


Airborne particulate matter  
“geotoxicology”:  
public health, policy, and environmental  
security

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Dusts in the Earth System  
Feb. 19, 2010, AAAS 2010 Annual Meeting, San Diego, CA

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Station wildfire, southern California, September, 2009  
Photo by Todd Hoefen, USGS

## Acknowledgements

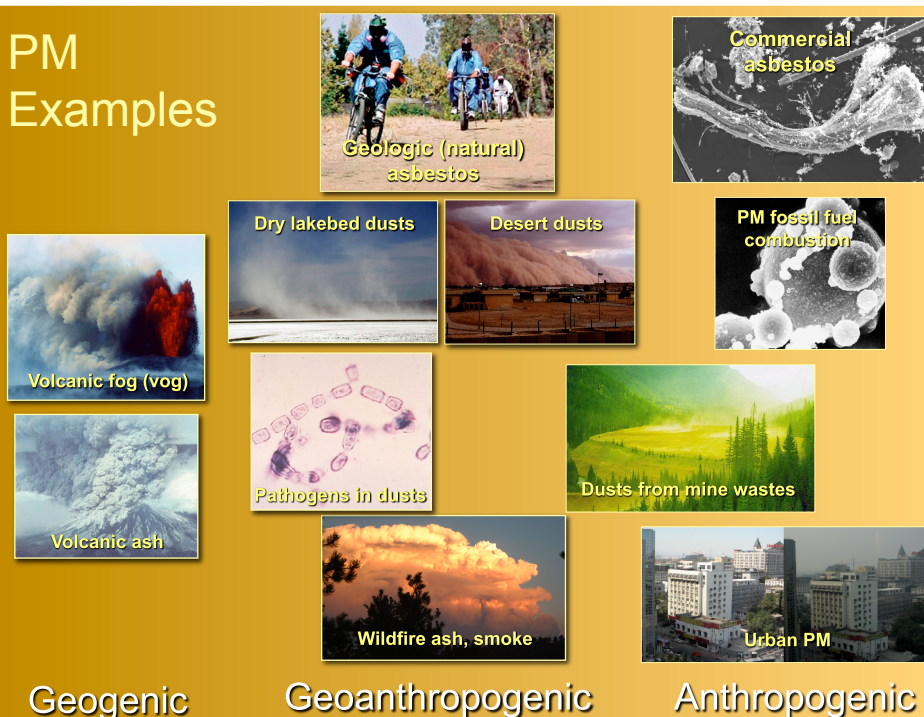
- USGS: Suzette Morman, Greg Meeker, Heather Lowers, Brad Van Gosen, Rich Reynolds, Todd Hoefen, Ray Kokaly, Gregg Swayze, Ginger Garrison, Joe Bunnell, George Breit, Monique Adams, Paul Lamothe, Harland Goldstein, Marith Reheis, Robert Fisher
- Many colleagues outside the USGS, including a number from the public health community

## Airborne particulate matter (PM)

- Dusts and other solid and liquid particles that are transported in the atmosphere
- Generated by/from:
  - natural processes/natural sources - “geogenic”
  - natural processes/sources that are modified or enhanced by human activities - “geoanthropogenic”
  - human activities/sources - “anthropogenic”
- PM is of concern for its potential to adversely effect the environment and human health
  - scales from local to intercontinental



### PM Examples





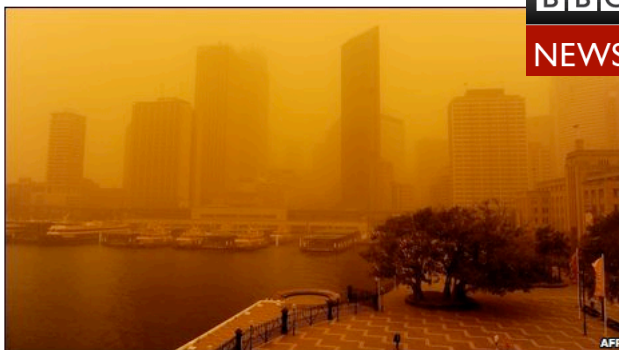
# PM is regularly in the news

What are the actual versus perceived environmental and health effects?

The earth sciences can help



## Sydney dust storm 'like Mars'



Sydney residents woke up to an ethereal scene on Wednesday

A storm which blew in from the Australian outback blanketed Sydney in a layer of orange dust. Here, residents describe the bizarre and frightening scene.

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### Study: Salinas Valley house dust carries pesticides

Pesticide residues found in hundreds of homes

BY DANIEL STRAIN • DSTRAIN@THECALIFORNIAN.COM • FEBRUARY 16, 2010

Comments (13) Recommend Print this page E-mail this article Share Type Size A A A

1 | 2 Next Page

Dust in many Salinas Valley homes carries traces of pesticides, a recent study reported.

In the largest study of its kind, researchers searched hundreds of local homes for tiny pesticide compounds sticking to dust layers and discovered widespread residues of 22 private and agricultural-use products.

The study was conducted by an investigator from the state Department of Public Health and researchers with the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) with the University of California, Berkeley.

Related Topics

- Places - Berkeley, CA, Salinas, CA
- Science/Technology - Entomology, Agriculture, Science

Contextual linking provided by Topix



Voice of the Rocky Mountain Empire

# THE DENVER POST

WEDNESDAY, SEPTEMBER 2, 2009 HAZY & 88° W 55° N 128° DENVERPOST.COM • © THE DENVER POST • 75 CENTS PRICE MAY VARY OUTSIDE METRO DENVER

**dp Online»** View historical highlights from the CU-CSU football series. » [denverpost.com/photos](http://denverpost.com/photos)

## L.A. fire colors Colorado


Western blazes fill sky with smoke and haze, obscuring Denver's mountain view



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### Veterans speak out against burn pits

A range of health problems are linked to the pits on military bases in Iraq and Afghanistan. Toxic substances have been found in the smoke.



A military environmental agency that tested air samples from Balad in 2007 found dioxins, metals, volatile organic compounds and other toxic substances in the smoke. (U.S. Air Force)

**Los Angeles Times** By David Zucchino  
February 18, 2010

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**Burn pits**

The noxious smoke plumes that wafted over the military base in Balad, Iraq, alarmed Lt. Col. Michelle Franco. The stench from a huge burn pit clung to her clothing, skin and hair.

"I remember thinking: This doesn't look good, smell good or taste good," Franco said recently. "I knew it couldn't be good for anybody."

She wheezed and coughed constantly. When Franco returned to the U.S., she was diagnosed with reactive airway dysfunction syndrome. She is no longer able to serve as an Air Force nurse.

**STORIES**

-  **Burn pits**
-  **Nerves on a hair trigger in Marine patrol**
- Taliban leader's arrest hinged on U.S. information**
- Top Afghan Taliban commander captured**
-  **Marines in Afghanistan inch forward against Taliban**

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## Potential acute and chronic health effects of PM

- Increased respiratory problems such as asthma, allergies
- Cardiovascular problems—increased risk of heart attack, stroke, due to inflammation of lungs, increased blood clotting
- Physical or chemical irritation of respiratory and gastrointestinal (GI) tracts, eyes
- Diseases from contained pathogens (Valley Fever, anthrax, etc.)



