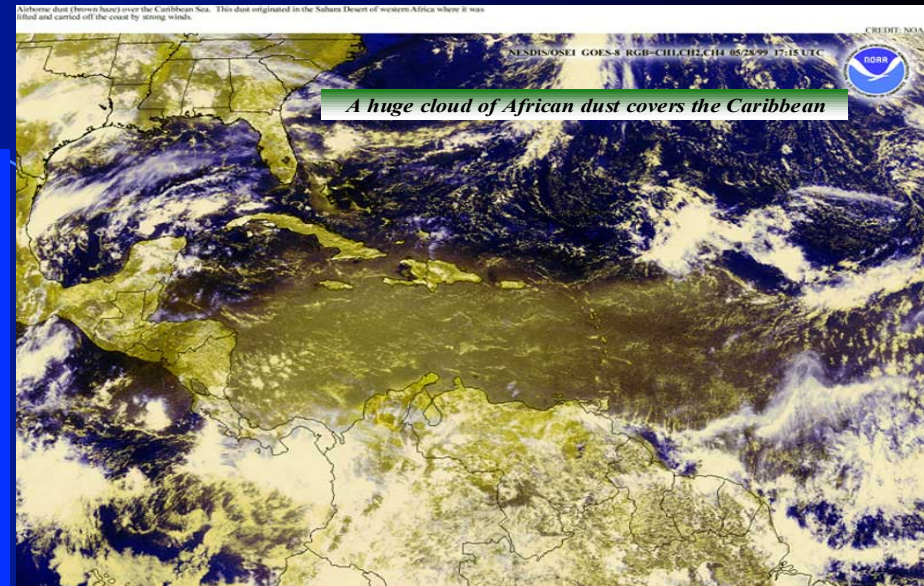
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African Dust-Event

St. Thomas, USVI, August 8, 2001

Atmospheric dust - Human and ecosystem health

- **Dust as a trigger for harmful algae blooms**
 - Death of marine organisms
 - Human illness – respiratory stress, skin rash, paralysis and memory loss from consumption of contaminated seafood
- **Dust as a carrier of toxins**
 - pesticides, herbicides, hydrocarbons, metals, industrial emissions...
 - implications – direct (*exposure = death/acute illness*) or indirect (*exposure = immune suppression*)
- **Dust as a carrier of microorganisms**
 - Pathogenic = disease outbreaks
 - Non-pathogenic = ecological change



~ 10% of Caribbean African dust isolates are known human opportunistic pathogens

~20% of Caribbean African dust isolates are known plant or animal pathogens

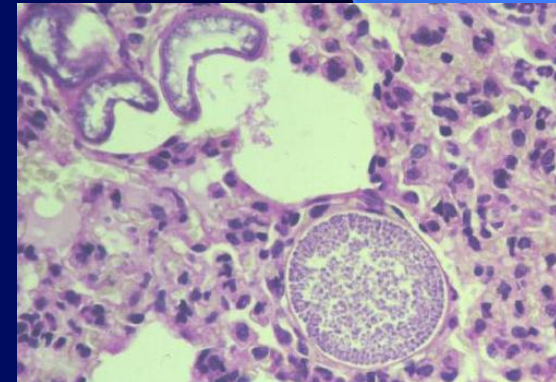
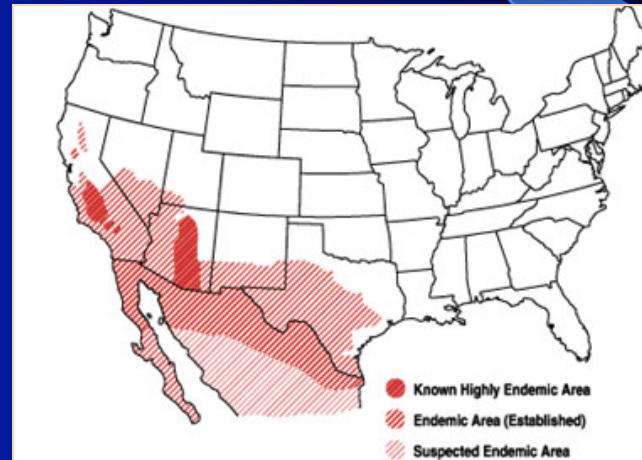
Photos Courtesy: Dr. Dale Griffin, USGS

