

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

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Different types of roadways

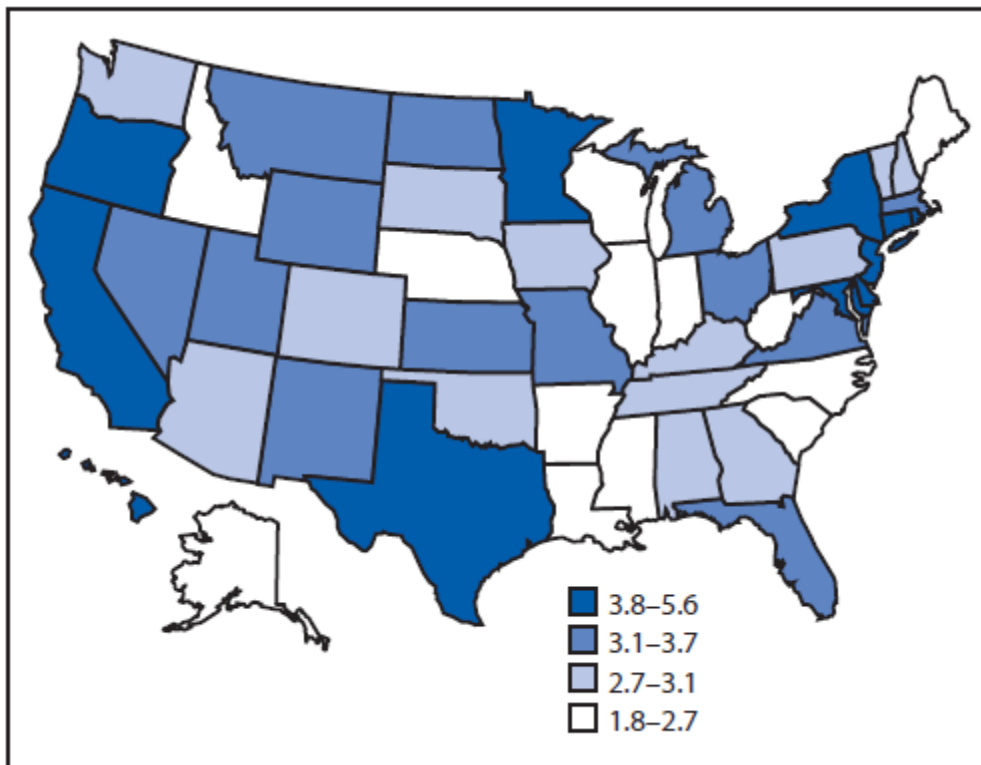
- Commuter Traffic
 - automobiles
- Goods Movements
 - trucks
- Mixed



Evening
commute in
Raleigh, NC



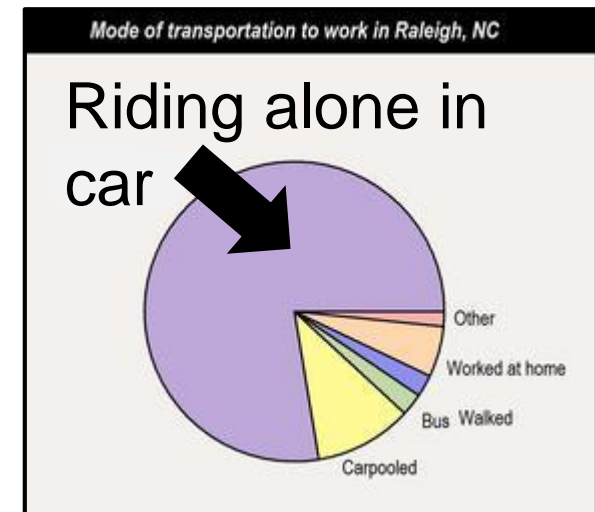
Percentage of population living within 150 meters of a major highway by state



- 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

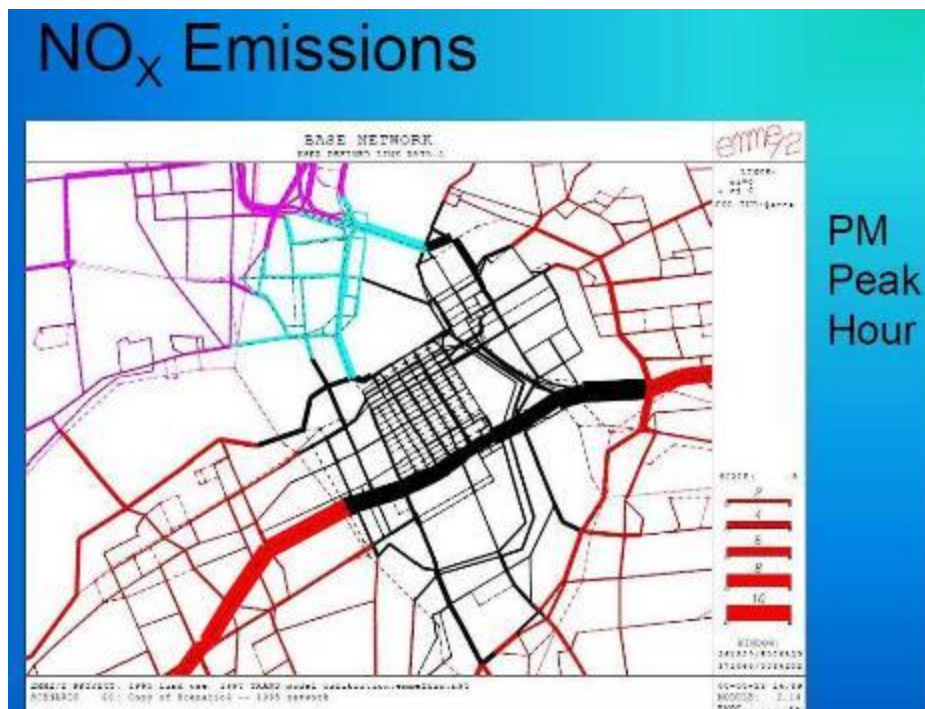
- > 45 million+ people in the U.S. live, work or go to school within 100 meters of a major road or transportation facility (airport or railroad) (Census AHS '09)
- Approximately 2 million school children attend classes within 200 meters of a large highway
- Americans spend (25 min x 2) ~1 hour per day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



Who lives, works or plays in the near roadway environment?