## Potential health effects of PM

- Pneumoconioses
  - fibrotic diseases of the lungs such as silicosis, asbestosis, coal workers' pneumoconiosis
  - secondary congestive heart failure, increased susceptibility to pathogens (i.e., tuberculosis)
- Lung cancer; mesothelioma; possible laryngeal, GI cancers; others?
- Toxicity from uptake of bioaccessible heavy metals, organic chemicals



## Toxicity effects of PM depend on

- Exposure pathway (ingestion, inhalation, dermal, ocular)
- Intensity and duration of exposure (dose)
- Personal factors
  - Age
  - Genetics
  - Smoker or non-smoker?
  - General health/nutritional status
- Particle characteristics (mineralogical, chemical, physical)
  - See summaries:
    - Plumlee et al., 2006, Rev. Min. Geoch., v. 64, chapter 2
    - Plumlee et al., 2007, Treatise on Geochemistry, online version, vol. 9, Chapter 7



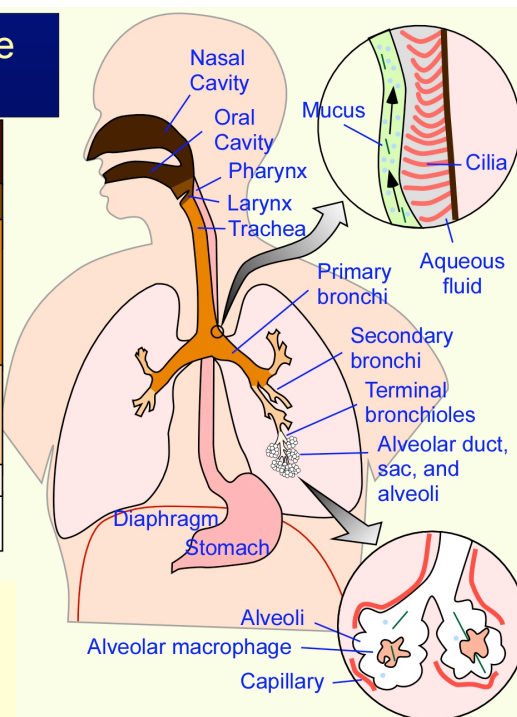
## Particle size / shape play a role

Approximate particle size deposition in respiratory tract during nasal breathing (microns).

7-10
5-7
3-5
2-3
1.0-2.5
0.5-1.0

Coarser particles can reach deeper into respiratory tract if oral breathing

Particles cleared from the respiratory tract by mucociliary action are either expectorated or swallowed





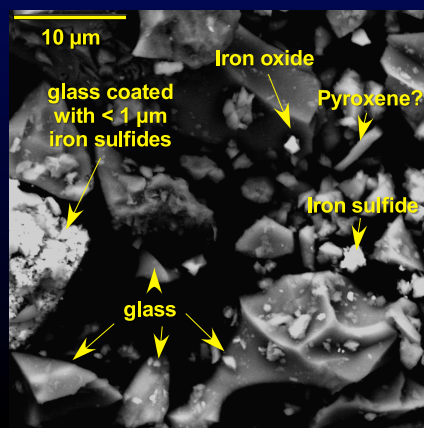
## PM in a biodurability, biosolubility and bioreactivity context

- **Biosolubility, bioaccessibility** – Some particles are soluble in the body's fluids and can readily release their contained toxicants
- **Bioreactivity** – Some PM can react with the body's fluids and tissues to cause adverse chemical consequences
  - **Acute** (ie caustic tissue damage) versus **chronic** (ie oxidative stress)
- **Biodurability** – PM that are biodurable (insoluble) can persist in the body for years



## PM in a biosolubility and bioreactivity context

- Many PM types are complex mixtures of biodurable, biosoluble, and/or bioreactive particles



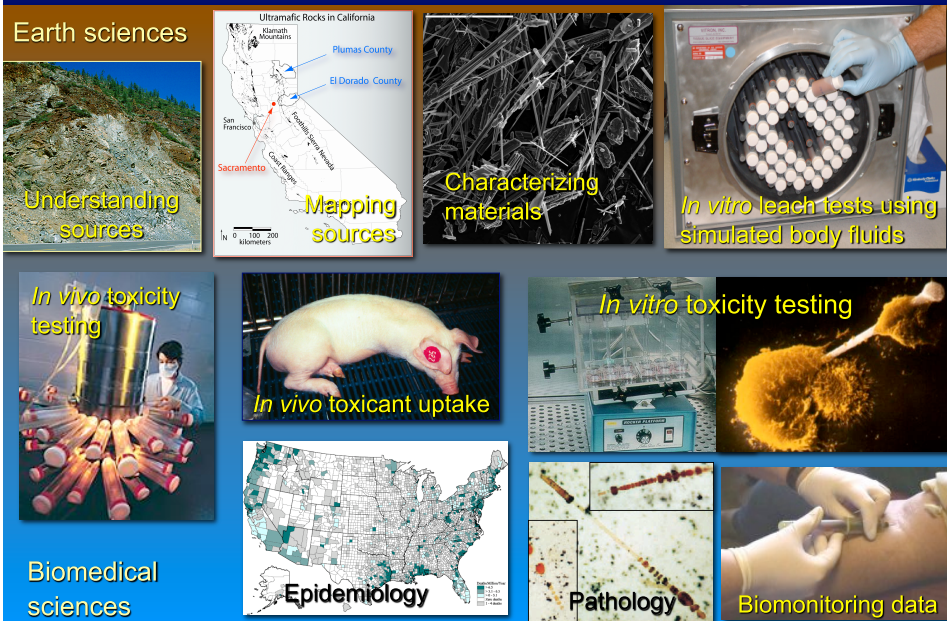
Volcanic ash

# Geotoxicology

- The study of the toxicological characteristics and potential health effects of earth materials such as geogenic and geoanthropogenic PM.
- Best accomplished collaboratively by earth and health scientists



## Interdisciplinary geotoxicology methods used to study the potential health effects of PM and other earth materials



## Urban particulate matter

- A complex mixture of materials from many natural and anthropogenic sources
  - Natural dust, pollen, other plant and animal matter
  - Combustion byproducts
    - autos, coal, fuel oil
  - Material abraded from tires, brake pads, tire weights, paint
  - Building dust and debris
  - Many others..

1970's urban particulate, Washington DC

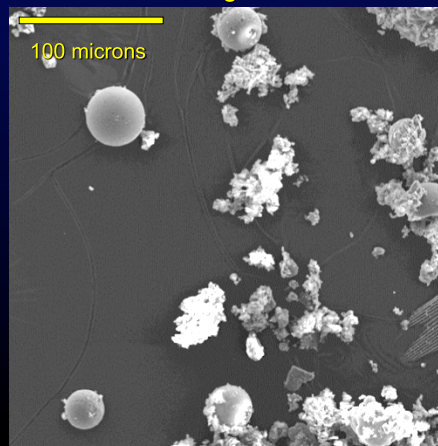


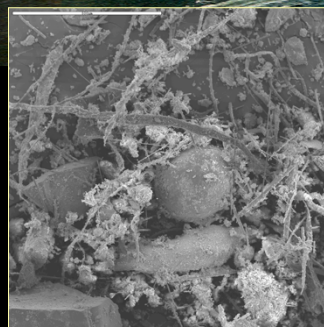
Photo by David Fitzpatrick, NYPD - Printed in Newsweek, 9-11-2002



### Dusts generated by the collapse of the World Trade Center towers, 9/11/2001

<http://pubs.usgs.gov/of/2001/ofr-01-0429/>

4 USGS papers in American Chemical Society, 2005, Symposium Series 919, *Urban Aerosols and Their Impacts: Lessons Learned from the World Trade Center Tragedy*, Gaffney and Marley, eds.





