EPA Tools and Resources Webinar: Health Impacts of Near Roadway Air Pollution and Mitigation Strategies

July 27, 2016

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Different types of roadways

• Commuter Traffic
  – automobiles

• Goods Movements
  – trucks

• Mixed

Evening commute in Raleigh, NC
Percentage of population living within 150 meters of a major highway by state

- The percentage of the U.S. population living within 150 meters of a major highway (2010).
- Divide the total population within 150 meters of a major highway by the total population per state x100.
- Blue by quartiles.
Near Roadway Air Pollution

- > 45 million people in the U.S. live, work or go to school within 100 meters of a major road or transportation facility (airport or railroad) (Census AHS ‘09)
- Approximately 2 million school children attend classes within 200 meters of a large highway
- Americans spend (25 min x 2) ~1 hour per day traveling

![Travel Time to Work in Raleigh, NC](image1.png)

Riding alone in car

Mode of transportation to work in Raleigh, NC

- Other
- Worked at home
- Bus
- Walked
- Car-pooled
Who lives, works or plays in the near roadway environment?
Roadway Emission Gradients

NO\textsubscript{X} Emissions

Prevailing wind

Hot spots
Approaches for Air Pollution Studies

- Epidemiology
- Experimental
- Mechanistic

https://www.epa.gov/air-research/research-near-roadway-and-other-near-source-air-pollution

Multi-stage high volume ambient air sampler
What? … in the near-road environment is problematic?

Who? … is at-risk for exposure to traffic-based emissions? … is most at-risk?

Why? … do certain populations appear to be disproportionately affected by traffic-related emissions?
What is in the Near Road Environment?

- Hagler et al shows consistency of gradients for ultrafine particles (UFP) across multiple studies in the U.S.
Near Roadway Air Pollutant Gradients and Fall Off

Panel 1

Panel 2

Panel 3

Rapid: >50% drop by 150 m

Less rapid or gradual decay

No trend

Pollutant concentration normalized to edge

Distance from edge (m)

Pollutant

Rapid: >50% drop by 150 m

CO (32)

EC (49)

NO (67)

NO\(_X\) (30)

UF1 Particle no. (76)

UF2 Particle no. (93)

VOC1 (80)

Less rapid or gradual decay

Benzene (33)

NO\(_2\) (125)

PM\(_{2.5}\) (61)

PM\(_{10}\) (57)

VOC2 (32)

No trend

Fine particle no. (19)
Should we be concerned?

• Strong international consensus on elevated health risks for near-road populations

Numerous reviews summarized findings of hundreds of studies conducted mainly in the last decade, concluding that exposures to traffic emissions near roads are a “public health concern.”

• Health Effects Institute (HEI 2010) meta-analysis special report showed associations and suggestive associations between near-road exposures and adverse health effects
• Centers for Disease Control & Prevention (CDC)
• World Health Organization (WHO)
• Academic journal review articles
Essential Health Questions

• What?
  … in the near-road environment is problematic?

• Who?
  … is at-risk for exposure to traffic-based emissions? … is most at-risk?

• Why?
  … do certain populations appear to be disproportionately affected by traffic-related emissions?
Respiratory Conditions

- Bronchitis
- Chronic rhinitis
- COPD
- Atopy
- Allergic sensitization
- Asthma

↑ Symptoms, severity, emergency dept. visits, hospitalization, and decreased lung function growth are all associated with traffic exposure.
Traffic proximity and risk of asthma

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Health Effects

- Many more epidemiology studies have been done since this 2010
  - Respiratory effects (e.g., asthma)
  - Cardiovascular effects
  - Adverse birth outcomes
  - Premature mortality
  - Cancer

Traffic (CO, NO\textsubscript{2}, PM\textsubscript{2.5})

Distance

Distance + air pollutant

Near-road

Near-road
Clean Air Research Centers

Respiratory Effects

Asthma

- Adult women: PM$_{2.5}$ exposure increased the risk of developing asthma. PM$_{2.5}$ and NO$_2$ increased the risk of developing wheeze [18]
- Closer residential proximity to a major roadway is associated with poorer asthma control in school age children [Brown 2012]
- PM$_{2.5}$ concentrations associated with pediatric ED visits for asthma [20]
- ED visits for pediatric asthma were most strongly associated with certain day types defined by multipollutant characteristics than days with low pollution levels, but no specific combinations appeared more harmful than others [21]
- Age and poverty were found to be susceptibility factors for asthma in response to air pollution, with school-age children and those in neighborhoods with high poverty levels having the highest susceptibility [22, 23]

Lung Function

- Living <100 m from a major roadway was associated with lower Forced Expiratory Volume (FEV$_1$) and a faster decline in FEV$_1$, compared with living >400 m away. Higher PM$_{2.5}$ exposure also associated with lower/faster declining FEV$_1$ [Rice MB 2015]
- Exhaled nitric oxide was found to increase after rush hour commutes, with the largest increases observed among participants with below-median asthma control [Mirabelli MC Epid 2015]

https://www.epa.gov/air-research/clean-air-research-center-grants
“Near roadway air pollution and coronary heart disease: Burden of disease and potential impact of a greenhouse gas reduction strategy in Southern California”

Published July 7, 2016 in Environmental Health Perspectives

The research was funded by National Institutes of Health, US EPA, and The Hastings Foundation.
Clean Air Research Centers: Prenatal Exposure

Exposure to higher traffic-related pollution in the third trimester may reduce fetal growth and cause more rapid postnatal weight gain.

