Compelling stories of transdisciplinary science at the intersection of environment and global health

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- Environmental geochemist
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Widespread Mercury Contamination Across Western North America

Mercury contamination is widespread, at various levels across western North America in air, soil, sediment, plants, fish and wildlife.

We provide science about the natural hazards that threaten lives and livelihoods; the water, energy, minerals, and other natural resources we rely on; the health of our ecosystems and environment; and the impacts of climate and land-use change. Our scientists develop new methods and tools to supply timely, relevant, and useful information about the Earth and its processes.
One Health

The recognition that there are direct relationships among the quality of the environment, the health of wildlife and other organisms, and human health.
USGS Environmental Health Science

- Transdisciplinary science that helps understand how the Earth and the environment influence toxicologic and infectious diseases in humans and other organisms.
- We collaborate extensively with colleagues from the health sciences.
Some compelling stories at the intersection of environment and health

- Environmental and health impacts of large scale mining Marinduque Island, Philippines
- Lead poisoning and artisanal mining
- Lead poisoning from imported folk cosmetics and remedies
- Deployment related respiratory disease
- Environmental and health implications of contaminants produced by disasters
- Vector-borne diseases, the environment, and contaminants
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- CP David, Hugh Miller, Mark Logsdon,…..
An independent U.S. interagency assessment of mining-related engineering, environmental, and health issues, Marinduque Island, Philippines
Pre-2000 events

CMI waste dump, causeway

1993 debris flow

1996 Tailings spill

1996 Dredge Channel

Calancan Bay, ca. ~1987

Photo by Catherine Coumans

Tapian Pit

Marcopper tailings causeway

Tapian Pit

Mogpog River Basin

Butan Sapa

Beboc

San Antonio Pit

Sta. Cruz

Boac River Basin

Makulapnit River

Ogbac

Hinapulan

Boac River

Marcopper

Boac

Boton

Lusok

Botilao

Tapian Pit
dams

Makulapnit

Tapian Pit

1993 debris flow

1996 Tailings spill
US Independent Team 2000 visit
2003 site visits, limited field sampling for verification data
Human and ecological health concerns
Were lead and arsenic poisoning linked to mining on Marinduque?

Calancan Bay, Marcopper tailings causeway, 2003
Reporting out

A costly exercise against environmental justice
Linking geology and health to help understand a fatal lead poisoning outbreak from artisanal gold mining and processing in Nigeria
In 2010, Doctors Without Borders (MSF) discovered the outbreak of lead poisoning, which has killed ~700 children under 5 years old, and that left several thousands of others permanently disabled.
CDC involvement

May, 2010 – CDC deployed a Response Team to Dareta and Yargalma (2 most heavily affected villages)

- With Terragraphics Environmental Engineering (TG), Nigerian Federal and State public health officials
- Extensive household surveys regarding extent of ore processing
- Handheld XRF of soil
- Field, lab analyses of blood lead (up to ~400 µg/dL), blood manganese (up to 41 µg/L)
Mining

Photos by Jim Durant, Antonio Neri, Carrie Dooyema, Casey Bartrem, Ian Von Lindern
Ore grinding with flour mills – a recent development

Ore crushing
Ore grinding with flour mills – a recent development

CDC photos
Antonio Neri, James Durant
Ore stored between processing steps in repurposed flour bags

CDC photos
Antonio Neri, James Durant
Washing, Sluicing
Amalgamation
Geology is an underlying contributor to the crisis.

Natural weathering prior to mining transformed minimally bioaccessible lead sulfides to highly bioaccessible lead carbonates.

Primary lead sulfide (galena)

Unprocessed quartz-rich "Gold ore"

Secondary lead phosphate

Secondary lead sulfate, carbonate
Grinding has caused vast majority of lead-rich particles to be ingestible by hand-mouth transmission (<250 µm). Many are inhalable (<10 µm).
Lead, mercury uptake from grain, herb, spice foodstuffs

- Minimal grain consumption required to exceed FDA young child PTTIL for lead.

Fuzzball of plant fibers, particles from steel grinding plates, and lead particles from ores

The fibers acted like “Swiffers”…
Lead in surface waters, shallow wells

- Shallow wells clearly contaminated by processing
- Highest lead levels likely particulate
- If 1.3 L water consumed per day, 13-26 µg/L lead uptake
- Water uptake subordinate to soil uptake
Dusts abraded from mud bricks made from contaminated soils and used in house construction

- A long-term lead exposure pathway?