## Evolving health concerns about asbestos

seattlepi Special Reports

Local Nation/World Business Sports A&E Life Comics

### A town left to die

Thursday, November 18, 1999

By ANDREW SCHNEIDER

SEATTLE POST-INTELLIGENCER SENIOR NATIONAL CORRESPONDENT

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LIBBY, Mont. — First, it killed some miners.

Then it killed wives and children, slipping into their homes on the dusty clothing of hard-working men.

Now the mine is closed, but in Libby, the killing goes on.

The W.R. Grace Co. knew, from the time it bought the Zonolite vermiculite mine in 1963, why the people in Libby were dying.

But for the 30 years it owned the mine, the company did not stop it.

Neither did the governments.

Not the town of Libby, not Lincoln County. Not the state of Montana, not federal mining, health and environmental agencies, not anyone else charged with protecting the public health.

Here is what is killing people in Libby:

Along with the enormous deposits of vermiculite in the earth of nearby Zonolite Mountain are millions of tons of tremolite, a rare and exceedingly toxic form of asbestos.



#### HEALTH

### ASBESTOS IN THE AIR

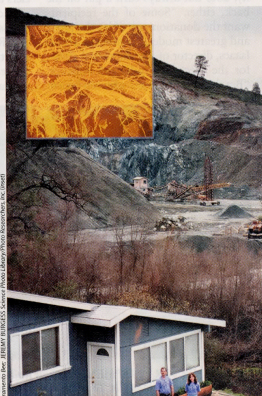
A housing boom stirs up natural asbestos in California

#### Science (2000)

There's a new gold rush in California's Sierra Nevada foothills—a rush to build homes. Tens of thousands of new residences have been approved for the area recently, and every day heavy machines carve out another future front yard. But the building boom that is transforming the once rural western part of El Dorado County into a suburb of Sacramento has also unearthed a health hazard: asbestos. Although government agencies say the area is safe, citizens and environmental experts argue that the agencies may be vastly underestimating the risk. A known human carcinogen, asbestos is highly regulated in buildings. For instance, building waste that contains more than 1 percent asbestos is considered hazardous waste. Yet exposure to naturally occurring asbestos is largely unregulated. "Just 1 percent is hazardous waste, but it's supposed to be okay for people to live on a 90 percent deposit," complains Lance McMahon, a civil engineer and hazardous-waste site manager who recently moved out of the area because he believes that the health risk is unacceptable. The issues confronting El Do-

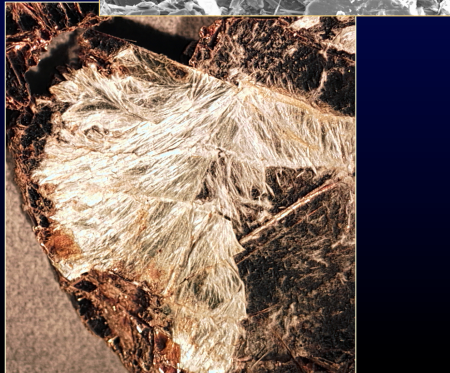
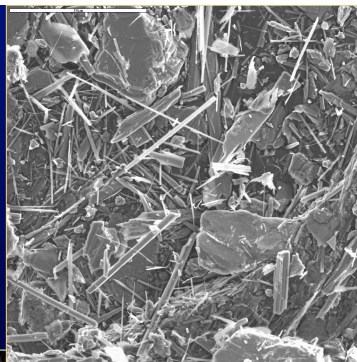
dug up and used to cover unpaved roads or when new homes are cut into the hillsides, asbestos fibers get into the air. Combine these activities with a rapidly growing population—expected to double to 225,000 by 2018—and the potential for disease becomes real. Of particular concern is mesothelioma, a fatal cancer of the membranes lining the chest, which has been linked to tremolite exposure.

Naturally occurring asbestos is supposed to be a local planning issue, state and federal officials say. Unfortunately, El Dorado County has historically ignored or denied the issue, according to recently elected county supervisor W.



### Libby, Montana

- Fibrous and asbestiform amphiboles are common trace minerals in the vermiculite mined at Libby
- Many of the amphibole fibers do not fit the standard regulatory definitions of asbestos, either compositionally or morphologically
  - Do these fibers contribute to toxicity?



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## El Dorado County, California

- Concerns about potential exposure to natural chrysotile and tremolite asbestos contained within two types of rocks underlying areas of rapid population growth and development



Figure 1: Contractor in protective gear simulates baseball activity

### News ASBESTOS

RELATED INFO

#### Foothills growing despite asbestos

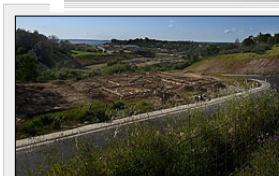
El Dorado County plans stronger rules to control dust but may build for 80,000 new residents.

By Mary Lynne Vellinga -- Bee Staff Writer  
Published 2:15 am PDT Sunday, May 8, 2005

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As El Dorado County's leaders search for ways to protect the populace from exposure to the region's naturally occurring asbestos, one option is not being considered: stopping the large-scale development that churned up the cancer-causing fibers in the first place.

sacbee PressClub MEMBER  
The Online Division of The Sacramento Bee



Housing takes shape in El Dorado Hills, where the bulldozing, grading and blasting of rocky areas can release toxic asbestos fibers into the air. A recent Environmental Protection Agency study warned that levels of the cancer-causing fibers were raised by everyday activities in the area.

• [See additional images](#)

Sacramento Bee/Carl Costas

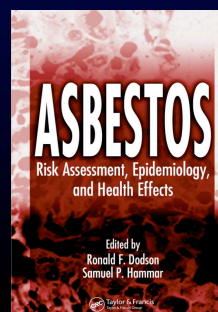
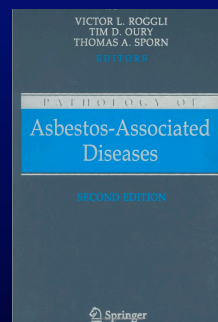


### U.S. EPA Asbestos Assessment for El Dorado Hills

U.S. ENVIRONMENTAL PROTECTION AGENCY • REGION 9 • SAN FRANCISCO, CALIFORNIA • MAY 2005

## Many aspects of asbestos toxicity are still debated

- Toxicity of fibers that do not meet standard definitions of "asbestos"
- Relative toxicity of different asbestos mineral types with geologically variable composition, accessory minerals, and biosolubility?
- Relative toxicity of short versus long fibers?
- Toxicity of **abundant** acicular crystals or **abundant** elongated cleavage fragments broken from prismatic or blocky crystals?
- Health risks of exposures to natural occurrences of asbestos (NOA)?
- Increased collaboration needed between earth and health sciences