Dusts and the origin of Valley Fever (Coccidioidomycosis)

- Coccidioidomycosis is a reemerging infectious disease
- A systemic infection caused by the inhalation of airborne spores of *Coccidioides immitis*
- *C. immitis* is a soil inhabiting fungus found in North, Central, and South America.
- Given proper conditions, infectious spores are released when soil is disturbed
 - ie, storms, construction, earthquakes
- Dust storms have been shown to carry spore laden dirt as far as 700 km, causing outbreaks



Tucson, Arizona
July 5, 2011



*Courtesy of Dr. Geoffrey Plumlee, USGS and
Dr. William Sprigg, University of Arizona

Valley Fever (Coccidioidomycosis)

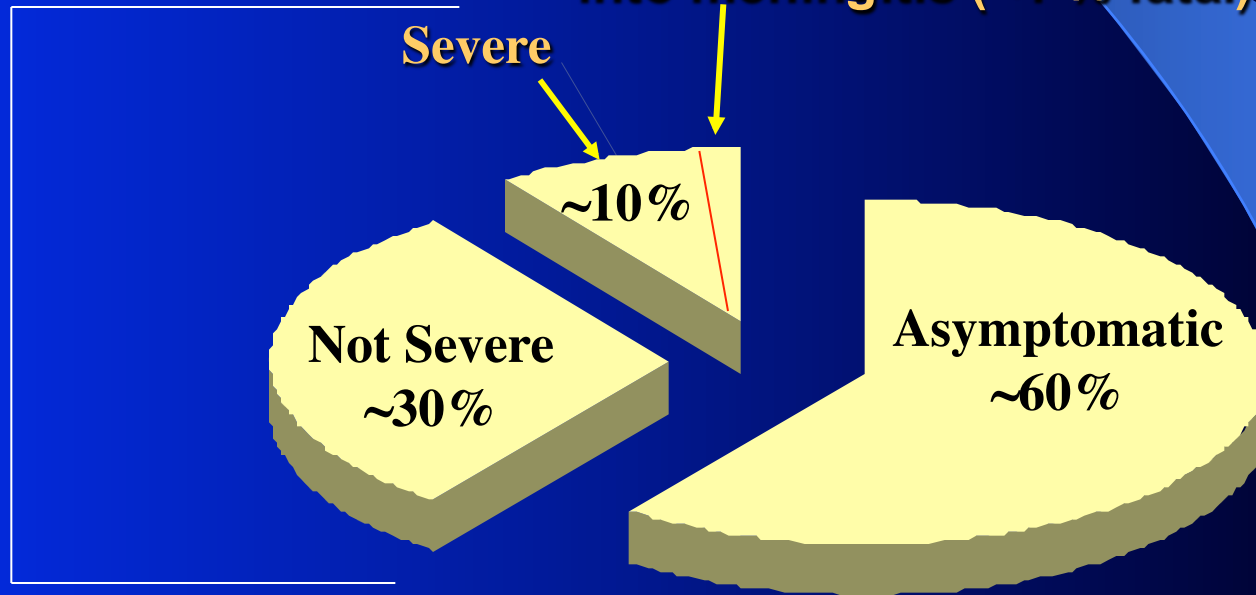
- Clinical manifestations occur in ~40% of infected persons



In ~1% to 2% of cases the disease becomes disseminated, and affects skin, bones, or joints, or develops into meningitis (<1 % fatal)

self-limited
influenza-like
illness to
pneumonia

fatigue
cough
chest pain
fever
rash
headache
joint ache



◆ 7,500 new cases of Valley Fever occur annually in the U.S.A, with a cost in excess of \$60 million a year.

Case Study

Coccidioidomycosis

Case History: 22-year-old active duty Army private, complaining of persistent chest pain and back pain for 1 month. He expend a two-year tour of duty to Fort Irwin, CA.

MAJ Barnett T. Gibbs, MC, USA
CPT Robert T. Neff, MC, USA
Walter Reed Army Medical Center

Gibbs BT, Neff RT. Case Management Study.
A 22-year-old Army private with chest pain and weight loss. *Military Medicine* 169, 2:157 (2004).