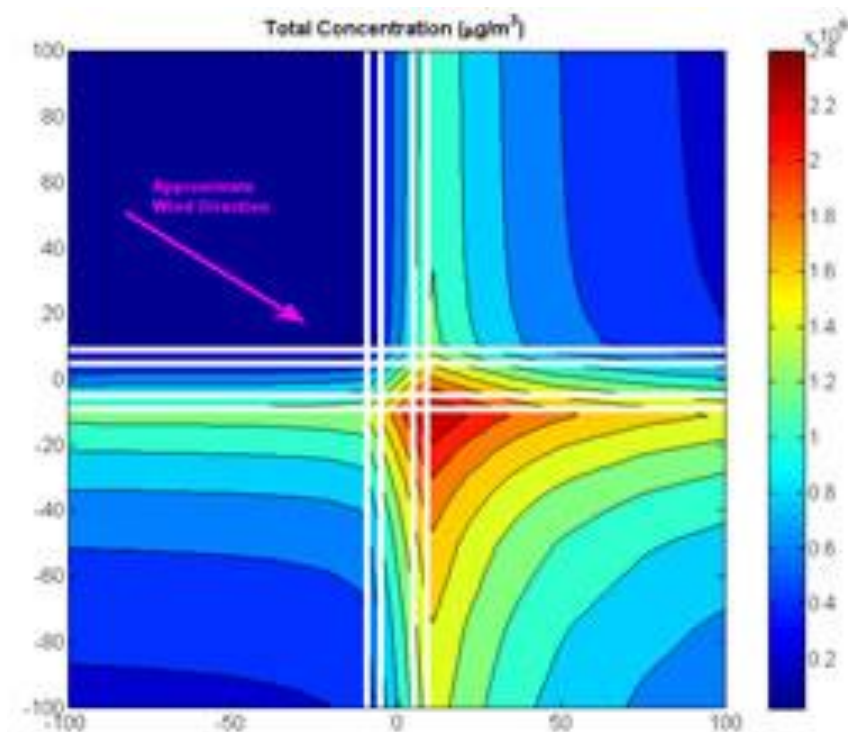


Roadway Emission Gradients



Hot spots

Prevailing wind



Approaches for Air Pollution Studies

- Epidemiology
- Experimental
- Mechanistic

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



Essential Health Questions

- **What?**

... in the near-road environment is problematic?

- **Who?**

... is at-risk for exposure to traffic-based emissions?

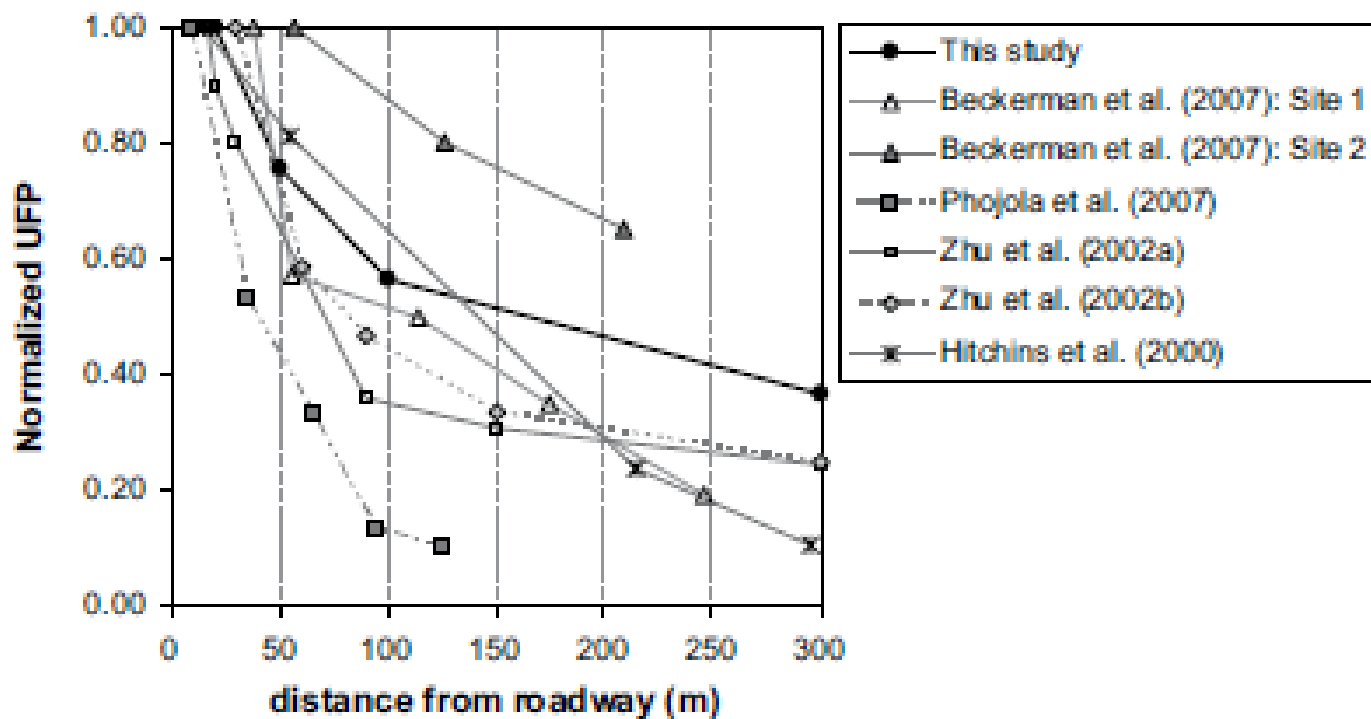
... is *most* at-risk ?

