Is NO_2 a Marker for Effects of Traffic Pollution or a Pollutant on Its Own?

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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

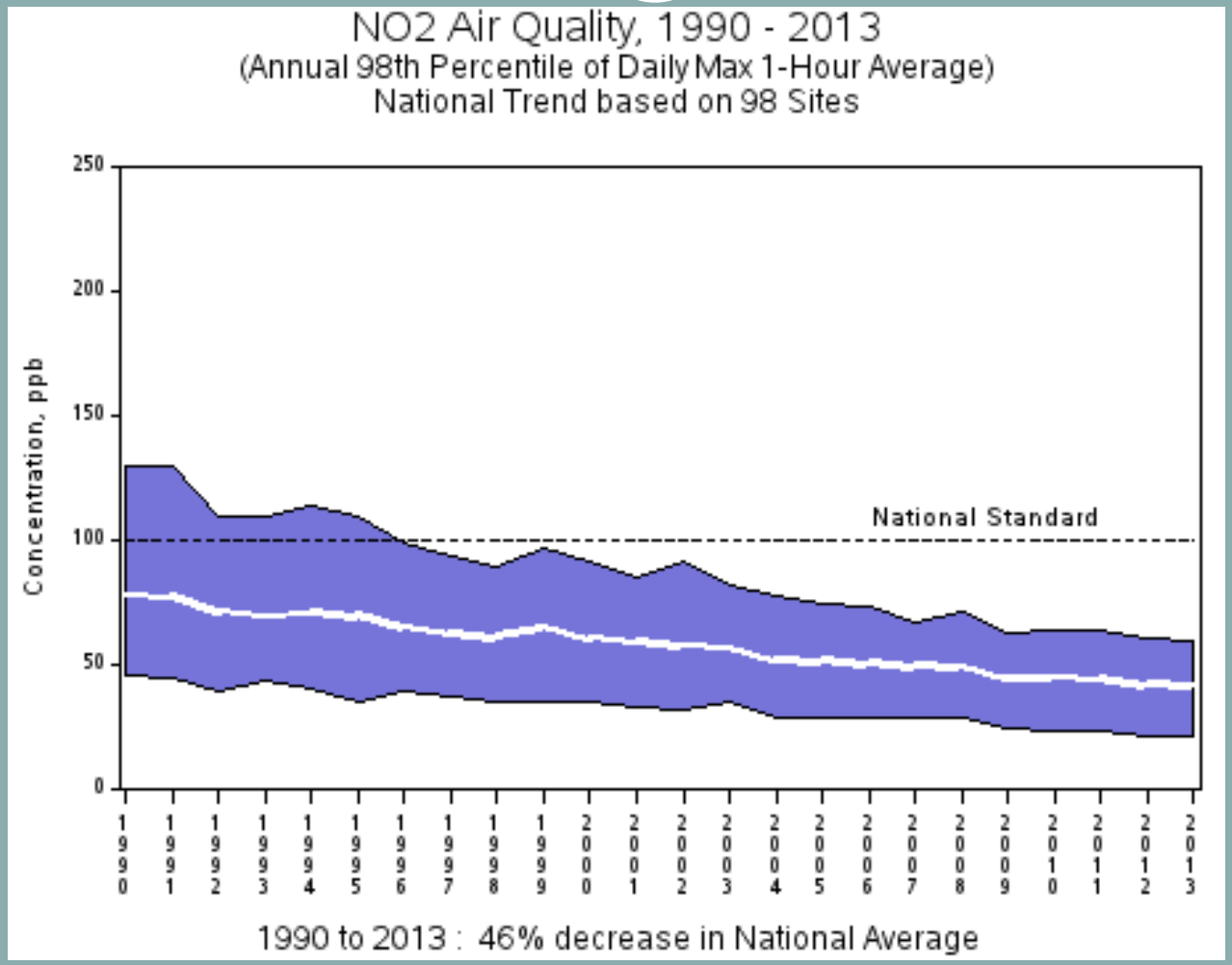
Nitrogen Oxides

- Emitted from motor vehicles (along with CO, CO_2, hydrocarbons, PM, benzene, formaldehyde, acetaldehyde, 1,3-buadiene,…)
  - NO_2 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 NO_2
- 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)

- NO_2 currently under review; 2nd external review draft ("DRAFT: Do Not Cite or Quote")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		
Short-term exposure		
Respiratory effects	Likely	
Cardiovascular effects	Inadequate	
Total Mortality	Suggestive	
Long-term exposure		
Respiratory effects	Suggestive	
Cardiovascular effects	Inadequate	
Reproductive and developmental effects	Inadequate	
Total mortality	Inadequate	
Cancer	Inadequate	

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_2 and by other traffic-related pollutants, noise, stress
  - Chan et al. EHP 2015; NO_2 associated with increased blood pressure among women in the Sister Study, but effects were smaller than for $PM_{2.5}$

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

	2008 EPA ISA Determination	Evidence since 2008 ISA*
Short-term exposure		
Respiratory effects	Likely	++
Cardiovascular effects	Inadequate	+
Total Mortality	Suggestive	+
Long-term exposure		
Respiratory effects	Suggestive	+
Cardiovascular effects	Inadequate	+
Reproductive and developmental effects	Inadequate	+
Total mortality	Inadequate	++
Cancer	Inadequate	+

*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?

