Urban green and built infrastructure as a tool to mitigate local air pollution

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Presentation Overview

Background
- Near-road health concerns
- Air quality mitigation options

Research on vegetation and noise barriers
- Impacts on near-road pollutant concentrations
- Implications for human exposures

Summary and Recommendations

Resources

Current Projects

Conclusions
Near-Road Health Concerns

People living, working and going to school near highways and large transportation facilities face increased health risks:

- Asthma and other respiratory diseases
- Cardiovascular effects
- Birth and developmental effects
- Premature mortality
- Cancer

Near-Road Health Concerns

Air pollution and exposures often highly elevated near large transportation sources, especially within first 200-300 meters.

Karner et al. 2010, Environ Science & Tech, 44(14), pp.5334-5344
Near-Road Health Concerns

Large portion of the world’s population exposed to near-road traffic emissions

In the US:

• Over 50 million people estimated to live within 100 m of a large highway or other transportation facility (e.g. airport, rail yard)

• Over 4 million school children attend classes within 150 m of a major highway
  • 1 in 11 schools
  • 1 in 5 new schools
Mitigating these traffic emission exposures and health effects can be achieved by:

- Reducing vehicle emissions
- Reducing vehicle activity
  - Public transit
  - Walk/bike options
  - Congestion pricing
- Creating development exclusion zones
- Using urban and transportation planning
  - Road location and configuration
  - Walk/bike options
  - Site design and layout
  - **Roadside barriers**
Roadside Barriers

Public wants to know what can be done now when concerned about near-road health impacts

Few “short-term” mitigation options exist

- Emission standards can take long to implement
- Planning, zoning and large investments often needed for activity reduction programs
- Development exclusion zones may not feasible in urban areas
Roadside barriers have other positive attributes with air quality only one of many potential benefits

- Noise barriers reduce noise and can improve aesthetics
- Roadside vegetation can:
  - Reduce stormwater runoff/flooding
  - Improve water quality
  - Increase carbon sequestration
  - Reduce urban heat island effects
  - Improve aesthetics/property values
  - Enhance community livability
  - Generally improve public health

"Exposure to green space has been associated with better physical and mental health"

Dadvand et al. 2015, Proc. Nat Acad Sciences, 112(26), pp.7937-7942
Vegetation and Noise Barrier Research
Roadside Vegetation Effects

- Particulate matter generally reduced downwind of a vegetation stand
- Higher reductions occurred closer to ground-level
- Variable winds altered effects

Steffens et al 2012, Atmospheric Environment, 50, pp.120-128
Roadside Vegetation Effects

- Smaller size PM have higher removal rates
- Removal increases at lower wind velocities
- Branch/leaf shape and size affects removal

Lin et al., 2012, Aerosol Science and Technology, 46(4), pp.465-472
Plant conditions affect downwind pollution

• Thick, tall and full coverage reduced pollution

• Gaps and porous vegetation led to higher levels
Computational Fluid Dynamics (CFD) modeling suggests:

- Decreased concentrations downwind of barrier
- Increased concentrations on-road due to upwind trapping
- The higher the barrier, the greater the downwind reduction and on-road increase

Hagler et al. 2011, Atmos. Environ, 45(15), pp.2522-2530
Tracer gas studies highlight downwind pollutant reductions from solid noise barriers.

Higher variability experienced during lower, stable winds.
Noise Barrier Effects

NO\textsubscript{2} concentrations

East Section (Afternoon)

West Section (Morning)

Baldauf et al., 2016, Atmos. Environ, 129, pp.265-276
- Noise barriers reduced concentrations of PM compared with a clearing
- Vegetation with noise barriers provided further reductions of PM concentrations and gradients

Baldauf et al., 2008, J. Air & Waste Manage Assoc., 58(7), pp.865-878
Baldauf et al., 2008, Atmospheric Environment, 42(32), pp.7502-7507
EPA has released recommendations for planting and maintaining roadside vegetation