- **Why?**

... do certain populations appear to be disproportionately affected by traffic-related emissions?

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.

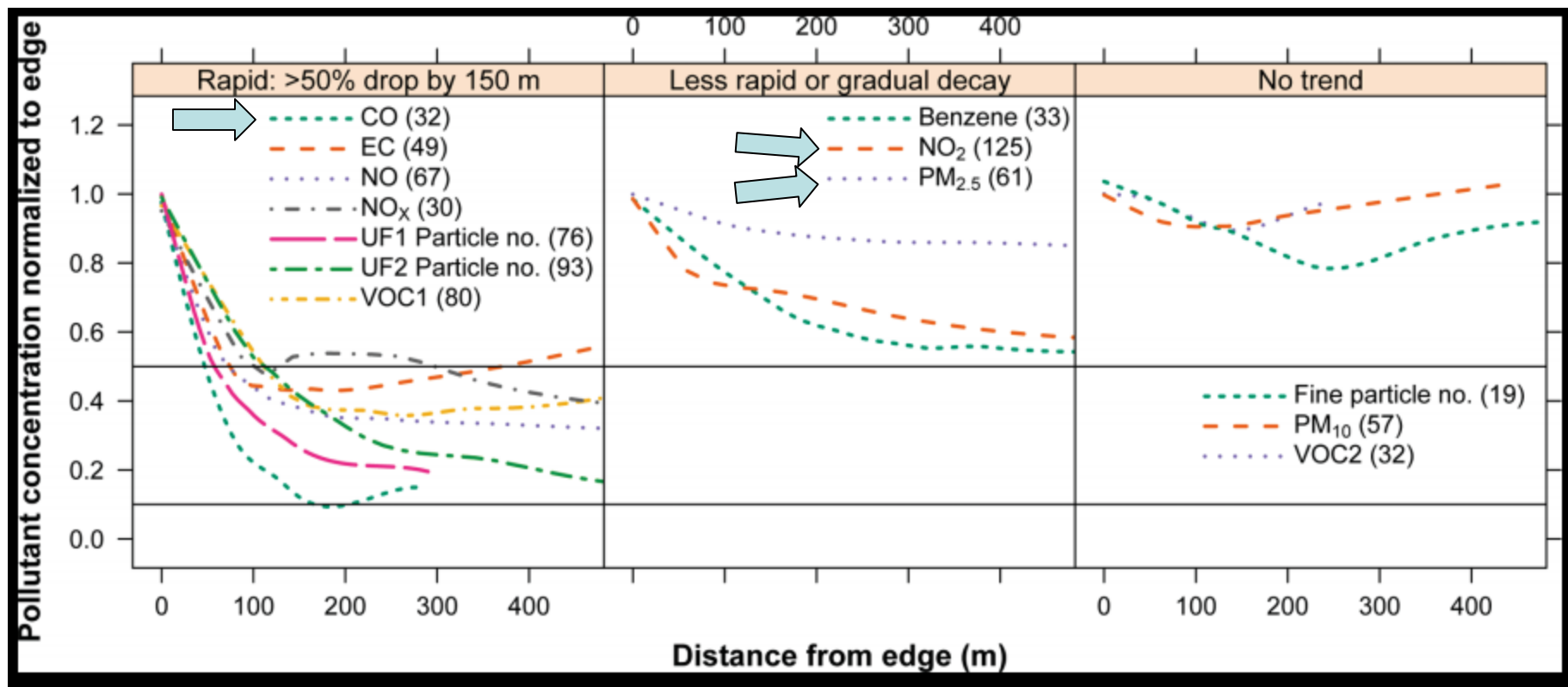


Near Roadway Air Pollutant Gradients and Fall Off

Panel 1

Panel 2

Panel 3



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?**

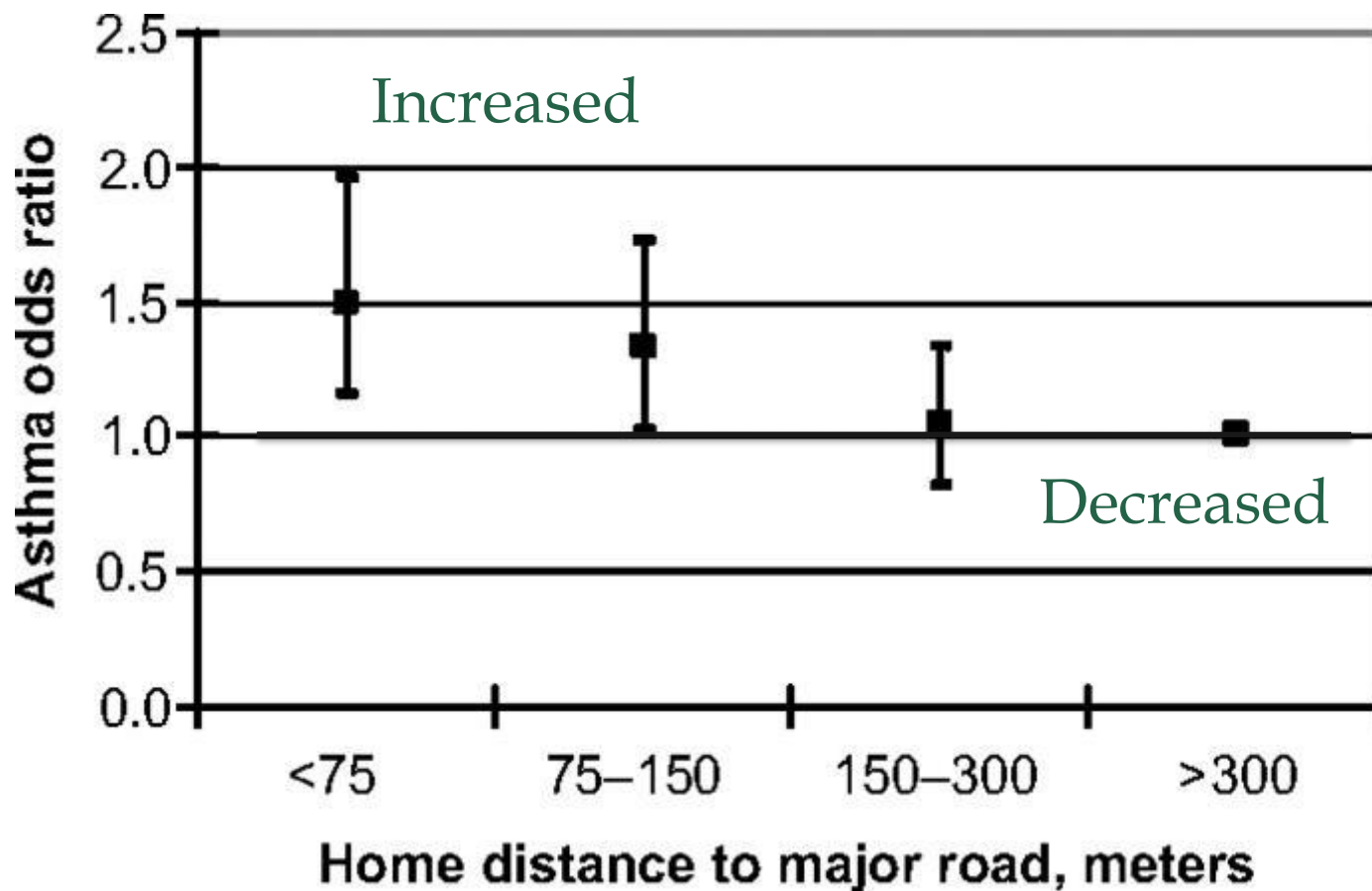
... do certain populations appear to be disproportionately affected by traffic-related emissions?

