Vegetation Influences on Near-Road Air Quality

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Background

• Concerns regarding population exposures near large roadways
  – Elevated pollutant concentrations
  – Adverse health effects
  – Potentially large population exposed

• Interest in the role near-road vegetation may play in mitigating traffic emission impacts
  – Workshop held in North Carolina, April 27-28
  – Representatives from academia, state and local agencies, environmental advocacy groups, and government agencies,
  – Participant expertise included air quality, urban forestry, ecosystem services, and policy
  – Reviewed the current science and identified future activities and research needs
Why are we concerned? Traffic Emissions

• More than 1,000 compounds have been identified in exhaust and evaporative emissions from mobile sources – many with known health implications
  – NAAQS Pollutants
  – Air Toxics
  – Particulate Matter

• Air quality measurements have indicated elevated pollutant concentrations near roads
  – CO and Pb the focus during the 70’s
  – Recent studies reveal complex mixture of pollutants

[from Baldauf, 2010 Vegetation Workshop]
Why are we concerned?  
Adverse Health Effects

• Living, working, or going to school near major roadways has been associated with numerous adverse health endpoints
  – Respiratory effects (e.g., asthma, bronchitis)
  – Cardiovascular effects
  – Adverse birth outcomes/developmental effects
  – Premature mortality
  – Cancer

• Hundreds of studies published this decade
  – Account for varying fleets, engine technologies, etc.
  – Health Effects Institute (HEI) summarized these findings, concluding that exposures to traffic emissions near roads are a “public health concern.”

[from Baldauf, 2010 Vegetation Workshop]
Why are we concerned?
Population Exposures

• Significant portion of U.S. population lives near large roads or transportation system
  – 2007 American Housing Survey estimates >45 million people
  – Additional portion of population works or goes to school near large roads
  – High density traffic residences and schools disproportionately lower income

[from Baldauf, 2010 Vegetation Workshop]
One way to mitigate impacts: Roadway Design and Roadside Features?

- Flat, At-Grade
- Vertical Road Cut
- Sloped Road Cut
- Noise Barriers
- Vegetation (porous) Barrier

(Heist et al., 2009)
Influence of Roadway Design and Roadside Features

(Baldauf et al., 2009)
Influence of Roadway Design and Roadside Features

- Flat, At-Grade
- Vertical Road Cut
- Sloped Road Cut
- Noise Barriers
- Vegetation (porous) Barrier
Field studies showed the influence of noise barriers and vegetation on both pollutant concentrations and gradients.

(Baldauf et al., 2008)

[from Baldauf, 2010 Vegetation Workshop]
Vegetation Effects

Khlystov et al., (Preliminary Data – do not cite, quote, or reference)

[from Hagler, 2010 Vegetation Workshop]
Vegetation Effects

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[from Hagler, 2010 Vegetation Workshop]
Factors Affecting Removal

- Crown texture (fine)
- Leaf complexity (pinnate)
- Leaf size (small)
- Leaf surface
  - Rough, resinous, hairy, sticky, etc.
- Leaf margins
  - Ciliate, serrulate, filamentous

Note: Vegetation can also increase mixing and dispersion

[Figure 5-3. Scanning electron microscope micrograph of the adaxial surface of an 8-week-old London plane leaf. Spore, pollen, carbonaceous, angular, and aggregate particles are visible. Scale, 10 μm. (Smith, 1990)]

[from Nowak, 2010 Vegetation Workshop]
Removal of very fine particles

BC/SET HETF/SMAQMD/UC Davis Wind Tunnel Vegetation Study

Fraction of particles 0.26 > Dp > 0.09 microns surviving after 2 m of branches

All S-XRF Sr data (red flare); Mean error in replicates +/- 15%

Fraction Downwind

Wind velocity m/s

Deodar
Redwood
Live Oak
Theory

[from Cahill, 2010 Vegetation Workshop]
Summary of all S-XRF analyses, all vegetation types

