Air Pollution: Every Breath You Take

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Air pollution

1. Overview; effects on indigenous populations. Christopher Sanford, MD

2. Study on travelers and pulmonary function
   Terry Gordon, PhD

3. Managing pollution in expatriates: developing a strategy and practical tips for travellers. Trish Batchelor, MD

Financial disclosures

• None.
A problem in both low- and high-income nations.

- Over 90% of deaths related to air pollution occur in low-income nations.

India, China

- India and China account for over 50% of deaths due to air pollution.
- Of the 25 cities with the worst air pollution, 20 are in India.

Increasingly, travelers are visiting regions with significant air pollution.

- 2017: 1.32 billion tourist arrivals globally

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>435 million</td>
<td>1.186 billion</td>
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<tr>
<td>Advanced economies</td>
<td>299 million</td>
<td>653 million</td>
</tr>
<tr>
<td>Emerging economies</td>
<td>136 million (31%)</td>
<td>533 million (45%)</td>
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</tbody>
</table>

Health effects of air pollution

- stroke
- heart disease
- sudden death
- COPD (chronic obstructive pulmonary disease)
- asthma
- lung cancer
- other cancers: breast, bladder, liver, pancreas, bile duct, and gall bladder

Different ways to measure air pollution

1) Air quality index (AQI).
   - Level of pollutant, via a piecewise linear function, is converted to a number on a scale on which values below 100 are good or moderate.
   - If multiple pollutants are measured at a monitoring site, then the largest or "dominant" AQI value is reported for the location.

Air Quality Index (AQI)

- Good: 0 to 50
- Moderate: 51 to 100
- Unhealthy for sensitive groups: 101 to 150
- Unhealthy: 151 to 200
- Very unhealthy: 201 to 300
- Hazardous: 301 to 500
2) Specific pollutants

- PM$_{2.5}$
- PM$_{10}$
- Ozone level
- etc.

US Clean Air Act

- Requires EPA (Environmental Protection Agency) to set National Ambient Air Quality Standards (NAAQS).
- NAAQS are currently set for six “Criteria Air Pollutants.”

Particulate matter

- Particulate matter (PM)
  - PM$_{2.5}$
  - PM$_{10}$
- Suspended solid or liquid matter
- Source:
  - Anthropogenic—burning fossil fuels
  - Natural—dust storms, fires

Why does size matter?

- Decreases lung function.
- Increases risk of sudden death.
- Lung CA (IARC [Int’l Agency for Research on Cancer] Group 1 carcinogen)
- Worsens asthma.

Particulate matter, 2013 study

- 312,044 people, in nine European countries
- No safe level of particulates
- For every increase of 10 μg/m$^3$ in PM$_{10}$, the lung cancer rate rose 22%.
- Smaller PM$_{2.5}$—stronger correlation—36% increase in lung cancer per 10 μg/m$^3$

PM$_{1.5}$, standards (in μg/m$^3$)

<table>
<thead>
<tr>
<th>WHO</th>
<th>EU</th>
<th>US</th>
<th>India</th>
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</thead>
<tbody>
<tr>
<td>daily PM$_{1.5}$</td>
<td>25</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>annual PM$_{1.5}$</td>
<td>10</td>
<td>25</td>
<td>12</td>
</tr>
</tbody>
</table>
Ground-level ozone (O₃)

- (Not to be confused with “good ozone,” which is in the stratosphere 10-50 km [6-31 miles] above the earth).
- Created by chemical reactions between oxides of nitrogen (NOₓ) and volatile organic compounds (VOC).
- Occurs when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, etc. chemically react in the presence of sunlight.  

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-emissions.png)  

28

Ground-level ozone (O₃) (cont.)

- Causes chest pain, coughing, throat irritation, and airway inflammation.
- Reduces lung function.
- Worsens bronchitis, emphysema, asthma.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-exposure-and-mortality.png)  

29

Ozone and relative mortality rate

- Mortality increases to a greater extent with increasing ozone concentrations.
- Mortality rates are also higher for specific demographic groups, such as the elderly, those with pre-existing diseases, and children.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-exposure-and-mortality.png)  

30

Carbon monoxide (CO)

- Released when something is burned.
- Greatest sources of CO to outdoor air: cars, trucks and other vehicles or machinery that burn fossil fuels.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-emissions.png)  

31

Carbon monoxide (CO) (cont.)

- Reduces the amount of oxygen that blood can transport.
- At low concentrations:
  - Can cause fatigue in healthy people.
  - Can exacerbate angina in those with heart disease.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-exposure-and-mortality.png)  

32

Nitrogen dioxide (NO₂)

- “Nitrogen dioxide (NO₂) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NOₓ). Other nitrogen oxides include nitrous acid and nitric acid. NO₂ is used as the indicator for the larger group of nitrogen oxides.”
- NO₂ is produced by burning of fuel: emissions from cars, trucks and buses, power plants, and off-road equipment.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-emissions.png)  

33

Nitrogen dioxide (cont.)