Adobe bricks have 8000 ppm lead (XRF)
Other potential health concerns

- Looming lead poisoning crisis for pregnant women, breastfed infants, longer term problems for adult workers?
- Mercury exposures via soils, dusts, waters, foods contaminated as result of amalgamation processing
- Mercury contamination in wetlands, streams may lead to mercury uptake into the food chain
Other potential health concerns

• Manganese, arsenic, and antimony from the processed ores
  – Manganese and lead co-exposures enhance lead toxicity

• Silicosis and related diseases (ie silicotuberculosis)?
Responding to the crisis

- Nigerian government banned organized gold mining, processing efforts in June 2010, ban was lifted in March, 2011
- MSF, Terragraphics, WHO efforts in progress
- MSF, Blacksmith worked with Emirate to move processing outside of 5 villages
- Removed topsoil from the villages
- Chelation therapy in remediated villages
  - 2000+ children
- Education about safe ore processing practices
The problem is getting better in the remediated villages, but is newly occurring in other parts of Nigeria.
Kabwe, Zambia – Ore deposit geology predictably influences potential health concerns

- “Low-sulfide” lead-zinc deposit hosted by carbonate rocks
- ~ 30,000 cases of severe lead poisoning in children living near the mine
- Pre-mining weathering transformed minimally bioaccessible lead sulfide into highly bioaccessible lead carbonate

Artisanal remining – workers bring lead dust home on their clothes

Soils, adobe bricks have extreme lead (G. Krieger photo)

Edible soils in local market made from mine wastes (M. Williams photo)
Lead poisoning from folk cosmetics, remedies

- CDC Centers for Disease Control and Prevention
- Morbidity and Mortality Weekly Report (MMWR)
- Infant Lead Poisoning Associated with Use of Tiro, an Eye Cosmetic from Nigeria — Boston, Massachusetts, 2011
- Weekly
  August 3, 2012 / 61(30);574-576
- Behbod et al., 2012
Lead poisoning from Malaysian folk diaper powder

- Study led by Matt Karwowski, Alan Woolf (Harvard U)
- Simulated gastric, urine bioaccessibility tests by Suzette Morman, USGS
Constrictive Bronchiolitis in Soldiers Returning from Iraq and Afghanistan

Matthew S. King, M.D., Rosana Eisenberg, M.D., John H. Newman, M.D., James J. Tolle, M.D., Frank E. Harrell, Jr., Ph.D., Hui Nian, Ph.D., Mathew Ninan, M.D., Eric S. Lambright, M.D., James R. Sheller, M.D., Joyce E. Johnson, M.D., and Robert F. Miller, M.D.

From the Division of Pulmonary and Critical Care Medicine, Meharry Medical College (M.S.K.); the Departments of Pathology (R.E., J.E.J.), Medicine (J.H.N., J.J.T., J.R.S., R.F.M.), and Surgery (E.S.L.), Vanderbilt University Medical Center; and the Department of Biostatistics, Vanderbilt University School of Medicine (F.E.H., H.N.) — all in Nashville; and the Department of Surgery, University of Tennessee Health Science Center, Memphis (M.N.). Address reprint requests to Dr. Miller at the Department of Medicine, Vanderbilt University Medical Center, 6134 Medical Center E., Nashville, TN 37232.


ABSTRACT

In this descriptive case series, 80 soldiers from Fort Campbell, Kentucky, with inhalational exposures during service in Iraq and Afghanistan were evaluated for dyspnea on exertion that prevented them from meeting the U.S. Army’s standards for physical fitness.

METHODS

The soldiers underwent extensive evaluation of their medical and exposure history, physical examination, pulmonary-function testing, and high-resolution computed tomography (CT). A total of 49 soldiers underwent thoracoscopic lung biopsy after noninvasive evaluation did not provide an explanation for their symptoms. Data on cardiopulmonary-exercise and pulmonary-function testing were compared with data obtained from historical military control subjects.

RESULTS

Among the soldiers who were referred for evaluation, a history of inhalational exposure to a 2003 sulfur-mine fire in Iraq was common but not universal. Of the 49 soldiers who underwent lung biopsy, all biopsy samples were abnormal, with 38 soldiers having changes that were diagnostic of constrictive bronchiolitis. In the remaining 11 soldiers, diagnoses other than constrictive bronchiolitis that could explain the presenting dyspnea were established. All soldiers with constrictive bronchiolitis had normal results on chest radiography, but about one quarter were found to have mosaic air trapping or centrilobular nodules on chest CT. The results of pulmonary-function and cardiopulmonary-exercise testing were generally within normal population limits but were inferior to those of the military control subjects.