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

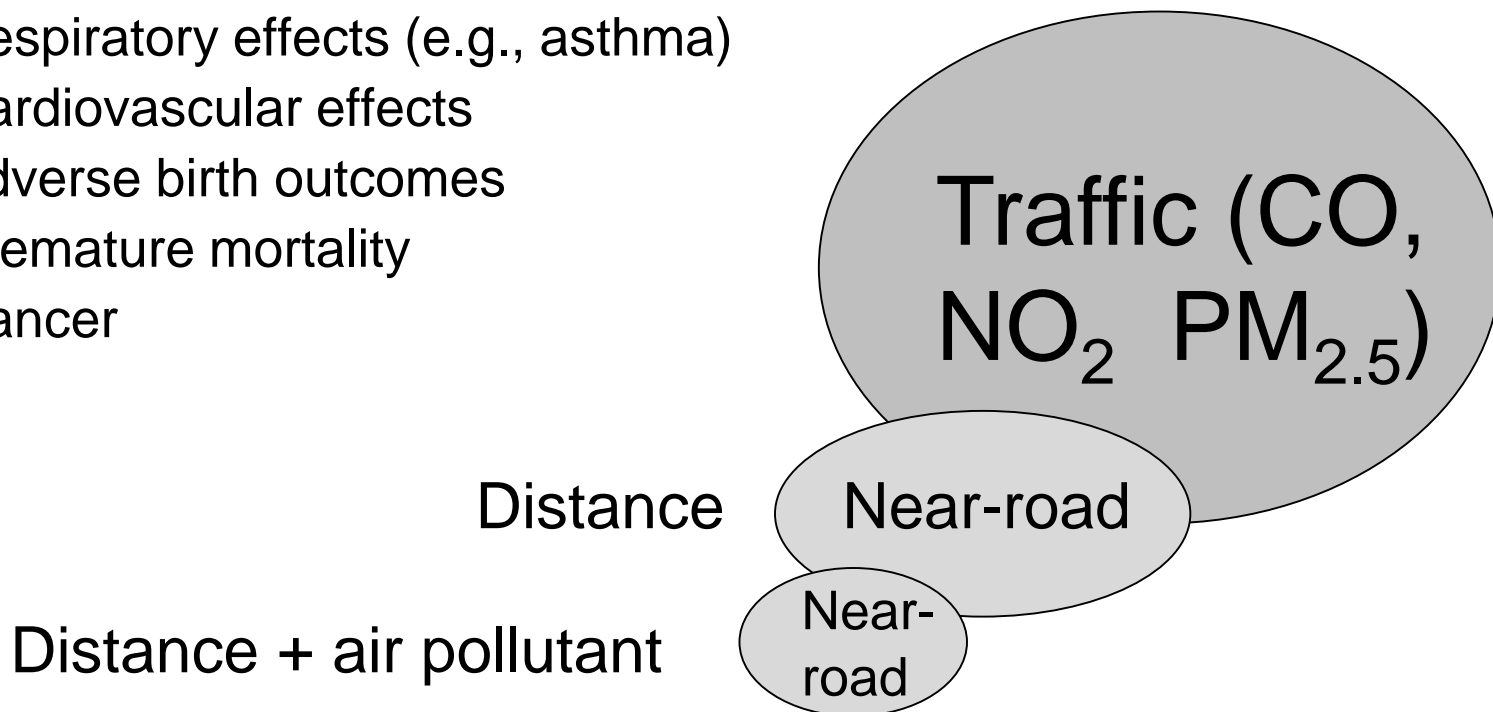


Traffic proximity and risk of asthma



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



Clean Air Research Centers

Respiratory Effects

Asthma

- W Adult women: PM_{2.5} exposure increased the risk of developing asthma. PM_{2.5} and NO₂ increased the risk of developing wheeze [18]
- E Closer residential proximity to a major roadway is associated with poorer asthma control in school age children (Brown 2012)
- E PM_{2.5} concentrations associated with pediatric ED visits for asthma [20]
- E 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]
- E 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]