- Aggravates respiratory diseases, including asthma.
- Long-term exposure elevates risk of asthma, and increases susceptibility to respiratory illnesses.
- At increased risk for health effects of NO₂: children, the elderly, those with asthma.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-emissions.png)  

34

Sulfur dioxide

- SO₂ is the sulfur oxide (SO₂) of greatest concern and is used as the indicator for the larger group of gaseous sulfur oxides.
- Sources:
  - primary: burning of fossil fuels by power plants and other industrial facilities.
  - secondary: industrial processes such as extracting metal from ore; natural sources such as volcanos; and locomotives, trucks and other vehicles and heavy equipment that burn fuel with a high sulfur content.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-emissions.png)  

35

Sulfur dioxide (cont.)

- Associated with respiratory symptoms and disease, difficulty in breathing, and premature death.
- People with asthma, particularly children, are sensitive to these effects of SO₂.
- High concentrations of SO₂ lead to the formation of other sulfur oxides (SO₃) which react with compounds in the atmosphere to form particulate matter (PM).
- Environmental: contributes to acid rain.
- At high concentrations, gasses SO₂ can harm trees and plants by damaging foliage and decreasing growth.

![Image](https://www.epa.gov/ground-nitrogen/ground-ozone-emissions.png)  

36
Lead

Sources of environmental lead: use of leaded fuels including past use of leaded gasoline, and past use of lead-based paint in homes

Countries that continue to use lead in gasoline: Algeria, Iraq, Yemen, Myanmar, North Korea, & Afghanistan.


Lead (cont.)

Adversely affects:

- Nervous system
  - Behavior and learning problems
  - Lower IQ
- Kidneys
- Hampers immunity.
- Children and pregnant women at increased risk.

What do pretravel providers talk about?

- Primarily: Infectious diseases.
- Travelers’ deaths:
  - ~50%: MI and CVA
  - ~25%: Road traffic injuries
  - Common: Drowning, falls from heights, homicide, suicide.
- Only 1-2% of traveler’s deaths due to ID causes.

The role of the pre-travel provider.

- Short-term:
  - Most young healthy people: symptoms are minor; irritating but not dangerous.
  - People with chronic pre-existing medical conditions
    - COPD
    - Asthma
    - CAD
  - Trish Batchelor to discuss.

Are masks of benefit?

Masks: proven benefit:

- 1) Surgeons/surgical staff
- 2) Bank robbers

Data is on residents, not travelers.

Minimal research on travelers to date.


Terry Gordon—will discuss.

Is air pollution related to sudden death in travelers?

Little research on deaths in travelers due to MI and CVA.

Why does the travel medicine community not address the most common cause of death in travelers?
Masks: proven benefit:

- 3) superheroes

What about travelers?

- Benefit is less clear.

CDC on masks and travelers:

- No recommendation.
- “The decision to wear a mask should be left to the traveler’s discretion.”

CDC: Health Information for International Travelers
Chapter 2: The Pretravel Consultation
Environmental Hazards
Armin Ansari, Suzanne Beavers
accessed 28 April 2019

Trish Batchelor will discuss masks and air purifiers in more detail

N95 mask

Regulation works

- Mexico City in 1992: worst air pollution in the world.
- Now markedly better. In 2012, ozone and other pollutants, about the same level as Los Angeles.
- For PM$_{2.5}$, not in top (worst) 500 cities in the world.

Mexico City: strategies

- Tightened regulations on fuel and cars.
- Authorities moved factories out of the capital.
- Invested in new sustainable buses and new bus routes.
- Invested in a public bicycle access program.
- Hoy No Circula, or “No‐Drive Days,” prohibited drivers from using their vehicles one weekday per week, with a schedule based on license‐plate numbers.
  - In 2008, this system was expanded to include Saturdays.

Los Angeles

- Large population
- Large number of cars
- Large number of trucks
  - (Port of Long Beach, Port of Los Angeles, biggest container port in the US, diesel trucks)
- Sunny days
- Inland mountains

- catalytic converter—mandatory as of 1975 in CA
- vehicle inspections
- starting in 1970, US gov’t phased out leaded gas
- emissions limits on industries
- regulating open burning in garbage dumps
- controls to reduce hydrocarbon emissions from industrial gasoline storage tanks, gasoline tank trucks and underground storage tanks at service stations
- citrus growers, smudge pots, cleaner fuels
Los Angeles: Still polluted, but better, despite increased population, more cars, more trucks.

Ozone in Los Angeles

• 1976-80: average of 112 Stage 1 ozone alerts per year
• None since 2003
  – (Stage 1 alert: when ozone is over 20 parts per million.)

A study that looked at asthma levels in children in Southern California between 1993 and 2014 found a correlation between declining ambient nitrogen dioxide and PM10 levels, and a reduced incidence of asthma.

References
• Air Quality Standards in India
  • http://www.arthapedia.in/index.php?title=Ambient_Air_Quality_Standards_in_India
  • accessed 6/21/2019
• CDS: Health Information for International Travelers, Chapter 1: The Personal Environment
  • accessed 6/21/2019
• Environmental quality of air on cars, trucks. Air pollution and lung cancer death in 27 European cities: prospective population study from the European Study of Cohorts for Air Pollution Effects (ESCAPE) project

References (cont.)
• accessed 6/21/2019
• accessed 6/21/2019
• accessed 6/21/2019
• accessed 6/21/2019
• accessed 6/21/2019

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