CONCLUSIONS

In 49 previously healthy soldiers with unexplained exertional dyspnea and diminished exercise tolerance after deployment, an analysis of biopsy samples showed diffuse constrictive bronchiolitis, which was possibly associated with inhalational exposure, in 38 soldiers.
Atmospheric particulates (PM) and military operations

Anthropogenic PM

Veterans Sound Alarm Over Burn-Pit Exposure

By JAMES RISEN
Published: August 6, 2010

WASHINGTON — When former Staff Sgt. Susan Clifford was stationed in 2004 and 2005 at Balad Air Base in Iraq, she was assigned to help dump her Army unit’s trash into a massive, open-air pit.

Every conceivable type of waste was piled high in the pit — plastics, batteries, appliances, medicine, dead animals, even human body parts — and burned, with a dosing of jet fuel. A huge black plume of smoke hung over the pit, nearly blinding Ms. Clifford on her twice-a-month visits, and wafted over the entire base.

By 2005, Ms. Clifford, who had been a serious runner, began to cough up phlegm, and soon found it difficult to do any physical training. As her breathing got worse and other symptoms became more serious, doctors discovered that her lungs were filling with fluids.
Anthropogenic PM

- Multiple exposure sources
Geogenic PM: from geologic sources

Geo(anthropo)genic PM: from geologic sources but with human influence/modified

Multi-day exposures to PM from local and some regional sources during windy periods

Western Iraq ‘haboob’, April 2005

Intense exposures to PM from regional and some local sources during dust storms

AP Photo/US Army, Sgt Shannon Arledge

USGS photo, Eric Livo

AP Photo, Misha Japaridze
Deployment-Related Lung Disease

Overview

Since 2001, over 2 million United States military men and women have deployed as part of Operation Iraqi Freedom and Operation Enduring Freedom. In the past few years, evidence has emerged that U.S. military personnel who have deployed to Iraq and Afghanistan may be at increased risk for developing lung symptoms and, in some cases, disabling chronic lung diseases including asthma and constrictive bronchiolitis. The causes of their lung diseases remain unknown, but may be related to exposure to dangerous chemicals and inhalation of small fragments of substances in the Southwest Asia environment.

Exposure Concerns

Military personnel deployed in Southwest Asia are exposed to emissions from:

- open-air burn pits – chemicals, metals, combustion products
- desert dust and sand storms
- industrial fires and emissions
- vehicular exhaust
- IED blasts
- temperature and humidity extremes in the desert climate.
Characterizing mineral matter in biopsied lung tissue samples from deployers, (+) controls, (-) controls
USGS with National Jewish Health, DoD funded

What the earth scientists see

What the pathologists see

Heather Lowers
George Breit
Geoff Plumlee
Greg Meeker
Environmental health implications of contaminants produced by disasters: examples of USGS studies

- World Trade Center collapse
- Ash from many volcanic eruptions
- Mine waste/tailings spills
- Hurricane Katrina
- Indonesian mud volcano eruption
- 2008 Iowa flooding
- Nigeria lead poisoning outbreak
- 2010 Gulf oil spill
- Hungary red mud spill
- Many wildfires at the wildland-urban interface
- Superstorm Sandy
- 2013 Colorado flooding
- 2014 Elk River WV chemical spill
- 2015 Hurricane Joaquin/Nor’easter

Fire Island, NY, damages from Sandy, USGS photo
World Trade Center dusts

Photo by Mark Rushing
World Trade Center dusts

- Gypsum, slag wool, window glass
- Caustic calcium hydroxide from concrete
- Stomach- and or lung-soluble lead (from paint, solder, etc.), antimony (fire retardant), and hexavalent chromium (girder coatings)
- 2-3% chrysotile asbestos from girder coating, spray on textures, old ceiling tiles
- Polynuclear aromatic hydrocarbons, other organic contaminants
- Rainfall neutralized the caustic alkalinity, leached water-soluble gypsum, concentrated the lead in outdoor dusts

*Unique USGS results*
Vector-borne diseases—Zika virus

- Transmitted by the mosquito *Aedes aegypti* from human to human
- Exploits artificial water-filled containers such as tires, buckets, barrels and stray trash for its aquatic life stages (egg, larvae and pupae).

Mitigating Zika?
Mitigating Zika?

Dorchester used an insecticide called Naled which has been used for mosquito control since 1959. Naled may be effective at controlling the populations of mosquitos that carry Zika, but it is also highly toxic to bees.
Summary

• Many complex issues are present at the intersection of environment and global health.

• Transdisciplinary science is essential to help understand, assess, mitigate, and clean up environmental problems that influence health.