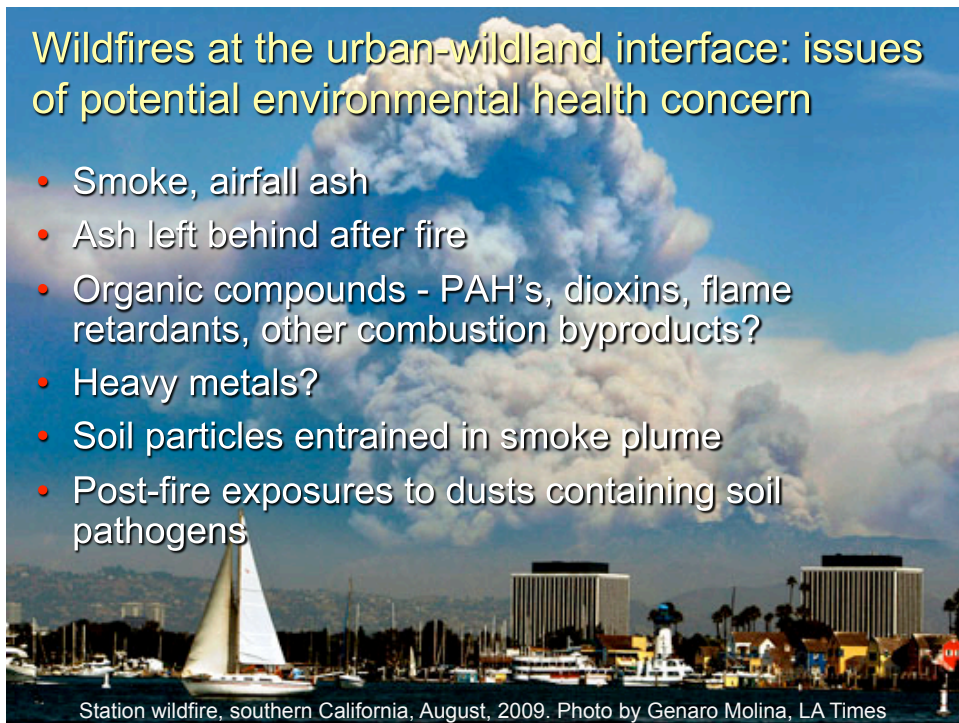
## Wildfires at the urban-wildland interface

Station wildfire, southern CA, Sept. 2010, photo by NASA/JPL?



## Wildfires at the urban-wildland interface: issues of potential environmental health concern

- Smoke, airfall ash
- Ash left behind after fire
- Organic compounds - PAH's, dioxins, flame retardants, other combustion byproducts?
- Heavy metals?
- Soil particles entrained in smoke plume
- Post-fire exposures to dusts containing soil pathogens



Station wildfire, southern California, August, 2009. Photo by Genaro Molina, LA Times



## Human health concerns

- Impacts of wildfire smoke, airfall ash on firefighters, general public

Photo by Nicole Lazar  
<http://www.flickr.com/photos/kpbs/1731836688/>



**Health**

Home > Health

**Firefighters' Health: Up in Smoke?**

Use of Firefighter Safety Equipment Impractical, Leading to Lung and Heart Risks

**abc NEWS**  
start here

**Your Opinion**

**Comment & Contribute**

**WHAT OTHERS ARE SAYING** 4 Comments

I hope there is a way to protect these firefighters...  
 winterlady7 Oct-28

Yes, definitely. I was a fire fighter for 15 years...  
 Firelit199 Oct-24

People who work in windowless buildings at...  
 MickfromMD Oct-24

**COMMENT**

**Post Video**

Firefighters from the U.S. Forest Service run back to safety as flames and smoke reverse on them as they try to protect homes and prevent flames from the Harris Fire from advancing in Jamul in California's San Diego County early Oct. 24, 2007. Wildfires in Southern California have forced nearly 1 million people to flee their homes. (Robyn Beck, AFP/Getty Images)

By RAJA JAGADEESAN, M.D. and DAN CHILDS  
 ABC News Medical Unit  
 Oct. 24, 2007

## WILDFIRES THREATEN RESPIRATORY HEALTH

**PULMONARYREVIEWS.COM**  
 Trends in pulmonary and critical care medicine

**SAN FRANCISCO**—Although many of the pollution sources now recognized as threats to respiratory health arose during or after the Industrial Revolution, some are much older: Vegetation burned either in wildfires or in the household for cooking or heating can significantly contribute to respiratory disease. In a session at the American Thoracic Society 97th International Conference, researchers gathered to review the epidemiology and biology of smoke's effects on respiratory health, as well as possible strategies for mitigation.

Smoke, ash health effects can extend great distances downwind



Voice of the Rocky Mountain Empire

**THE DENVER POST**

WEDNESDAY, SEPTEMBER 2, 2009 HAZY • 88° • 55" • 128 • DENVERPOST.COM • © THE DENVER POST • 75 CENTS PRICE MAY VARY OUTSIDE DENVER

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**L.A. fire colors Colorado**

Western blazes fill sky with smoke and haze, obscuring Denver's mountain view

**Cops risk layoffs, Hick says**

Denver's mayor says officers' rejection of deferred pay raises will result in "a large number" being let go.

By Christopher N. Osher  
 The Denver Post

Denver police officers' rejection of deferred pay raises will bring "a large number" of layoffs to their ranks and likely a restructuring of the force to ensure their street presence isn't diminished, Mayor John Hickmole said Tuesday.

To meet that end, the city could re-deploy officers to desk jobs, he said.

"In the present situation, we're going to have a reduction in the size of the force if there's not some sort of change or we can't come up with some sort of compromise," Hickmole said.

"Again, the door is always open. But now we must look at it and say, 'How can we make sure we have the same number of police on the streets?'"

He added: "Where are officers in desk jobs, and how can we redeploy our force?"

Chief Gerry Whitman, through a

## Human health concerns

- Exposure to disturbed ash following fire

San Diego News

10NEWS.com

### Experts: Ash From Wildfires Remain In San Diego Air

POSTED: 5:57 pm PST November 5, 2007  
UPDATED: 7:02 am PST November 6, 2007



**SAN DIEGO --** When the fires raged on the ground, ash and smoke gathered in the air.

Building materials, plastics, chemicals, and electronics – those are some of the harmful substances that burned up and polluted the air San Diegans breathe.

Local lung experts told 10News that when the smoke clears there are lingering hazards, even now.

Kaiser pulmonary specialist Dr. David Levine said, "The air quality is still not going to be good for several weeks and people still need to be concerned."

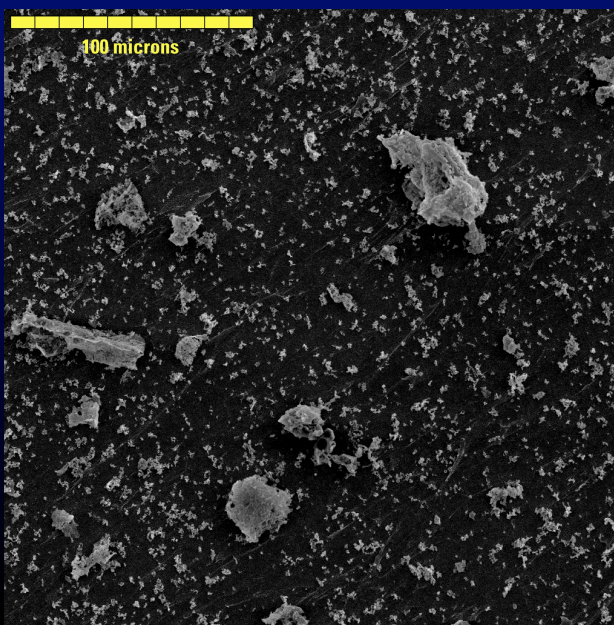
Minute particles that remain in the air, or get stirred up by winds, are the chief danger, experts said.