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

Respiratory Effects

Lung Function

- H Living <100 m from a major roadway was associated with lower Forced Expiratory Volume (FEV₁) and a faster decline in FEV₁ compared with living >400 m away. Higher PM_{2.5} exposure also associated with lower/faster declining FEV₁ (Rice MB 2015)
- E 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)

Links to Coronary Heart Disease

- “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

Prenatal Exposure

- H** Exposure to higher traffic-related pollution in the third trimester may reduce fetal growth and cause more rapid postnatal weight gain (Fleish AF 2015)
- E** Exposure throughout pregnancy to traffic-related pollutants (CO, NO₂, PM_{2.5}) was associated with preterm birth. Associations tended to be higher for mothers with low educational attainment + African American mothers, and for births occurring around week 30 (Hao J et al 2016; Chang HH 2016)
- E** Associations between multiple pollutant concentrations and ED visits for asthma or wheeze were found to be larger among children born preterm (Strickland Epid 2014)



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

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?

MECHANISMS

Roadway Particulate Matter



- 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

(ug/g)	Al	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Ni	Pb	SO ₄	Sb	SiO ₂	Sn	Sr	Ti	Vn	Zn
NEAR C	12000	1400	22000	14	48	790	19000	11000	6500	510	33	59	57000	110	32000	33	110	970	61	990
F	3600	340	3600	11	18	250	5500	3100	1400	130	23	67	370000	54	9200	76	34	170	42	520
UF	1900	10	4500	18	13	150	1700	5500	900	100	30	69	440000	47	340	21	23	31	54	920
FAR C	9000	540	20000	11	31	320	10000	9900	6000	390	27	39	63000	41	24000	32	100	960	63	400
F	3700	120	3200	10	14	100	3000	3600	1600	110	23	75	440000	24	9100	131	30	74	33	400
UF	1800	3	2900	16	11	110	1300	5500	900	90	32	67	450000	42	170	44	16	20	58	980

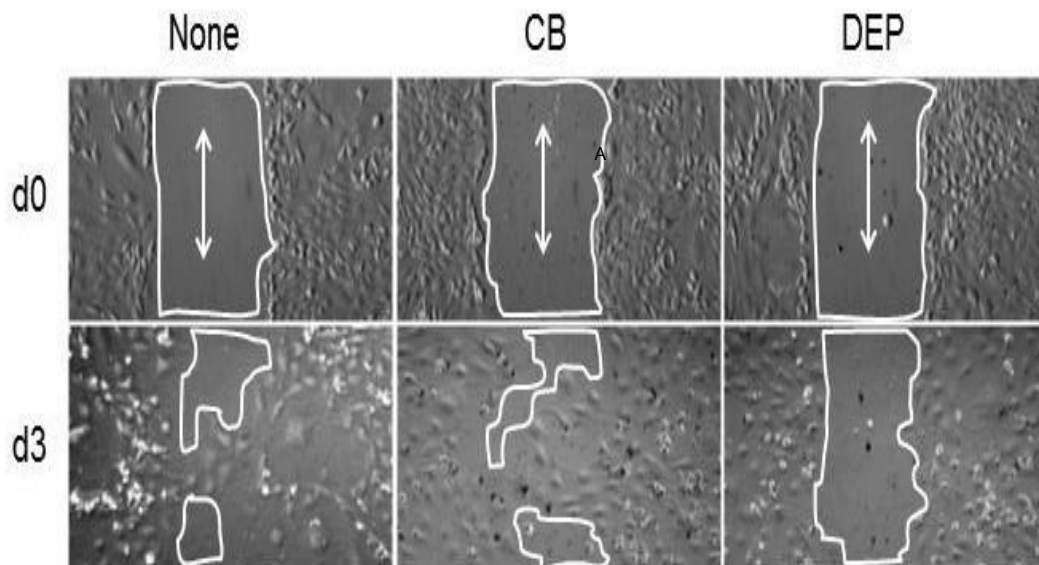
Amount of elements in saline (vehicle) solution was < 5% compared to that in PM solutions

Near > 30%
vs.
Far > 50%



- 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.

Effects of diesel exhaust particles (DEP) in airway/lung injury model

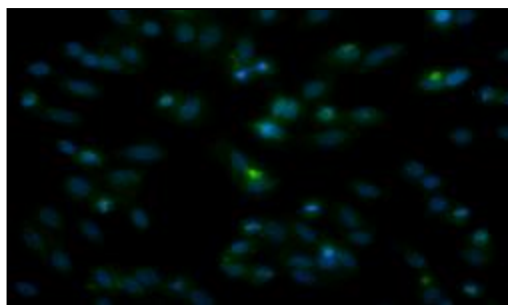


Relevance: Healing (post-infection)
Lung growth

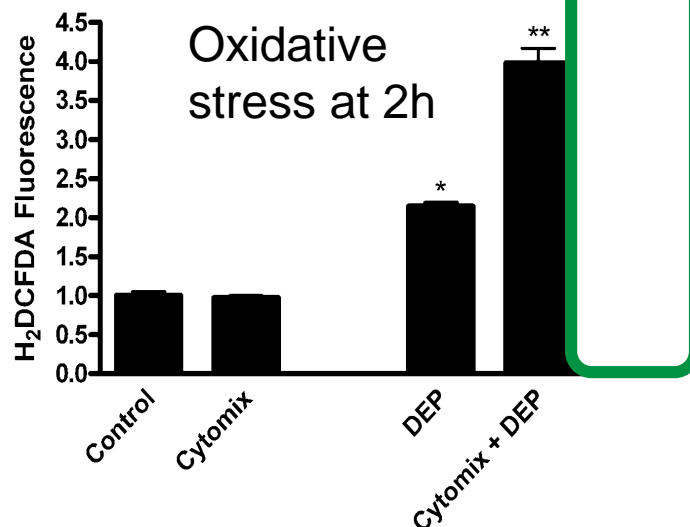
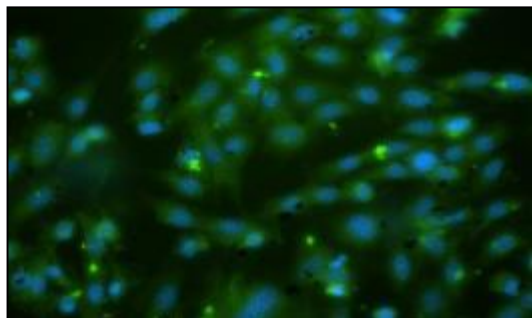
In vitro asthma (cytokine) model