Case Management Study

Walter Reed Army Medical Center

A 22-Year-Old Army Private with Chest Pain and Weight Loss

Guarantor: MAJ Barnett T. Gibbs, MC USA
Contributors: CPT Robert T. Neff, MC USA; MAJ Barnett T. Gibbs, MC USA

The objective of this study was to delineate an efficient and effective diagnostic approach in evaluating a patient with weight loss and a posterior mediastinal mass. This case demonstrates the evaluation and management of a 22-year-old Army private with weight loss, chest pain, and a posterior mediastinal mass on chest X-ray. The importance of obtaining a thorough travel history to formulate the differential diagnosis is highlighted.

A 22-year-old active duty Army private, complaining of persistent chest and back pain for 1 month, presented to the Emergency Room at Womack Army Medical Center in Fort Bragg, Fayetteville, North Carolina. He noted a 20-kg weight loss over 1 year and a right upper lip lesion for 1 month (Fig. 1). He had no significant past medical history and took only ibuprofen as needed for pain. The patient drank alcohol occasionally and smoked one pack of cigarettes every 3 days. His family history was noncontributory. He was raised in the southeastern United States and had remained in the Southeast except for a 2-year tour of duty to Fort Irwin, California before transfer to Fort Bragg, North Carolina. Upon presentation, his vital signs were normal. A 1-cm erythematous papule was present over his right upper lip. The remainder of the physical examination was normal. The white blood cell count was 9.7 K/ μ L (4.4–11.0 K/ μ L), hemoglobin 9.9 g/dL (13.0–17.2 g/dL), platelet count 440 K/ μ L (142–424 K/ μ L), and serum chemistry were normal. Posteroanterior and lateral chest X-ray showed bilateral reticulonodular infiltrates and a midline posterior mediastinal mass. Computed tomography of the chest showed a millary type interstitial pattern of both lower lobes with pleural thickening. A paraspinal soft tissue mass was noted at the T3–T7 level. The patient was placed in respiratory isolation. An examination of three sputum samples for acid-fast bacilli was negative.

1. Based on the presentation and the above findings, which of the following was the most likely diagnosis?
a. Tertiary syphilis
b. Metastatic osteosarcoma
c. Disseminated histoplasmosis
d. Disseminated coccidioidomycosis

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The opinions or assertions contained herein are the private views of the authors and are not to be construed as reflecting the views of the Department of the Army or the Department of Defense.
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e. Tuberculosis

Gummas of tertiary syphilis are granulomatous lesions that typically involve the skin, upper respiratory tract, liver, and stomach, but any organ can be involved. The lesions can range from microscopic to several centimeters in size and from benign to destructive in nature. This patient's paraspinal soft tissue and skin lesions could have been consistent with tertiary syphilis, but his pulmonary parenchymal involvement was inconsistent with this diagnosis. Additionally, late syphilis usually occurs 10 to 30 years after primary infection in untreated patients, making this diagnosis rare.

Osteosarcoma is a disease occurring in the first 3 decades of life, involving the long bones and causing swelling at the usual site of the lesion. The patient's chest X-ray findings were inconsistent with this diagnosis.

Histoplasmosis is a common, endemic to the central and eastern United States. Most infections are self-limited and rarely cause severe disease. However, disseminated histoplasmosis can occur in immunocompromised patients, typically within 2 to 4 months of exposure. The patient's geographic location and clinical presentation were inconsistent with this diagnosis.

Coccidioidomycosis is a common, endemic to the southwestern United States and South America. Like range from asymptomatic to severe disease. The disease can be characterized by a variety of clinical presentations, including pulmonary, cutaneous, and systemic. The patient's presentation was consistent with this diagnosis.

Tuberculosis is caused by *Mycobacterium tuberculosis*. Tuberculosis can present as either primary or secondary pulmonary disease or with extrapulmonary symptoms. Worldwide, primary pulmonary tuberculosis often occurs in children, involves the middle and lower lobes, and is associated with hilar adenopathy. Secondary tuberculosis occurs with reactivation of the bacteria, manifested as cough, fever, night sweats, and weight loss. The apices of the lungs are usually involved. Extrapulmonary tuberculosis can affect almost every organ system, most commonly the lymph nodes, genitourinary system, musculoskeletal system, and central nervous system. Signs and symptoms of extrapulmonary tuberculosis depend on the system involved. Tuberculosis could have explained this patient's presentation. However, given his extensive pulmonary involvement and serial negative acid-fast bacilli stains, it was less likely.