## Ash particle characteristics

White ash contains a high proportion of inhalable ( $< 10\text{-}20$  microns) to respirable ( $< 2.5\text{-}5$  microns) particles

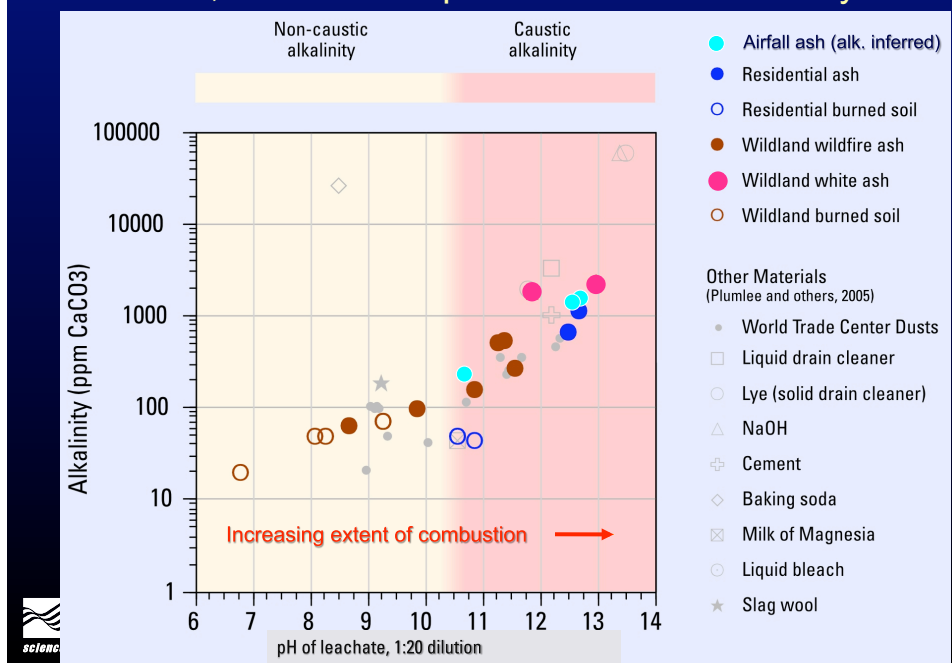
Most particles are ingestible via incidental hand to mouth contact ( $< 250$  microns)



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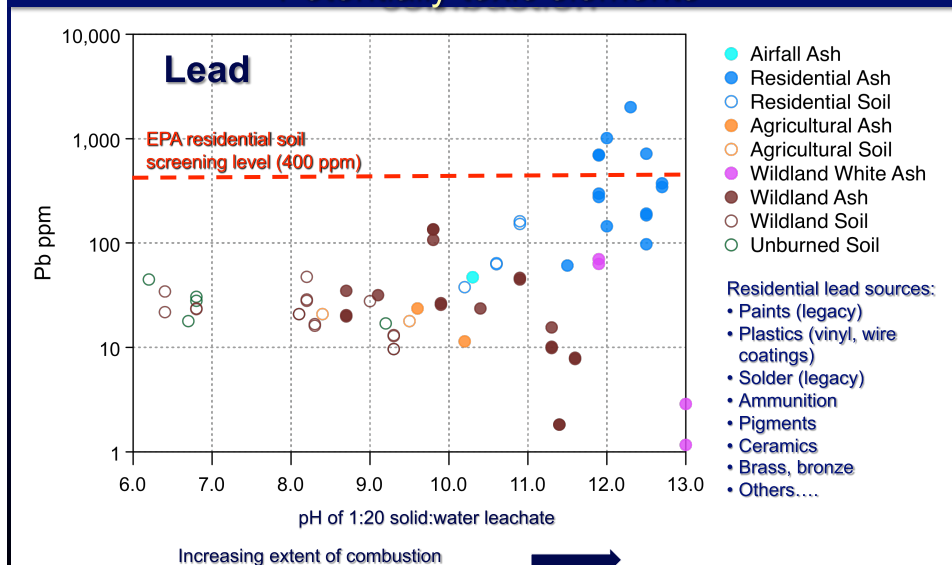


## Airfall, residual ash produce caustic alkalinity



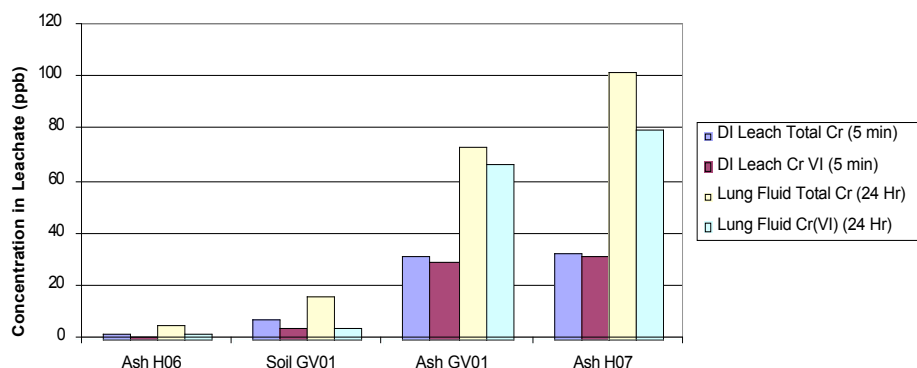
## Bulk chemical composition vs. extent of combustion

### Potentially toxic elements



## Hexavalent chromium is present in residential ash

- Somewhat soluble in water leaches
- Somewhat bioaccessible and persistent in simulated lung fluid leaches
- Wolf, Ruth E., Morman, Suzette A., **Plumlee, Geoffrey S.**, Hageman, Philip L., and Adams, Monique, 2008, Release of hexavalent chromium by ash and soils in wildfire-impacted areas: U.S. Geological Survey Open-File Report 2008-1345, 22 p., <http://pubs.usgs.gov/of/2008/1345/>.