Exposure throughout pregnancy to traffic-related pollutants (CO, NO₂, PM₂.5) was associated with preterm birth. Associations tended to be higher for mothers with low educational attainment and African American mothers, and for births occurring around week 30.

Associations between multiple pollutant concentrations and ED visits for asthma or wheeze were found to be larger among children born preterm.

https://www.epa.gov/air-research/clean-air-research-center-grants

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Essential Health Questions

• What?
  … in the near-road environment is problematic?

• Who?
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  … is most at-risk?

• Why?
  … do certain populations appear to be disproportionately affected by traffic-related emissions?

MECHANISMS
Cho (2009) study showed certain metals elevated near roads compared to far away and these occurred in multiple size fractions.

Olson (2010) showed that SVOCs are also elevated near roads, affecting pop’l exposures.

Amount of elements in saline (vehicle) solution was < 5% compared to that in PM solutions.

Near vs. Far
- > 30%
- > 50%
Effects of diesel exhaust particles (DEP) in airway/lung injury model

- DEP comprise a significant amount of the PM$_{2.5}$ associated with traffic emissions.
- DEP with more organic carbon content caused delayed healing in “wounded” lung epithelial cultures compared to simple carbon black (CB) particles.

Relevance: Healing (post-infection) Lung growth
In vitro asthma (cytokine) model

Healthy/Inflamed lung cells

Saline-exposed

DEP-exposed

Oxidative stress at 2h

- More oxidative stress and injury of cells
- within an inflammatory micro-environment

Injury at 24h

- ROS + RNS

Manzo et al. Particle & Fibre Tox 2012
Summary of Tox Findings

**In vivo studies**
- Coarse particles – respiratory effects
- Ultrafine particles – CV
- Allergic/asthmatic murine models – more susceptible to particles across sizes
- Other studies – in progress

**In vitro studies**
- Diesel exhaust particles (DEP) with relatively greater organic carbon content
- Delayed healing in “wounded” lung epithelial cultures
- More oxidative stress and injury of cells within an inflammatory microenvironment due to oxidative-nitrosative interactions
Coherence with Epidemiologic Reports

Southern California Children's Health Study

- Since 1993, focused on chronic impacts of urban air pollution, especially traffic-related.
- This large body of evidence shows association with:
  - increased asthma prevalence,
  - new-onset asthma,
  - risk of bronchitis and wheezing,
  - deficits of lung function growth,
  - airway inflammation.

Conclusion

- Children's Health Study (CHS) studies - associations may be modulated by key genes involved in oxidative-nitrosative stress pathways via gene-environment interactions.

So What Can We Do?

• Public health concerns have raised interest in developing and implementing methods to mitigate these traffic emission impacts.

• EPA research has highlighted mitigation options to reduce traffic impacts, including:
  – Vehicle emission standards
  – VMT reduction/alternative transportation options
  – Use of urban planning and roadway design
    • Development site design and layout
    • Development buffer/exclusion zones
    • Road location and configuration
    • Roadside structures and vegetation
Vehicle Emissions and Activity Reductions

• EPA leads regulatory and voluntary programs that reduce air pollution emissions from trucks and other mobile sources
  
  – Vehicle emissions
    • Standards for heavy-duty diesel vehicles
    • Standards for light-duty passenger cars and trucks
    • Standards for non-road mobile source emissions (ships, trains, construction equipment)
    • Voluntary programs such as the National Clean Campaign and anti-idling
  
  – VMT reduction/alternative transportation options
    • Promotion of public and active transit
    • Promotion of compact, smart growth development
    • Auto restricted zones and congestion pricing
Some organizations promote land development options to reduce near-road exposures

- Buffer/Exclusion Zones: California currently restricts new schools and other sensitive land uses from being built near large roads
- Site Layout: Development can be implemented so that sensitive land uses are farthest from the road compared with other, less-sensitive uses
- EPA analyzing research that has been conducted on relationships among land use, air pollution concentrations, exposures and/or adverse health effects

![Diagram showing High Exposure layout vs Improved layout](image-url)
Roadway Design

- Re-routing traffic away from sensitive populations and public facilities can reduce exposures in nearby communities
- Roadside features may also reduce local air pollution
  - Few other “short-term” mitigation options
    - Emission reductions take long to implement (fleet turnover required)
    - Planning and zoning involved in rerouting/VMT reduction programs
    - Buffer/exclusion zones often not feasible
  - Roadside features often have other positive impacts including
    - Noise reduction (noise barriers)
    - Improved water runoff control; aesthetics (vegetation)
Roadway Design Effects

- EPA’s Wind Tunnel Facility allowed for research on near-road pollution gradients.
- Highest concentrations occurred near and away from the road when no obstructions were present.
- Lowest levels occurred with noise barriers and roads below the surrounding terrain (cut or depressed).