Healthy/Inflamed lung cells

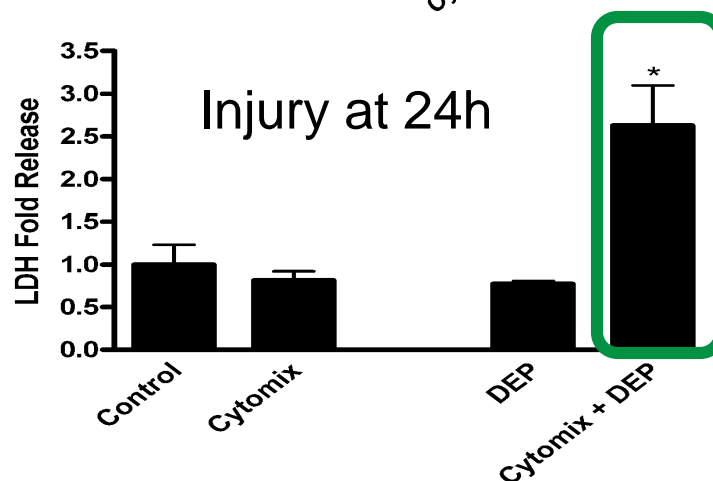
Saline-exposed



DEP-exposed



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



- ROS + RNS

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.

[Chen Z et al. J Thorac Dis. Review 2015](#)



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



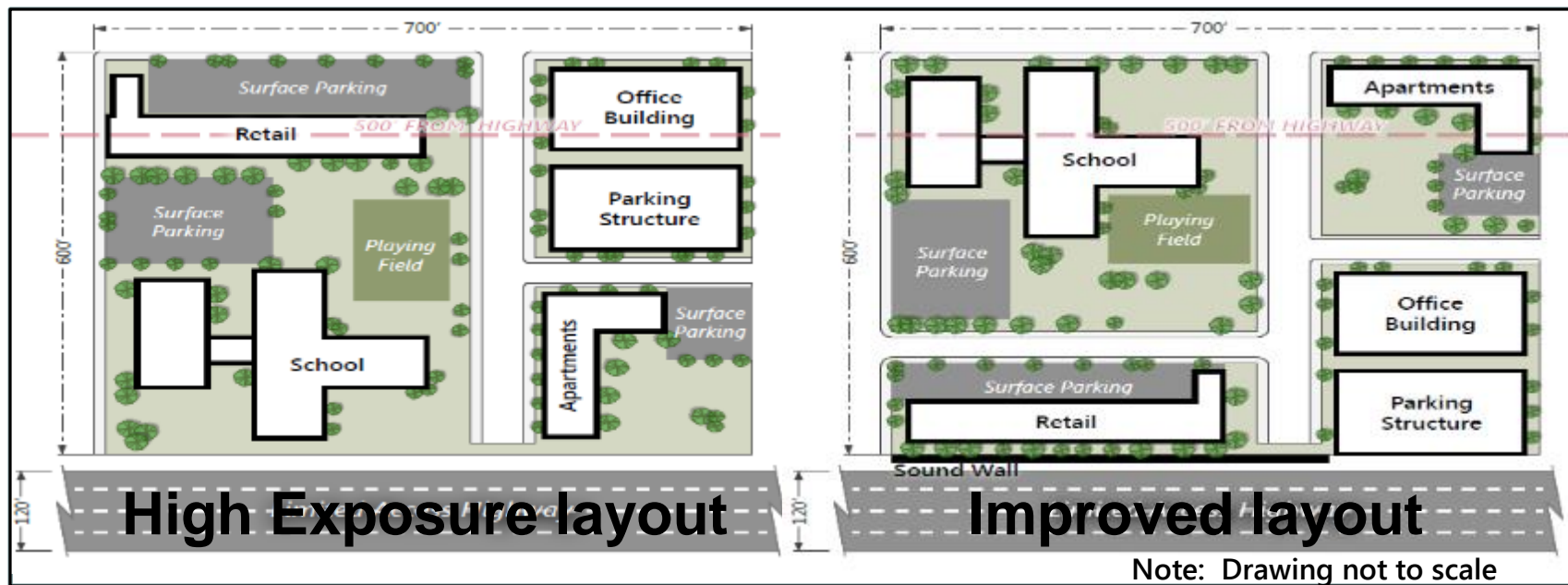
Vehicle Emissions and Activity Reductions