## Valley Fever and wildfire-burned areas?

**CaliforniaHealthline**  
The Daily Digest of News, Policy & Opinion

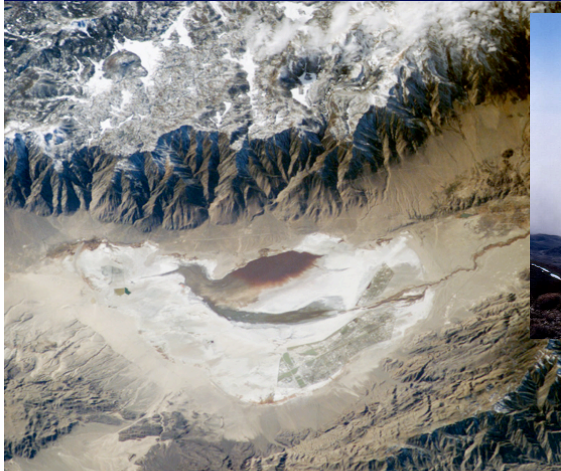
**March 26, 2004**

**Valley Fever Cases Increase in Southern California Following Wildfires**

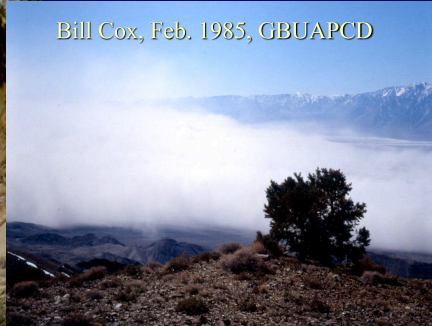
Ventura County has seen a "spike" in cases of valley fever – a flu-like illness caused by airborne fungus – since last fall's wildfires, the *Los Angeles Times* reports. According to Dr. Robert Levin, county public health officer, the fires destroyed vegetation and ground cover in the area, exposing soil that contains fungal spores that can be transmitted by dust particles in the wind. Since October, more than 70 cases of valley fever, or coccidioidomycosis, have been reported in Ventura County, two-thirds of which were in the eastern part of the county where the Simi fire destroyed more than 108,000 acres. Normally, the county sees about two cases of valley fever per month. About 60% of people who contract the disease do not have symptoms, but those who become ill can experience fever, respiratory problems, coughs, headaches, muscle aches and

## Recently dried or drying lakes

- Are a major global issue
- Water loss as a result of human water consumption and, in some cases, drought



Bill Cox, Feb. 1985, GBUAPCD



Owens Lake,  
California, USA

## Dusts from dry lake beds - a potential health concern



**BBC NEWS**

You are in: World: Asia-Pacific  
Friday, 18 February, 2000, 13:41 GMT

**Aral Sea poison dust danger**

**By Central Asia correspondent Louise Hidalgo**

Researchers have discovered that contaminated dust from the Aral Sea has blown hundreds of kilometres across Central Asia, raising new concerns about the consequences for human health.

The study, by a team from the UK, found that some of the highest deposits from the old Aral seabed are in southern Turkmenistan, far away from the epicentre of what's been described as the world's worst man-made environmental disaster.

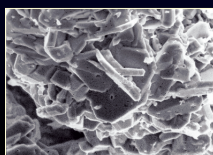
A ship stranded by the receding Aral Sea

## Toxicants in playas or dry lake beds?

- A variety of elements, especially those that are geochemically mobile in alkaline waters, can be enriched in the lake waters and the lake bed sediments and efflorescent salts

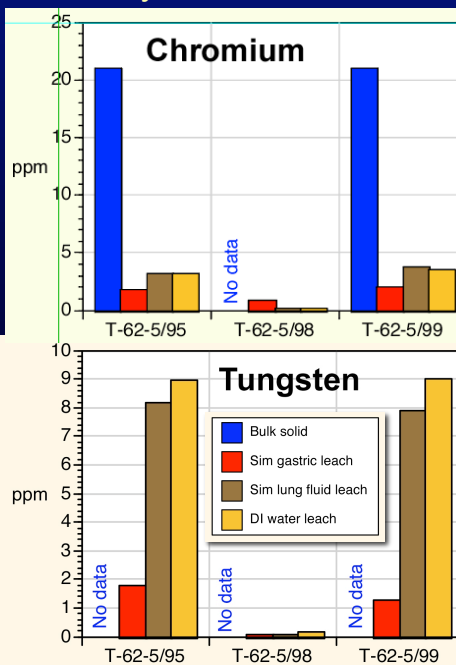
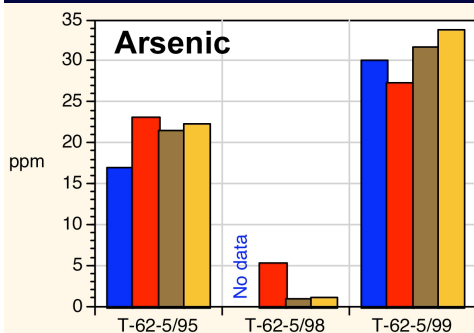
B, As, Al, Cr, Cd, U, V, W, Pb, Zn, Sb, Mo, .....

- Pesticides, fertilizers
- Toxicants taken up by evaporative efflorescent salts are stored in soluble, possibly bioaccessible form?
- The efflorescent salts are readily wind-borne



## Potential human health effects of dry lake bed dusts?

- Physiologically based extraction tests with simulated body fluids indicate that dry lake dusts (plots shown for dusts from Owens Lake, CA) can have quite high levels of bioaccessible metalloids





## Military exposures to PM



### Veterans speak out against burn pits

A range of health problems are linked to the pits on military bases in Iraq and Afghanistan. Toxic substances have been found in the smoke.



A military environmental agency that tested air samples from Balad in 2007 found dioxins, metals, volatile organic compounds and other toxic substances in the smoke. (U.S. Air Force)

### Los Angeles Times

By David Zucchino  
February 18, 2010



Burn pits



Nerves on a hair trigger in Marine patrol

Taliban leader's arrest hinged on U.S. information

STORIES  
Top Afghan Taliban commander captured



Marines in Afghanistan inch forward against Taliban

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The noxious smoke plumes that wafted over the military base in Balad, Iraq, alarmed Lt. Col. Michelle Franco. The stench from a huge burn pit clung to her clothing, skin and hair.

"I remember thinking: This doesn't look good, smell good or taste good," Franco said recently. "I knew it couldn't be good for anybody."

She wheezed and coughed constantly. When Franco returned to the U.S., she was diagnosed with reactive airway dysfunction syndrome. She is no longer able to serve as an Air Force nurse.

## Exposures to geogenic, geoanthropogenic PM should also be evaluated



© Reuters

Kandahar Airbase, Afghanistan 7-14-06

Photo by Jared Abraham, USGS

Samples of settled dust were collected and analyzed as part of ground truthing for a remote sensing study of Afghanistan