- HEI 2010 Report – Traffic-Related Air Pollution (HEI Special Report 17, 2010)
- 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_2 a Marker for Effects of Traffic Pollution?

- NO_2: has many other sources
  - ~30% of NO_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_2 is often correlated with traffic density (more so than $PM_{2.5}$)
  - Evidence not consistent
  - Varies depending on location, distance to source, other sources
  - Recent data from near-road NO_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

Distance decay gradients

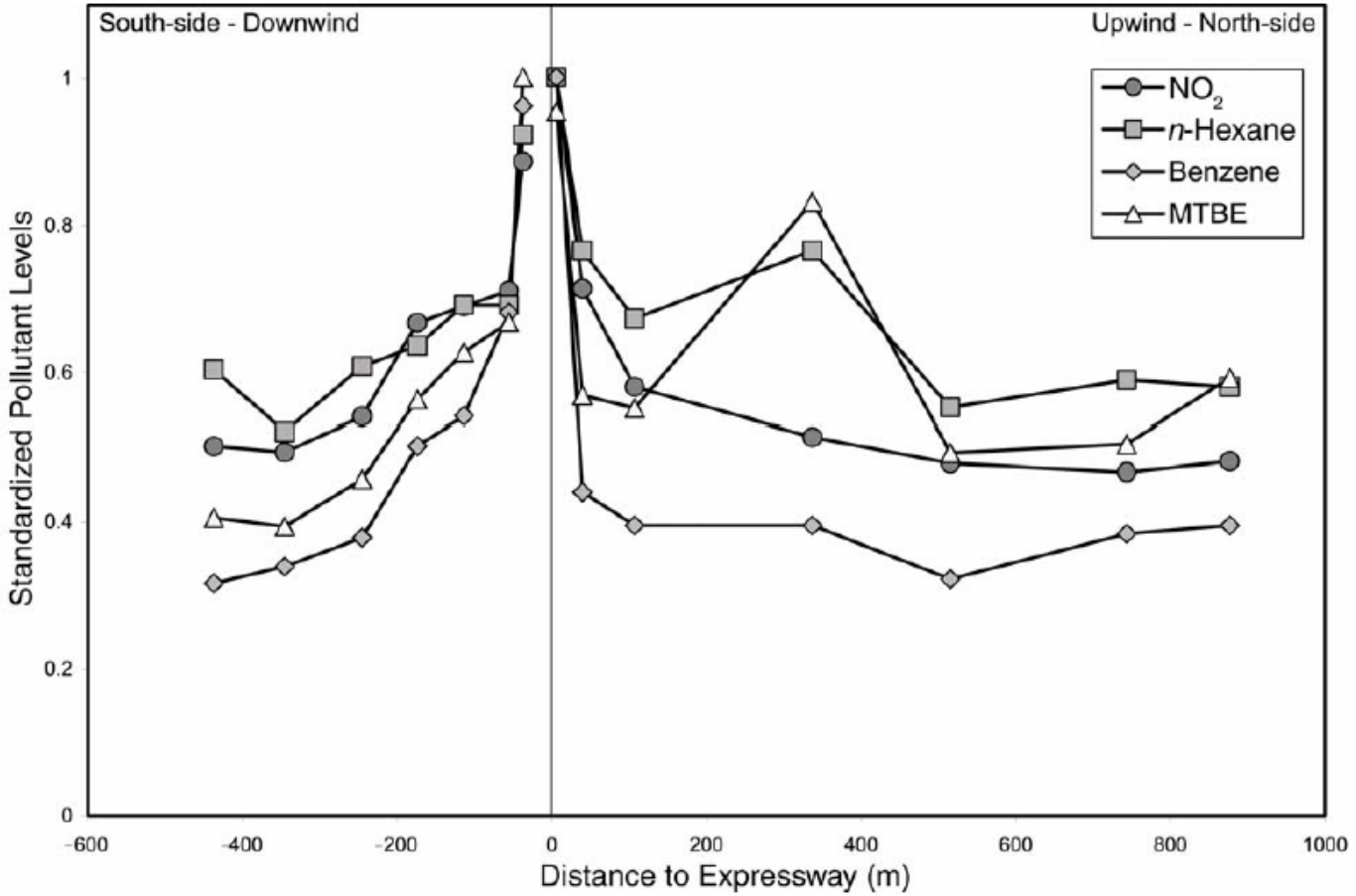


Figure 3.3. Distance-decay gradients of benzene, methyl *tert*-butyl ether (MTBE), and *n*-hexane at the Resources Road (MOE) site in Toronto compared with those observed with NO_2. All gradients decreased consistently with distance from the roadway and correlate with NO_2. The pollutants gradient concentrations (*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.)

HEI Special Report 17, 2010

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 – 1500ppb 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 NO_2 and: BC, benzene, CO, VOCs, $PM_{2.5}$, 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?