- 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



Land Use and Planning

- 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



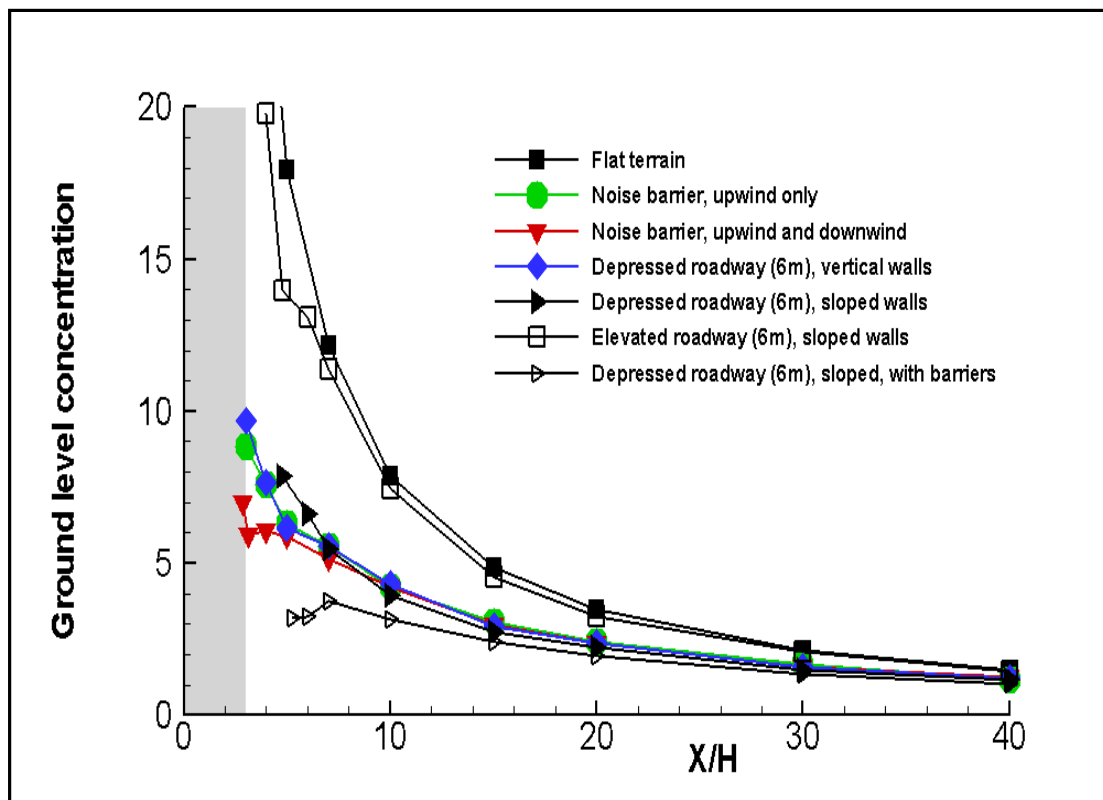
Roadway Design

- 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

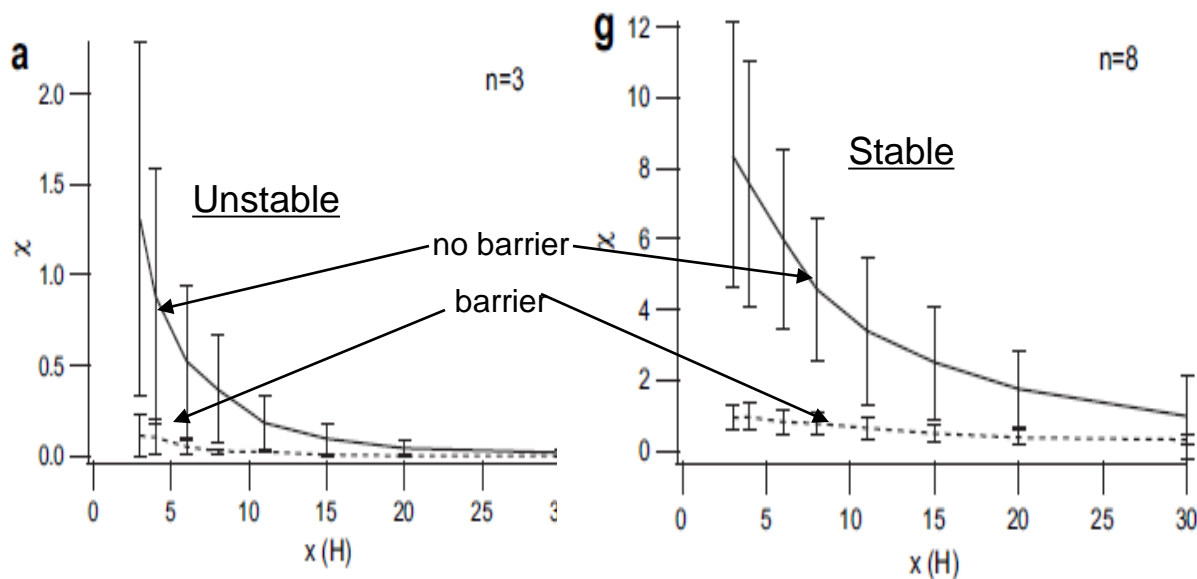
- EPA's Wind Tunnel Facility allowed for research on near-road pollution gradients
- Highest concentrations occurred near and away from the road when no obstructions were present
- Lowest levels occurred with noise barriers and roads below the surrounding terrain (cut or depressed)



(Baldauf et al., 2009; Heist et al., 2009)