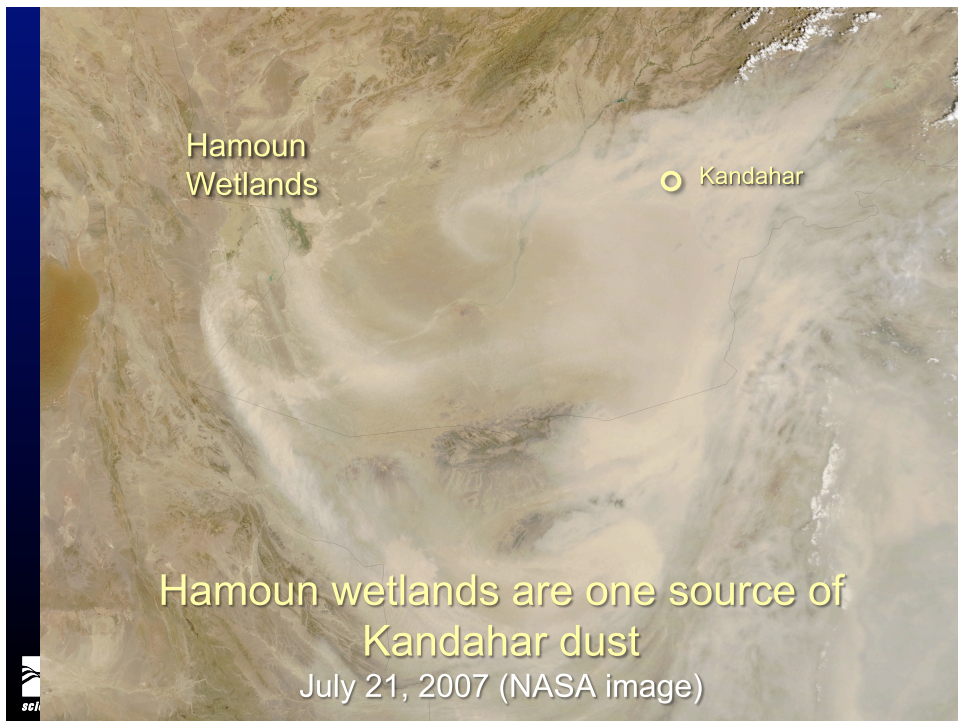


Hamoun  
Wetlands

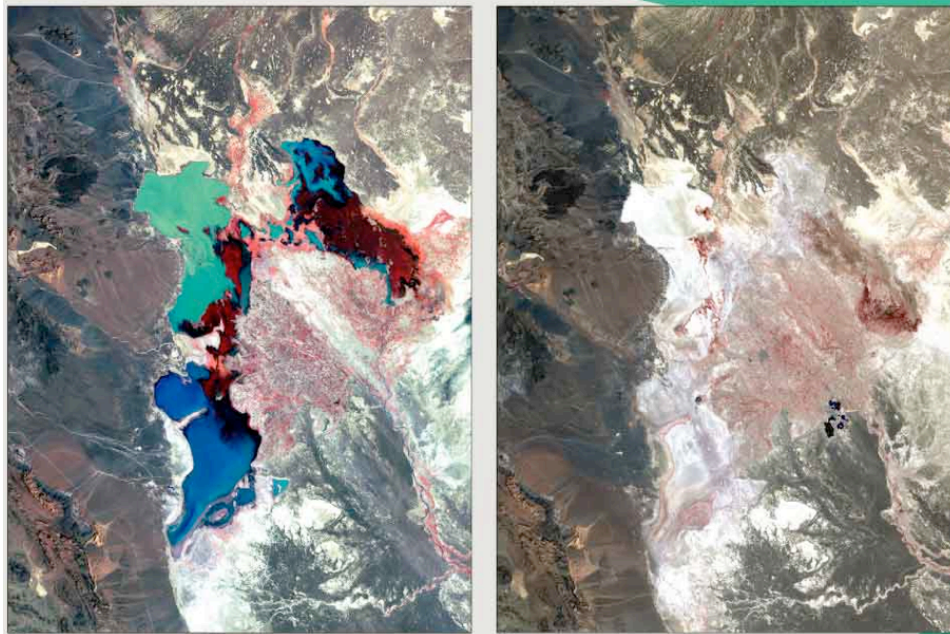
Kandahar

Hamoun wetlands are one source of  
Kandahar dust

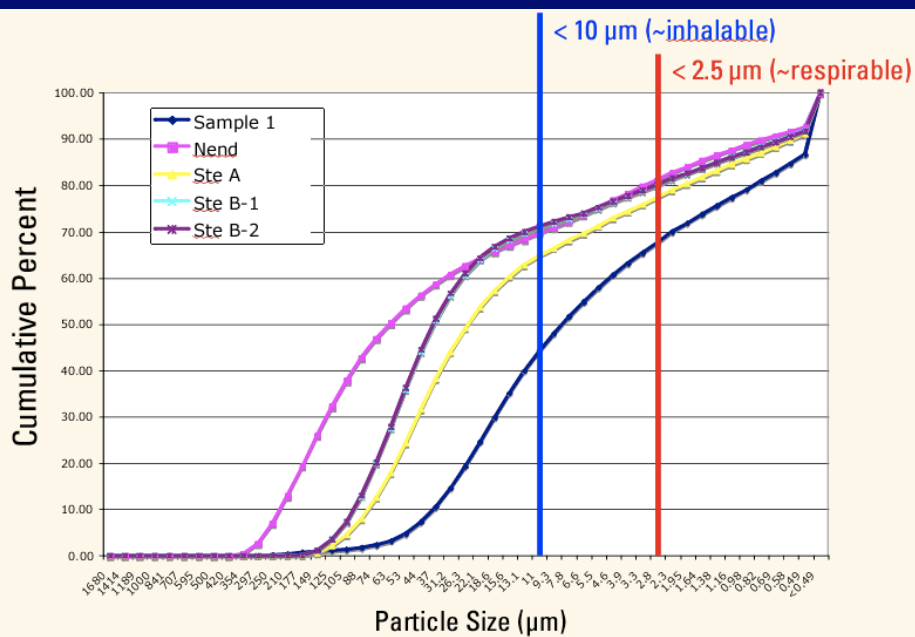
July 21, 2007 (NASA image)



Hamoun wetlands, 1976 (L), 2001 (R)  
 ([http://www.grid.unep.ch/activities/global\\_change/sistan/poster.jpg](http://www.grid.unep.ch/activities/global_change/sistan/poster.jpg))

