National Primary Care Week
October 5-9, 2015

COAL & HEALTH:
PAST, PRESENT, AND FUTURE

Alan H. Lockwood, MD,
Emeritus Professor of Neurology
University at Buffalo
Past President and Co-Chair
Environment and Health Committee
Physicians for Social Responsibility
CME Declarations

- Nothing to declare
- Book royalties donated to PSR
Objectives

- Coal in today’s society
- Health effects of coal’s life cycle: mining, transport, combustion, waste disposal
- Coal and hazardous air pollutants (HAPS)
- $\text{SO}_x$ and $\text{NO}_x$: contributions to heart disease, cancer, respiratory disease, stroke
- Air of the future: $\text{CO}_2$ and ozone
- Climate interventions and “Clean Coal”
Tom Toles, Coal, The Pope: This is Hardball
Air Pollution Damages in 2005
406 Coal Plants: $62 billion

Source: NAS Hidden Costs of Energy, 2009
Coalworkers Pneumoconiosis Fell for years after 1969 law

Source: AS Laney & MD Attfield, Occup Enviorn Med, 2010
As coal production increased, health status worsened and rates of cardiopulmonary disease, lung disease, cardiovascular disease, diabetes and kidney disease worsened.

Example result for COPD: odds ratio and 95% confidence interval

- Less than 4 million tons: 0.969 (0.596 – 1.577)
- More than 4 million tons: 1.559 (1.069 – 2.272)

Coal Transport

- About 70% of all rail traffic is related to coal transport
- Rail accidents are much more common per ton-mile than road traffic
- Diesel locomotives emit particulates that are harmful to health
- Trucks produce particulates from diesel engines and wear and tear of roads

Two Killed in Coal Train Derailment, August 12, 2012
Coal Ash

- We burn about 1 billion tons of coal each year
- This produces about 100 million tons of coal combustion waste
- As pollution control devices become more efficient as mandated by the Clean Air Act, the ash becomes more toxic
- Ash is poorly regulated and often stored under substandard conditions
  - Repositories commonly unlined
  - Heavy metals, e.g., arsenic, leak into water supply

Kingston spill, December 22, 2008

- Dam failed holding back a 84 acre area
- 1.1 billion gallons released
- At dozens of other sites, arsenic and other toxicants have leached into ground water
Air Pollutants

- Criteria Air Pollutants: harmful to health and environment, have National Ambient Air Quality Standards (NAAQS)
  - Carbon Monoxide
  - Lead
  - Nitrogen Dioxide
  - Particulates (10 and 2.5 micron aerodynamic diameter)
  - Ozone
  - Sulfur Dioxide
- Mercury
<table>
<thead>
<tr>
<th>Hazardous Air Pollutants (HAPS) Released by Coal Combustion (from over 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxides of sulfur</td>
</tr>
<tr>
<td>Oxides of nitrogen</td>
</tr>
<tr>
<td>Arsenic</td>
</tr>
<tr>
<td>Beryllium</td>
</tr>
<tr>
<td>Cadmium</td>
</tr>
<tr>
<td>Chromium</td>
</tr>
<tr>
<td>Mercury</td>
</tr>
<tr>
<td>Nickel</td>
</tr>
<tr>
<td>HCl</td>
</tr>
<tr>
<td>HF</td>
</tr>
<tr>
<td>Acreolin</td>
</tr>
<tr>
<td>Dioxins</td>
</tr>
<tr>
<td>Formaldehyde</td>
</tr>
<tr>
<td>Uranium and Thorium</td>
</tr>
</tbody>
</table>

Source: EPA Report to Congress, publication 453/R-98-004a
Leading Causes of Death Due to Disease in Americans

- Heart Disease – leading cause in US – 611,103 in 2013
  - Myocardial Infarct
  - Congestive Heart Failure
  - Fatal Arrhythmia
- Malignant neoplasms – Second leading cause in US, 584,881 deaths in 2013
- Respiratory disease – third leading cause in US – 149,205 in 2013
  - Asthma (esp. kids)
  - Emphysema
  - Bronchitis
  - Cancer

Source: CDC, 2015, 2013 data (most recently available)
Satellite Derived PM$_{2.5}$ Concentration 2001 - 2006

Source: van Donkellar et al., EHP 2010;118:847
PM and Cardiovascular Disease

- Harvard 6 Cities Study: 26% increase mortality in most versus least polluted cities
- ACS Cancer Prevention Study: each 10 µg/m³ increase in PM$_{2.5}$ associated with increases of 4% in all cause and 5% cardiopulmonary mortality
- Other studies: show increases in acute myocardial infarct, defibrillator discharges, myocardial ischemia during stress test

Air Pollution and Stroke

- **Korean Study:** increased ischemic stroke risk with daily increases in suspended particulates and sulfur dioxide, one day lag nitrogen dioxide, and carbon monoxide, and 3 day lag for ozone.