(Baldauf et al., 2009; Heist et al., 2009)
Noise Barrier Effects

- EPA and NOAA conducted tracer gas studies to assess noise barrier impacts and develop computer models.
- Noise barriers reduced air pollutant concentrations under all meteorological conditions.

(Finn et al., 2010)
Vegetation Effects

(Steffans et al., 2011)

- Research has shown that roadside vegetation can reduce pollutant levels, especially for soot and other very small particles.
- Higher reductions most often occurred closer to ground-level.
- Variable winds caused variable effects.
Noise Barriers and Vegetation

- Field studies have confirmed that noise barriers can reduced air pollution levels compared with a clearing.
- Combining vegetation with solid noise barriers provided further pollution reductions, especially for airborne particles.

(Baldauf et al., 2008a; 2008b)
Observed Health Benefits of Mitigation

- Update to the So. Cal Children’s Health Study
- Long-term improvements in air quality were associated with statistically and clinically significant positive effects on lung-function growth in children
Observed Health Benefits of Mitigation

- Enforcement of measures to control automobile emissions based on Japanese auto NO$_x$/PM regulations
- Reductions observed in air pollution (e.g. NO2)
- Decreases observed in the prevalence of respiratory and allergic disorders in 3 year-old children

EPA Programs Relevant to Near-Road Air Quality

- EPA research has led to the development of multiple resources to assist local government and community stakeholders in understanding near-road concerns and mitigation options.

- Examples of these resources include:
  - Near-Road Q&A webpage
  - School Siting Guidelines
  - Best Practices for Near-Road Schools
  - Recommendations for Designing Roadside Vegetation
• EPA maintains a Q&A document on near road issues related to:
  – Emissions
  – Air Quality
  – Exposure
  – Adverse Health Effects
• In the form of “Frequently asked questions”
• Links to research and outreach materials

http://epa.gov/otaq/nearroadway.htm
School Siting Guidelines

• Recommendations for evaluating the environmental and public health risks and benefits of potential school locations

• Near-Road exposures a prominent concern in the guidelines
  – Consider health effects from exposures to elevated pollutant concentrations from road, rail, port or airport emissions
  – Evaluate near-road exposures with benefits of active commuting (walking, biking, etc.)
  – School mitigation options to consider:
    • Indoor air treatment
    • Site layout
    • Roadside features/barriers
    • Buffer/exclusion zones

https://www.epa.gov/schools/school-siting-guidelines
Best Practices for Reducing Near-Road Pollution Exposure at Schools

https://www.epa.gov/schools/best-practices-reducing-near-road-air-pollution-exposure-schools

• Developed to provide practical solutions to mitigate traffic-related pollution based on issues in the School Siting Guidance

• Document for schools and parents

• Types of solutions provided:
  – Building Design and Operation Strategies
    • Ventilation, filtration and indoor air
    • Building occupant behavior
  – Site-Related Strategies
    • Transportation policies
      – Anti-idling and idle reduction policies
      – Upgrade bus fleets
      – Encourage active transport
    • Site location and design
  • Roadside barriers
    – Noise barriers
    – Vegetation

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EPA has developed recommendations for designing and planting roadside vegetation:

- Developed for implementing pilot studies in the cities of Oakland and Detroit
- Includes vegetation alone and vegetation in combination with solid barriers
- Recommends designs to maximize the potential for near road air pollution reduction, and
- Avoids unintended consequences such as increased downwind pollution concentrations due to gaps or open spaces in the vegetation

In cooperation with US DOT, EPA is planning to develop similar resources for designing and installing solid barriers for air quality benefits.
Summary

• Today many people live very close to very busy roads
  – Proportion appears to be increasing
  – Smart growth and trends towards urban living (up to 70% by 2050)
  – Disparities in race/ethnicity/income exist (Environmental Justice)
  – Differences in susceptibility to near roadway emissions exist
• As public health concerns increase, understanding near-road exposures is important in identifying and implementing effective mitigation strategies
• These factors should be considered in transportation and urban planning

https://www.epa.gov/smartgrowth
https://www.epa.gov/smartgrowth/hud-dot-epa-partnership-sustainable-communities
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