BC/SET HETF/SMAQMD/UC Davis Wind Tunnel Vegetation Study
Fraction of particles $0.26 > D_p > 0.09$ microns surviving after 2 m of branches
All S-XRF Sr data (red flare); Mean error in replicates +/- 15%

[Graph showing wind velocity vs. fraction downwind]
Pollution Removal by Trees

[Diagram showing pollution removal by trees of different diameters, with categories for CO, SO2, NO2, PM, and O3, adapted from Nowak, 2010 Vegetation Workshop]
Modeling Vegetation Effects

Key Parameters: “Simple Scenario”

**Meteorology factors:**
- Wind direction and speed
- Stability category

**On-road factors:**
- Traffic activity/fleet mix
- Vehicle-induced turbulence
- Surface temperature of the road
- Emissions characteristics

**Vegetation factors:**
- Species
- Dimensions
- Porosity
- Location/Season

**Behind barrier factors:**
- Building height/location
- Any other pollution sources?

[from Hagler, 2010 Vegetation Workshop]
Beneficial Vegetation Characteristics

- Large leaf area
- High transpiration
- Low VOC emissions
- Evergreen
- Long-lived
- Low maintenance
- Healthy – right tree for location
- Leaf texture (particles)

[from Nowak, 2010 Vegetation Workshop]
Potential Environmental Benefits

- Temperature – reduced urban heat-island effect
- Water regulation – modulates flooding and droughts
- Water filtration – reduces sediments and toxins

[from Jackson, 2010 Vegetation Workshop]
Sketch of an Urban Heat-Island Profile


(from Akbari et al., 1992)

(from Nowak, 2010 Vegetation Workshop)
Potential Additional Benefits to Human Health and Well-Being

- Carbon storage – mitigate global warming
- Reduce air conditioning – decreased energy use, save $$
- Connect nature preserves through corridors
  – increase resilience of wildlife populations
- Improved aesthetics

[from Jackson, 2010 Vegetation Workshop]
Carbon Storage established in 2008 to assess whether a roadside carbon sequestration effort is appropriate and feasible for state DOTs.
Potential Societal and Ecological Dis-Benefits

• May provide corridors for fire, invasive pests, crime
• May increase pollen load
• May result in net water loss
• May increase sprawl
• How healthy are trees/soils used as pollutant buffers?

*Buffer Design and Species Selection are Critical to Minimize Dis-Benefits*

[from Jackson, 2010 Vegetation Workshop]
Comprehensive Net-Benefits Analysis

[from McPherson, 2010 Vegetation Workshop]
Summary

• Growing interest in near road air quality due to public health concerns

• Data suggests vegetation may play a role in mitigating near-road air quality
  – Removal of PM and other traffic-related pollutants
  – Benefits may be site-specific
  – Key factors include:
    • Local meteorology
    • Site configuration
    • Traffic activity
    • Vegetation parameters
    • Other pollution sources behind vegetation
  – Trade-off may exist between on-road and near-road air quality
Summary

• Areas identified for future policy and research:
  – Field data assessing long-term concentration difference for behind-vegetation vs. unobstructed air flow
  – Effects of vegetation configuration
    • Leaf area distribution
    • Height
    • Width
  – Species effectiveness
  – Assessing importance of “breaks” in vegetative barrier
  – Assessing effect of distributed vegetation vs. noise wall
  – Quantifying on-road impacts
  – Integrated studies linking local to regional impacts
  – Standardized open source measurement methods
  – Integration of policy and science in the planning and design process
Acknowledgements

The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions

On April 27-28, 2010, a meeting was held in Research Triangle Park, North Carolina on "The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions." Concerns over population exposure to traffic-generated pollutants near roads have grown with an increasing number of health studies reporting links between proximity to roads and adverse health effects. Recent studies indicate that vegetation present along roadways may help to mitigate air pollutant concentrations near roads. This workshop brought together representatives from government agencies, academia, state and local agencies, and environmental advocacy groups with expertise in air quality, urban forestry, and policy to review the current science and identify future activities in evaluating the potential role of vegetation in mitigating near-road air pollutant concentrations.

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List of Participants (PDF) (2 pp, 16 KB)