- **Taiwan study:** on warm days (> 20 C) positive association between PM$_{10}$, NO$_2$, SO$_2$, CO, and O$_3$ for cerebral hemorrhage and ischemic stroke admissions.

- **Women’s Health Initiative:** an increase of 10 μg/m$^3$ in the PM$_{2.5}$ concentration was associated with a 24% increase in the risk for a cardiovascular event and an increased risk for a cerebrovascular event.

Stroke and PM$_{2.5}$

Increase in odds ratio for stroke comparing 25$^{th}$ with 75$^{th}$ percentile increase (6.4 µg/m$^3$)

$P = 0.001$

Source: Wellenius Arch Int Med 2012;172(3):229
Sulfur Dioxide and Nitrogen Oxides Emissions
Under Clean Air Act, Acid Rain Program

<table>
<thead>
<tr>
<th>Year</th>
<th>Sulfur Dioxide</th>
<th>Nitrogen Oxides</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>96</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>97</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>98</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>99</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2000</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2001</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2002</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2003</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2004</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2005</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2006</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2007</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2008</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>2009</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: US EPA
Greenhouse Gases, 0 - 2005

Global Warming Mean Lifetime
Potential, 20 Year

\[
\begin{align*}
\text{CO}_2 &= 1 & & 30,000-35,000 \text{ years} \\
\text{Methane} &= 86 & & 12.4 \text{ years} \\
\text{N}_2\text{O} &= 268 & & 114 \text{ years}
\end{align*}
\]
CO₂ Emissions From Coal: 1995-2013 From Over 36 Trillion Total tons/year

Source: Globalcarbonatlas.org

- China, 7,179 Mt in 2013
- India, 1,667 Mt in 2013
- Russian Federation, 465 Mt in 2013
- USA, 1,688 Mt in 2013
- Brazil, 60 Mt in 2013
US Path to Deep Decarbonization

Electricity Use By Sector

2010
12 EJ

2050
22 EJ

CO₂ Emissions by Fuel Type

1 EJ = 10^{18} \text{ J}

EJ = \text{Exajoule}

Source: Institute for Sustainable Development and International Relations
Carbon Capture and Storage

Source: IPCC CCS Report, 2005
Oklahoma Earthquakes Magnitude 3.0 or Greater

Earthquakes in Oklahoma of M3+

Source: Oklahoma Geological Survey; 14–Apr–2015

Count

Year

1978 to 1999 Average


1.6 1 0 3 0 2 2 1 2 20 35 64 35 109 584 267 941

Projected

University at Buffalo
The State University of New York

PSR
Physicians for Social Responsibility
Elements of Carbon Capture and Storage

- Production of waste stream with high carbon dioxide percentage (Capture)
- Compression and liquification of carbon dioxide
- Transport to disposal site: pipeline
- Disposal in perpetuity (Storage)
Carbon Capture and Storage: Must deal with 35+ trillion tons per year

- Still in experimental stage
- Energy intense process
- Requires huge new infrastructure
  - Modify or construct new generating units
  - New pipelines
- Unproven long-term storage strategies
- Will not be 100% efficient: less may not be enough to prevent climate change
Increase in Daily Summer 1-h Maximum Ozone: 1990s-2050

Source: Bell et al. Climatic Change 2007;82:61-76
Tropospheric Ozone Formation

VOC Oxidation Chemistry:
Ozone and Secondary Organic Aerosol Formation

VOC-HOx-NOx Cycle

VOCs
Benzene
Toluene
Xylene

Isoprene
Terpenes
MBO

Oxygenated VOCs

HCHO
α-Dicarbonyls

Secondary Organic Aerosol

Target Molecules

Greenhouse gases

O3
CO2

hv, OH, O2
Wall Street and Coal
Whose War Is It?

Alpha Natural Resources (bought Massy for $7.1 billion 4 years ago), Walter Energy, Patriot Coal, many smaller companies, all have filed for bankruptcy.

But, domestic coal consumption rose by 4% between 2012 and 2015.
Costs versus Benefits, Clean Air Act

Source: US EPA
Sustainable Energy Future

- Improve efficiency
- Use more renewables
- More Wind Energy
- More solar
  - Photovoltaic
  - Sun-powered boilers
  - Now-experimental
    - Artificial photosynthesis
    - Hydrolysis to generate hydrogen
- Federal support for R&D and Education
US Solar Energy Flux
11,000 times consumption
Wind Energy 78 times annual usage
Photocatalytic Splitting of H$_2$O

- Catalysts added to cell
- Illuminated by artificial sunlight
- Bubbles: oxygen, front of cell; hydrogen, back of cell

Everyone Can Do Something
It’s Your Professional Responsibility

- Ask your candidates if they support EPA’s current clean air and carbon dioxide emission standards.
- Speak to your friends, family, and colleagues about the importance of clean air and protecting our health.
- Join Physicians for Social Responsibility
  go to: www.psr.org
Here is Some of What We Do, Thanks!

Lockwood home, Buffalo, NY, 4,400 Watt PV Array

We replace CFLs With LEDs