Based on the computed tomography scan, the patient was referred for computed tomography-guided biopsy that showed granulomatous tissue containing numerous fungi consistent with *C. immitis*. Lip biopsy also showed fungi consistent with *C. immitis*. Cultures from both samples eventually grew *C. immitis*.

2. Regarding this patient's disease, all of the following are true EXCEPT:
a. African-American race puts him at increased risk for disease
b. Human immunodeficiency virus (HIV) testing should be performed
c. Alcohol use puts him at increased risk for disease
d. Tobacco use does not increase his risk of disseminated disease
e. ESR tests puts him at increased risk for hospitalization

This patient had disseminated coccidioidomycosis defined by spread of disease beyond pulmonary parenchyma or hilar

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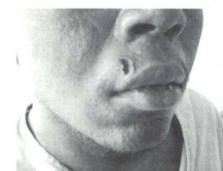


Fig. 1. Upper lip lesion on case subject.

endemic area was an obvious risk factor especially because he was at a training site where exposure to airborne organisms from soil disruption through digging of fighting positions, heavy vehicle traffic, etc. was likely. This patient's history of travel to an endemic area and features consistent with disseminated coccidioidomycosis made it a likely diagnosis.

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nodes. There are various risk factors for disseminated coccidioidomycosis including African-American race, low socioeconomic status, and pregnancy.³ African-American descent is associated with a 4.6 times increased risk for disseminated, severe disease possibly due to differences in major histocompatibility genes that play a role in cell-mediated immunity. The most important risk factor for disseminated disease is defective cell-mediated immunity, as seen in patients with HIV; those on higher doses of corticosteroids (more than 20 mg/day prednisone), or transplant recipients. Alcohol use and a history of cigarette smoking do not confer increased risk for disseminated coccidioidomycosis.³ In a case series of Navy personnel, junior pay grades (E1–E6) had higher hospitalization rates for coccidioidomycosis than higher pay grades. It is unclear whether the higher hospitalization rates represented increased exposure from daily duties performed by junior personnel or were a result of efforts to isolate infected personnel from their barracks.⁴

3. Which of the following would NOT be an appropriate test to perform at this time:
a. Lumbar puncture with fungal culture
b. Erythrocyte sedimentation rate (ESR)
c. Meridian Premier Coccidioides enzyme immunoassay
d. Complement fixation (CF) for coccidioidomycosis
e. Coccidioidin skin testing

In patients with disseminated coccidioidomycosis, there are several important tests to perform. As *C. immitis* has a predilection to disseminate to the central nervous system, a lumbar puncture must be performed. Routine cerebrospinal fluid laboratories such as protein, glucose, and cell count should be sent as well as fungal culture. If lumbar puncture results show *C. immitis* involvement, therapy will differ.

The ESR is a nonspecific test that indirectly measures inflammation. Acute phase reactants (especially fibrinogen) rise in response to any acute inflammatory stimulus. Higher levels of fibrinogen in the blood cause erythrocyte clumping and a rise in ESR.⁵ Disseminated coccidioidomycosis causes a rise in acute phase reactants and ESR. As the infection is effectively treated, the ESR will correspondingly decrease. Therefore, serial ESR measurements can be a good, albeit nonspecific, way to monitor response to therapy.

The Meridian Premier Coccidioides enzyme immunoassay otherwise known as MFC-EIA is a recently developed enzyme-linked immunosorbent assay that qualitatively detects both IgM and IgG antibodies to *C. immitis* antigens. It can be used on both serum and cerebrospinal fluid specimens. Favorable test characteristics and a rapid turnaround time make it an excellent screening and confirmatory test for coccidioidomycosis. A limitation of this method is that it cannot be used for serial test measurements.⁶

CF is an indirect way of quantitatively measuring serum IgG antibody against *C. immitis*. The CF antibody is useful for both diagnosing acute disease and for following disease course. A positive CF at any titer level is a good indication of an active infection when confirmed with a titer test. A CF titer above 1:64 indicates the possibility of disseminated disease, and levels above 1:256 virtually confirm dissemination. After initial diagnosis and initiation of treatment, CF levels can be followed serially, with fourfold changes in titer indicating other progress.

