Is NO$_2$ a Marker for Effects of Traffic Pollution or a Pollutant on Its Own?

JENNIFER L. PEEL, PHD, MPH
JENNIFER.PEEL@COLOSTATE.EDU
COLORADO STATE UNIVERSITY
MAY 4, 2015
HEI ANNUAL MEETING
PHILADELPHIA, PA
Outline

- NO$_2$ standards, trends
- Review recent evidence – health effects of NO$_2$
- Discuss NO$_2$ as a marker for traffic-related pollution vs. a pollutant of interest on its own
- Research needs
- Conclusions
Nitrogen Oxides

- Emitted from motor vehicles (along with CO, CO₂, hydrocarbons, PM, benzene, formaldehyde, acetaldehyde, 1,3-buadiene, ...)
  - NO₂ quickly formed

- Also emitted from:
  - Power plants
  - Industrial point sources
  - Any combustion process
  - Forest fires
  - Lightening
Nitrogen Dioxide: A Criteria Pollutant

- United States
  - One of the six criteria pollutants regulated by the US EPA
  - Annual primary standard: 53 ppb (1971)
  - 1-hour primary standard: 100 ppb (2010)
  - No areas of US are currently out of attainment for NO₂

- European Union
  - Annual primary standard: 20 ppb
  - 1-hour primary standard: 105 ppb

- WHO guideline (outdoor air)
  - Annual primary standard: 20 ppb
  - 1-hour primary standard: 100 ppb
Nitrogen Dioxide: Decreasing trends in some developed countries

http://www.epa.gov/airtrends/nitrogen.html
Nitrogen Dioxide

- 2008: Most recent finalized US EPA integrated science assessment (ISA)
- NO₂ currently under review; 2nd external review draft ("DRAFT: Do Not Cite or Quote")
EPA Integrated Science Assessments: Causal designations

- Causal
- Likely to be causal
- Suggestive, but not sufficient, to infer a causal relationship
- Inadequate to infer a causal relationship
- Not likely to be a causal relationship
### 2008 EPA ISA Determination

<table>
<thead>
<tr>
<th></th>
<th>Short-term exposure</th>
<th>Long-term exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiratory effects</strong></td>
<td>Likely</td>
<td>Suggestive</td>
</tr>
<tr>
<td><strong>Cardiovascular effects</strong></td>
<td>Inadequate</td>
<td>Inadequate</td>
</tr>
<tr>
<td><strong>Total Mortality</strong></td>
<td>Suggestive</td>
<td>Inadequate</td>
</tr>
<tr>
<td><strong>Reproductive and developmental effects</strong></td>
<td>Inadequate</td>
<td>Inadequate</td>
</tr>
<tr>
<td><strong>Total mortality</strong></td>
<td>Inadequate</td>
<td>Inadequate</td>
</tr>
<tr>
<td><strong>Cancer</strong></td>
<td>Inadequate</td>
<td>Inadequate</td>
</tr>
</tbody>
</table>
Short-term Exposure

- **Respiratory effects**
  - Additional evidence reported, particularly for asthma exacerbation
  - Strengthened by controlled human exposure studies (increased airway responsiveness and allergic inflammation), personal NO$_2$ measurements

- **Cardiovascular**
  - Recent evidence for triggering of acute myocardial infarction, cardiac repolarization
  - Results of copollutant models are inconsistent
Short-term Exposure

- **Total mortality**
  - Recent evidence from numerous geographic locations
  - Limited evaluation of confounding by other pollutants
  - Limited understanding of underlying biologic processes
Long-term Exposure

- **Respiratory effects**
  - Evidence strengthened for asthma incidence
  - Still limited experimental evidence
  - Residual concerns about confounding by other pollutants
  - Jacquemin et al. EHP 2015; ESCAPE; NO\(_2\) associated with increase in asthma incidence
Long-term Exposure

- Cardiovascular effects
  - New evidence for development of heart disease
  - Some experimental evidence for systemic inflammation and oxidative stress
  - Limited by exposure assessment
  - May be confounded by short-term exposure to NO\textsubscript{2} and by other traffic-related pollutants, noise, stress
  - Chan et al. EHP 2015; NO\textsubscript{2} associated with increased blood pressure among women in the Sister Study, but effects were smaller than for PM\textsubscript{2.5}
Long-term Exposure

- Reproductive and developmental effects
  - Numerous recent studies, especially for adverse birth outcomes
  - Fertility and miscarriage: Frutos et al. 2015 review; evidence for adverse effects of NO$_2$ as well as other pollutants, but no prospective studies
  - Cognitive effects in children:
    - Sunyer et al. 2015: EC, UFP, NO$_2$ (both indoor and outdoor) associated with smaller growth in cognitive measurements in Barcelona
    - Lertxundi et al. 2015: PM$_{2.5}$ and NO$_2$ exposure during pregnancy associated with decreases in psychomotor development in children at 15 months in Spain
  - Limited control for other pollutants, understanding of biologic mechanisms
Long-term Exposure

- **Total mortality**
  - Numerous recent studies from different geographic locations
  - Typically modeled NO$_2$
  - Faustini et al. 2014 review: evidence for effects of NO$_2$ independent of PM$_{2.5}$; stronger effects for cardiovascular mortality
  - Fischer et al. EHP 2015: NO$_2$ associated with total and cause-specific mortality (not for circulatory disease); not always robust to control for PM$_{10}$; did not have PM$_{2.5}$
  - Some residual concern about confounding (noise, stress, copollutants)
Long-term Exposure