- Used to design planting projects in Oakland and Detroit
- Includes vegetation alone and combined with solid barriers
- Provides designs intended to:
  - maximize the potential for near-road air pollution reduction
  - avoid unintended consequences and designs that may increase downwind concentrations and exposures

Vegetative Barrier Recommendations

Areas desired for reduced pollutant concentrations should avoid gaps and edge effects
  • Complete coverage from the ground to the top of the canopy
  • Thickness adequate to reduce porosity and avoid gaps

Pine/coniferous trees and thick bushes may be good choices
  • No seasonal effects
  • Complex, rough, waxy surfaces

Mix of species (bushes/trees) may increase coverage and robustness

Examples of full coverage, pine and bush barriers
Vegetative Barrier Recommendations

Pollutants can meander around edges or through gaps

- No spaces between or under trees
- No gaps from dead or dying plants; maintenance important

Examples of inadequate barriers due to gaps
Research shows noise barrier design characteristics that can reduce downwind pollutant levels

- The higher the barrier, the higher the downwind pollution reduction
  - Most studies conducted with barriers > 4m
  - Pollutants can meander around edges
    - Sensitive areas should be ≥ 50m from edges
    - Sensitive areas should be below barrier top
  - Pollutants can be trapped on the upwind side of the barrier
    - “Upwind” sources need to be considered
    - May lead to increased levels on the road
- Barrier should be close to the road
  - Most studies had barriers ≤5m of travel lane
Combination of solid noise and vegetative barriers may have the most benefit

- Increases air pollutant dispersion and removal
- May be solid noise barrier with vegetation behind and/or in front
- Use of climbing vegetation on solid surfaces still uncertain

Examples of solid/vegetation barriers
Other Considerations

Vegetation characteristics:

- Species (e.g. native vs. non-native)
- Appropriateness for site
  - Drought/flood resistant
  - Road treatment tolerant (e.g. salt, sand)

Physical characteristics the barrier needs:

- Height, thickness, length and porosity
- Non-seasonal vegetation (conifers, bushes, etc.)
- Waxy leaf and branch surfaces for pollutant removal
- Low pollution/pollen emissions
Other Resources
Urban Trees and Air Quality

Urban trees can have positive and negative effects on urban and regional air quality as well.

- Trees can remove pollutants through deposition and absorption.
- Some vegetation species emit volatile organic compounds (VOCs), precursors for ozone.
- The U.S. Forest Service’s i-Tree model estimates pollutant loss and emissions.

https://www.itreetools.org/
Best Practices for Reducing Near-Road Pollution Exposure at Schools

Developed to provide schools and parents with practical solutions to mitigate traffic-related pollution

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

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

Discuss roadside features

http://epa.gov/otaq/nearroadway.htm
Best Practices for Planners

- EPA drafting recommendations for Near-Road development
  - Encompasses Corridor Management, Building Design and Operations, Site Design and Layout, and Barrier Use
  - Site Layout: Development can be implemented so that sensitive land uses are farthest from the road
  - Barriers can provide added benefits

Note: Drawing not to scale
Current Projects
EPA Roadside Vegetation Projects

- Roadside vegetation planting in Detroit and Oakland
- Collecting air quality, meteorology, and noise (Detroit only) measurements before and after roadside vegetation planting
- Assessing benefits for air quality and water runoff control

Detroit, MI
EPA Roadside Vegetation Projects

Oakland, CA
International Projects

Improving the Smart Control of Air Pollution in Europe

Instrument: Research and Innovation Action (RIA)

Call: H2020-SC5-04-2015 “Improving the air quality and reducing the carbon footprint of European cities”

Mexico City

Singapore
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Conclusions

• Health concerns from transportation emissions have raised the importance of understanding how urban infrastructure affects human exposures and can be used for mitigation.

• Roadside green and built infrastructure can provide air quality benefits when designed properly.

For More Information:

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