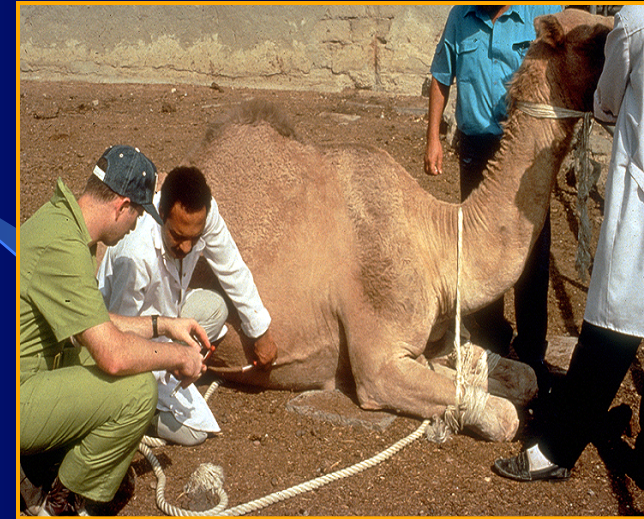
Valley Fever (Coccidioidomycosis)

- *“Military physicians in particular must be vigilant of this disease (Coccidioidomycosis), as there are large numbers of personnel stationed in the desert southwest and even more who pass through while training at the National Training Center at Fort Irwin, California” MAJ Barnett J. Gibbs and CPT Robert T. Neff, Military Medicine 2004.*

Health Effects of Middle East Sand (Dust)

A Military Medical Geology Research Case

- ❖ Evidence of microbial transfer of pathogens via African Dust. (EA Shinn, et al., African Dust and the Demise of Caribbean Coral Reefs, *Geophys Res Lett.* 27, (2001) p.3027-32)
- ❖ Description of novel condition triggered by exceptionally fine sand of the central and eastern Saudi Arabian peninsula. Concludes that immunosuppression aggravated by opportunistic infections and other non-microbial ailments brought on by exposure to the ubiquitous fine sand of the area cause Persian Gulf Syndrome. (Korenyi-Both, et al., Al Eskan Disease: Persian Gulf Syndrome, *Military Medicine*, 162, (1997), p.001).
- ❖ Obstructive bronchitis and bronchiolitis in 86 autopsied casualties from Kuwait, with observation of sand particle in lung parenchyma. (NS Irey, Kuwait Casualties: Morphologic and Toxicologic Findings, NIH Technical Assessment Statement, April 27-29, 1994).
- ❖ From March through August 2003, 19 US military personnel developed pneumonia severe enough to warrant medical evacuation and mechanical ventilation; two died. (AF Shorr, et al., Acute eosinophilic pneumonia among US military personnel deployed in or near Iraq. *JAMA*. 2004 Dec 22;292(24):2997-3005.)
- ❖ Constrictive Bronchiolitis in Soldiers Returning from Iraq and Afghanistan. King MS et al (2011) *N Engl J Med* 365(3);222-230.



Middle East Dust – Trace Composition

Links between selected elements and some known lung function conditions and diseases

	DUST <10 µm	DUST 20-40 µm
Mn (%)	0.04	0.03
Fe (%)	2.5	1.8
Co (ppm)	11.72	8.24
Pb (ppm)	17.22	9.45
Cu (%)	0.02	0.02
Cd (ppm)	1.24	0.70
Mg (%)	1.3	1.1
Al (%)	1.6	1.3
Ca (%)	13.9	14
Na (%)	0.1	0.1
Cr (%) [but species critical]	0.02	0.02
Zn (%)	0.01	0.01
Ni (%)	0.01	0.01
Ti (%)	0.1	0.05

Cancer

Cancer suspected

Cancer & asthma

Emphysema

Asthma

SUMMARY

- Dust and other particulates (“Dust” is used here to cover dust and other finer particulates) from both natural and anthropogenic sources have major implications for human health, agriculture and livestock and the natural environment.
- Several studies have demonstrated that fine particles may contain relatively high concentrations of transition metals implicated to catalyzed the formation of oxygen radical species, increasing the oxidative stress burden and tissue damage.
- Substantial research has been undertaken on aspects of this subject, but an integrated understanding of these materials from an inter-disciplinary point of view is still lacking. It is important for risk assessment studies, quantifying the public health impact of fine-particulate exposure using a multi-disciplinary approach.

Photo by David Fitzpatrick, NYPD