- **Cancer**
  - Filippini et al. 2015 review: traffic density, NO$_2$, and benzene associated with increased risk of childhood leukemia (postnatal exposure; stronger evidence for benzene)
  - Hystad et al. 2015: NO$_2$ associated with increased risk of breast cancer (no association for road proximity)
  - Hart et al. 2015 EHP: NO$_2$, BS, PM$_{2.5}$ and traffic measures associated increased risk of adult lung cancer
  - Hamra et al. 2015 EHP review: NO$_2$ associated with increased risk of lung cancer, robust to adjustment for confounding
  - IARC: air pollution and PM are human carcinogens; NO$_2$ not specifically implicated, but traffic-related pollution was
  - Limited understanding of biologic mechanism
Long-term Exposure

- **New endpoints: diabetes**
  - Diabetes: Eze et al. EHP 2015 review; concerns about potential confounding by noise, SES
<table>
<thead>
<tr>
<th>2008 EPA ISA Determination</th>
<th>Evidence since 2008 ISA*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-term exposure</strong></td>
<td></td>
</tr>
<tr>
<td>Respiratory effects</td>
<td>Likely</td>
</tr>
<tr>
<td>Cardiovascular effects</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Total Mortality</td>
<td>Suggestive</td>
</tr>
<tr>
<td><strong>Long-term exposure</strong></td>
<td></td>
</tr>
<tr>
<td>Respiratory effects</td>
<td>Suggestive</td>
</tr>
<tr>
<td>Cardiovascular effects</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Reproductive and</td>
<td>Inadequate</td>
</tr>
<tr>
<td>developmental effects</td>
<td></td>
</tr>
<tr>
<td>Total mortality</td>
<td>Inadequate</td>
</tr>
<tr>
<td>Cancer</td>
<td>Inadequate</td>
</tr>
</tbody>
</table>

*Note: Not based on EPA designations*
Is NO$_2$ a Marker for Effects of Traffic Pollution or a Pollutant on Its Own?

- Yes and yes (and no)
Is NO$_2$ a Marker for Effects of Traffic Pollution?


- NO$_2$, CO, EC/BC/BS, PM, ultrafine particle number, benzene often used as makers of traffic pollution

- HEI report: None are ideal as surrogates for traffic
Is NO\textsubscript{2} a Marker for Effects of Traffic Pollution?

- NO\textsubscript{2}: has many other sources
  - ~30% of NO\textsubscript{2} comes from on-road vehicles (plus another ~25% from off-road vehicles)
  - Will not be an ideal marker unless other sources can be ruled out

- NO\textsubscript{2} is often correlated with traffic density (more so than PM\textsubscript{2.5})
  - Evidence not consistent
  - Varies depending on location, distance to source, other sources
  - Recent data from near-road NO\textsubscript{2} monitors suggest that concentrations near roads are not as high as expected
Is NO$_2$ a Marker for Effects of Traffic Pollution?

- On-road patterns of NO$_2$ are similar to those of other traffic-related pollutants
  - NO$_2$, BC, PM$_{2.5}$, and benzene all decrease to background within 150 meters
  - Decay in concentration for NO$_2$ similar to that for ultrafine PM, PM$_{2.5}$, and VOCs
Figure 3.3. Distance-decay gradients of benzene, methyl tert-butyl ether (MTBE), and n-hexane at the Resources Road (MOE) site in Toronto compared with those observed with NO₂. All gradients decreased consistently with distance from the roadway and correlate with NO₂. The pollutants gradient concentrations (y-axis) were normalized by dividing each pollutant by the largest value observed at a given study site. (Reprinted from Beckerman et al. 2008, with permission of Elsevier.)
Is NO$_2$ a pollutant (of concern) on its own?

- Ambient NO$_2$: evidence is building
- Indoor environments
  - WHO guideline for indoor NO$_2$: 1-hour max 100 ppb
  - 40 – 1500 ppb and higher
  - Evidence from occupational and residential exposure studies
    - Primarily for asthma exacerbations and respiratory symptoms
- Evidence for threshold? Susceptible populations?
- Residual concerns about confounding
  - Other pollutants, noise, stress
Research needs (to really answer this question)

- Further characterization of the relationships between NO₂ and: BC, benzene, CO, VOCs, PM₂.₅, ultrafine particles, noise, stress in various environments (on-road, off-road, indoors)

- Health effects of other traffic-related pollutants
  - Including effects of short-term long-term exposure to benzene, VOCs, air toxics, noise
Research needs (to really answer this question)

- **New analytic approaches**
  - Challenges with multi-pollutant models
  - Several groups developing new approaches for evaluating multiple pollutants
  - Regression trees (Gass et al. 2014), Combined effect of pollutants (Winquist et al. 2014, Sorensen et al. 2014), Causal inference methods (Snowden et al. 2015), others

- **Causes of variation observed in health effect estimates**
  - Scale of study region? Monitoring location (on-road, near-road, off-road)? Measured vs. modeled NO$_2$?

- **New questions?**
  - Health effects of traffic likely due to numerous pollutants
  - Useful to compare the relative strength of effects of individual components of traffic?
  - US - 22 million housing units are located within 300 feet of a highway (4 lanes or more), railroad, or airport (American Housing Survey 2009)
Conclusions

- Evidence of adverse health effects continues to build...for both NO$_2$ and traffic (and other traffic-related pollutants)
  - Indoor and outdoor NO$_2$
- Limited supporting evidence for some health outcomes (controlled human exposure, toxicology)
  - Especially relative to PM
  - Necessary to be causal?
- NO$_2$ is not an ideal marker for traffic, but may be as good as any we have right now
Conclusions

- NO$_2$ is likely not acting as a surrogate for PM$_{2.5}$; not as clear for other traffic-related pollutants
  - Varies by location of study, location of monitors
  - Limited health effects studies using on-road monitors
  - Do not have sufficient evidence to evaluate

- What are the relevant questions to move forward?
Questions?