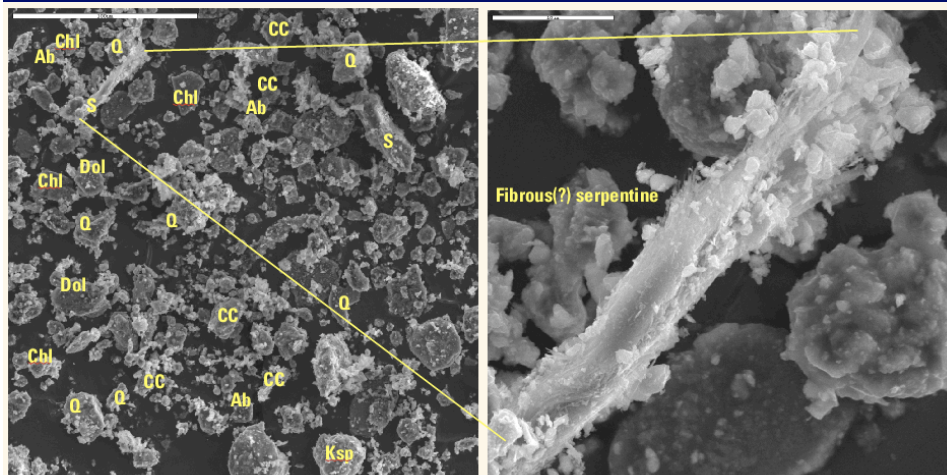


## Kandahar settled dust



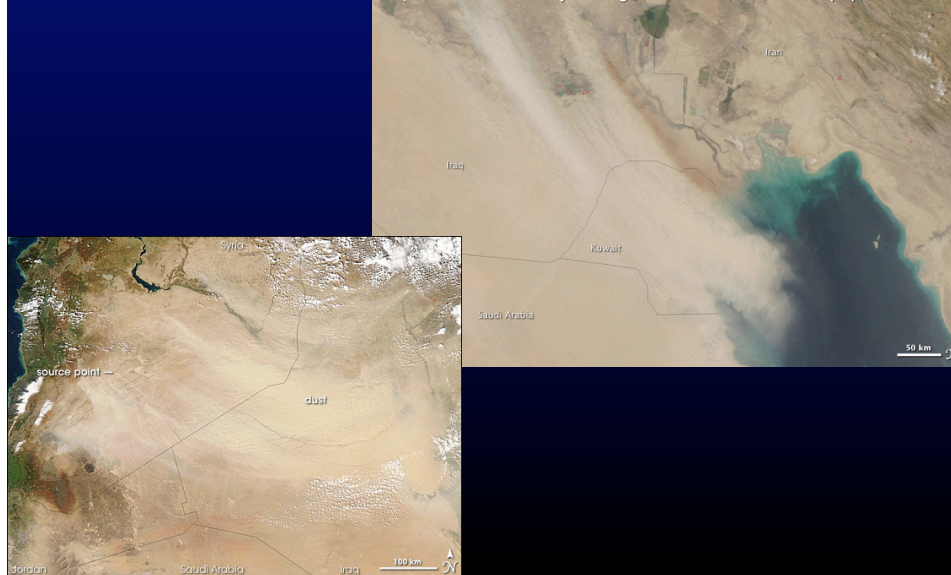


## Kandahar settled dust



## Multiple geogenic and geoanthropogenic sources of dust create a complex mix of exposures

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=39839>



## Regional impacts of dust?

### Opinions differ on cause of UAE dust

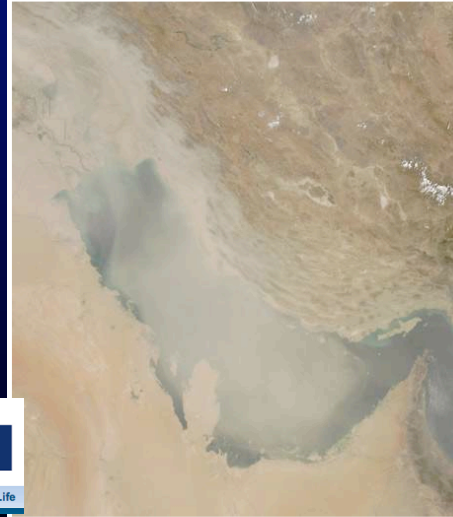
Matt Kwong and Vesela Todorova

Last Updated: August 04, 2009 4:51PM UAE / August 4, 2009 12:51PM GMT

Tuesday, February 08, 2010 | Abu Dhabi 13 °C

# TheNational

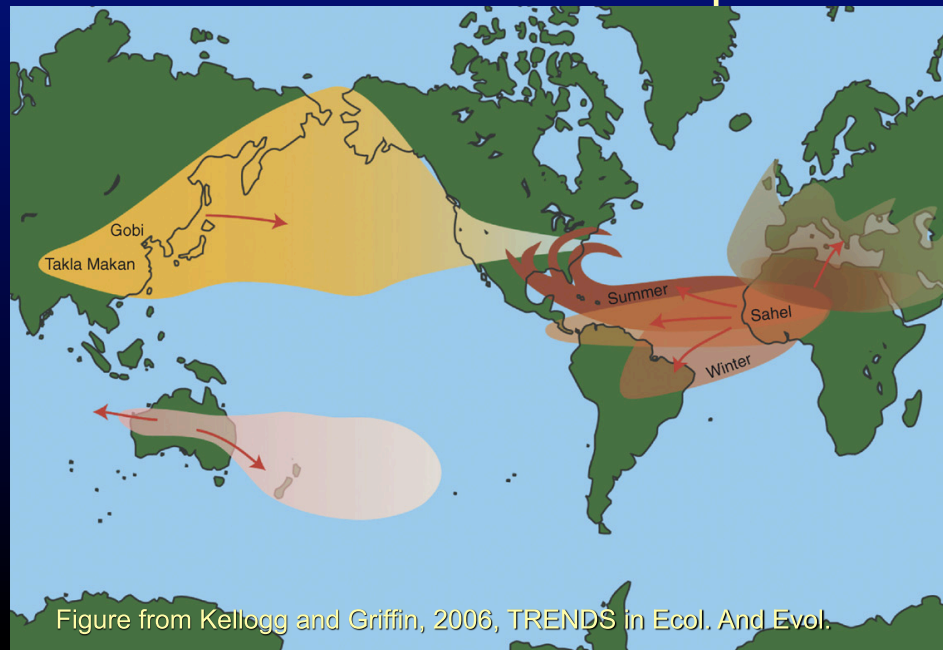
Home UAE World Business Opinion Sport Arts Life



Nasa's satellite picture shows the dust storm moving south-east towards the UAE from Iraq. *Nasa and Karim Kadim / AP Photo*

This is the dust cloud that has been blighting the UAE, as seen from space. The image was captured 700km away by a Nasa satellite, Terra. It shows an enormous concentration of dust heading towards the UAE from Iraq on Friday.

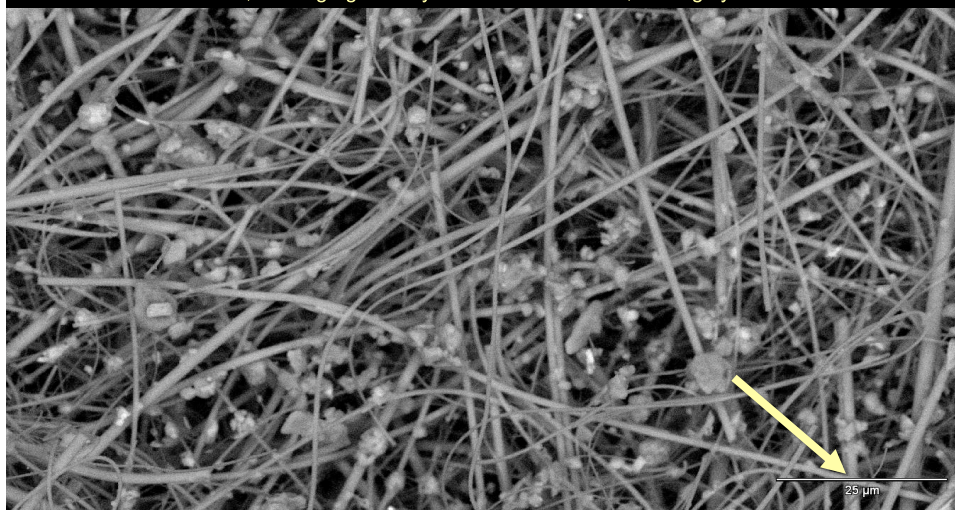
## Intercontinental dust transport





Scanning electron photomicrograph of quartz fiber filter with trapped dust particles from Africa, collected in US Virgin Islands  
Suzette Morman, Ginger Garrison, Heather Lowers unpub. data

- Majority of particles are respirable ( $<3$  microns),
- Largely geogenic dusts: Clays (smectite, kaolinite and illite), quartz, iron oxide, feldspar, dolomite, sodium sulfate, gypsum, calcite, titanium dioxide
- Metals and metalloids, although generally low in concentration, are highly bioaccessible



## Summary

- There are many different types of PM
  - Spectrum from natural (geogenic) to anthropogenic
- PM is at the core of diverse policy issues that link
  - Air quality, workplace safety, public health, and environmental security
  - At scales from local to global
- Earth science characterization methods can help public health experts better understand the types, sources, and potential toxicity of PM and better evaluate the potential risks posed by PM from diverse sources (ie, the exposure and the dose)

## Summary

- There are significant and growing opportunities for collaboration between the earth and health science communities to study the environmental and health effects of earth materials such as PM