Noise Barrier Effects

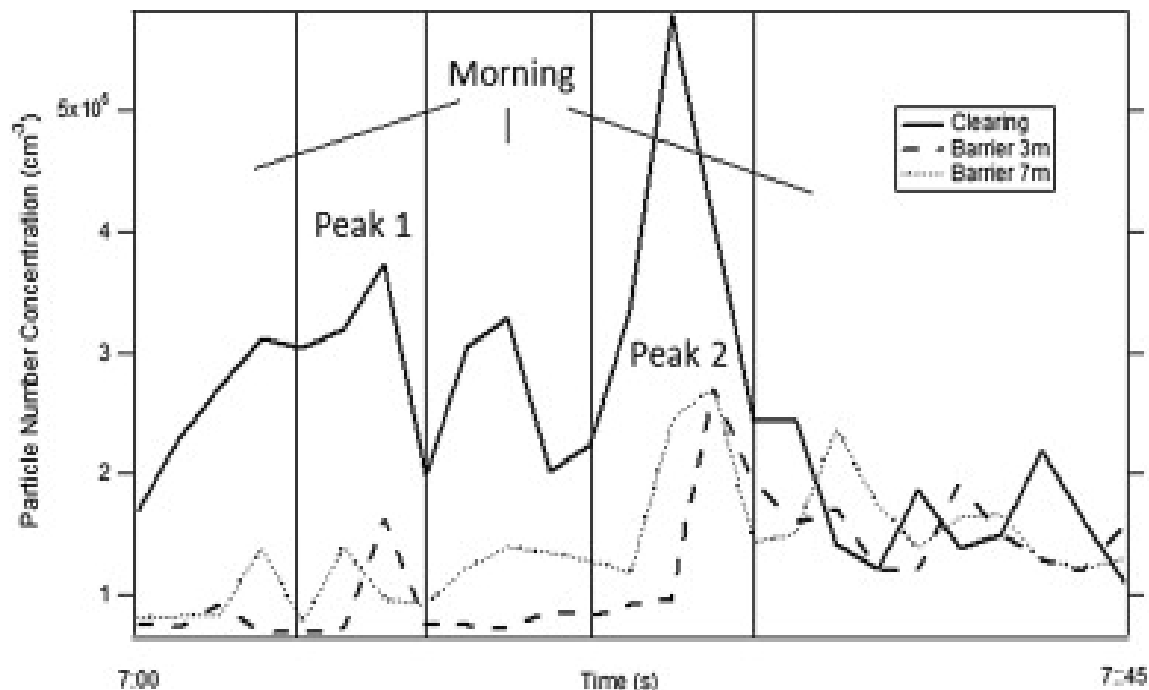
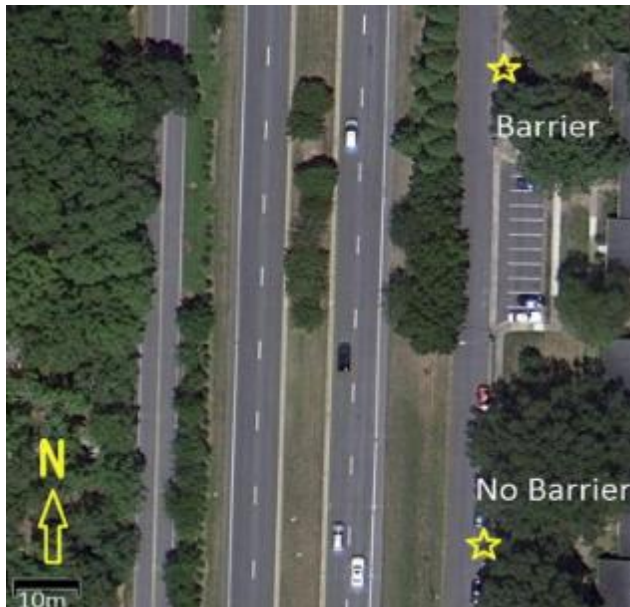
- EPA and NOAA conducted tracer gas studies to assess noise barrier impacts and develop computer models
- Noise barriers reduced air pollutant concentrations under all meteorological conditions



(Finn et al., 2010)

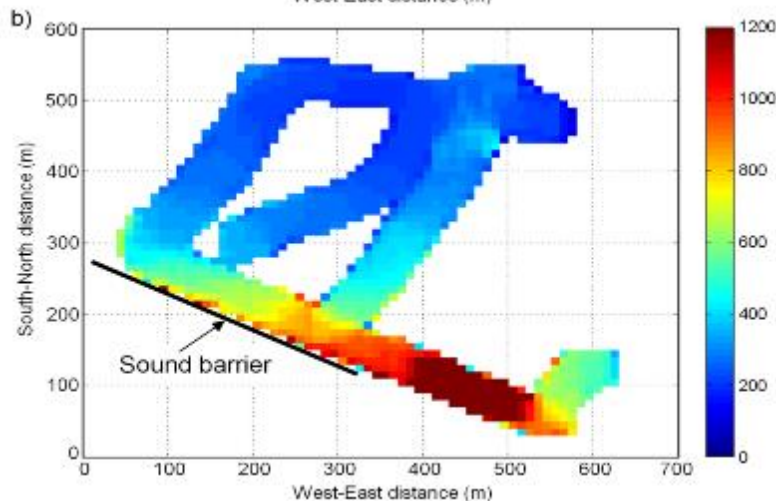
Vegetation Effects

(Steffans et al., 2011)

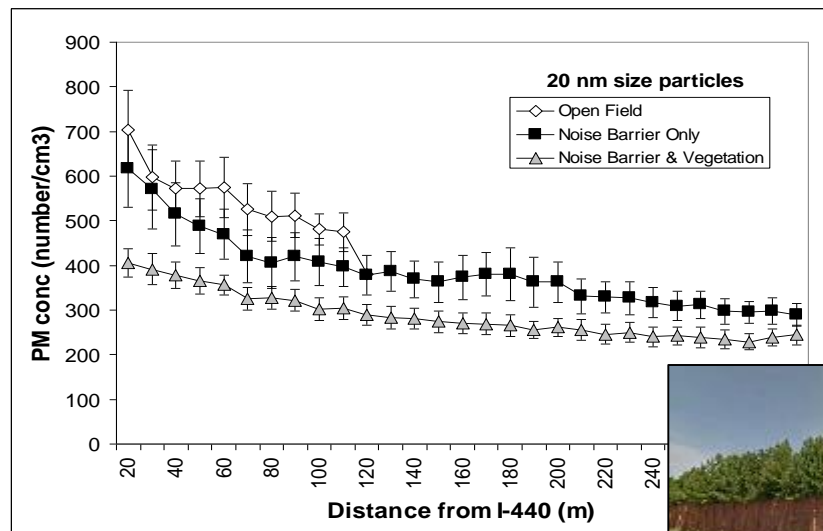


- Research has shown that roadside vegetation can reduce pollutant levels, especially for soot and other very small particles
- Higher reductions most often occurred closer to ground-level
- Variable winds caused variable effects

Noise Barriers and Vegetation

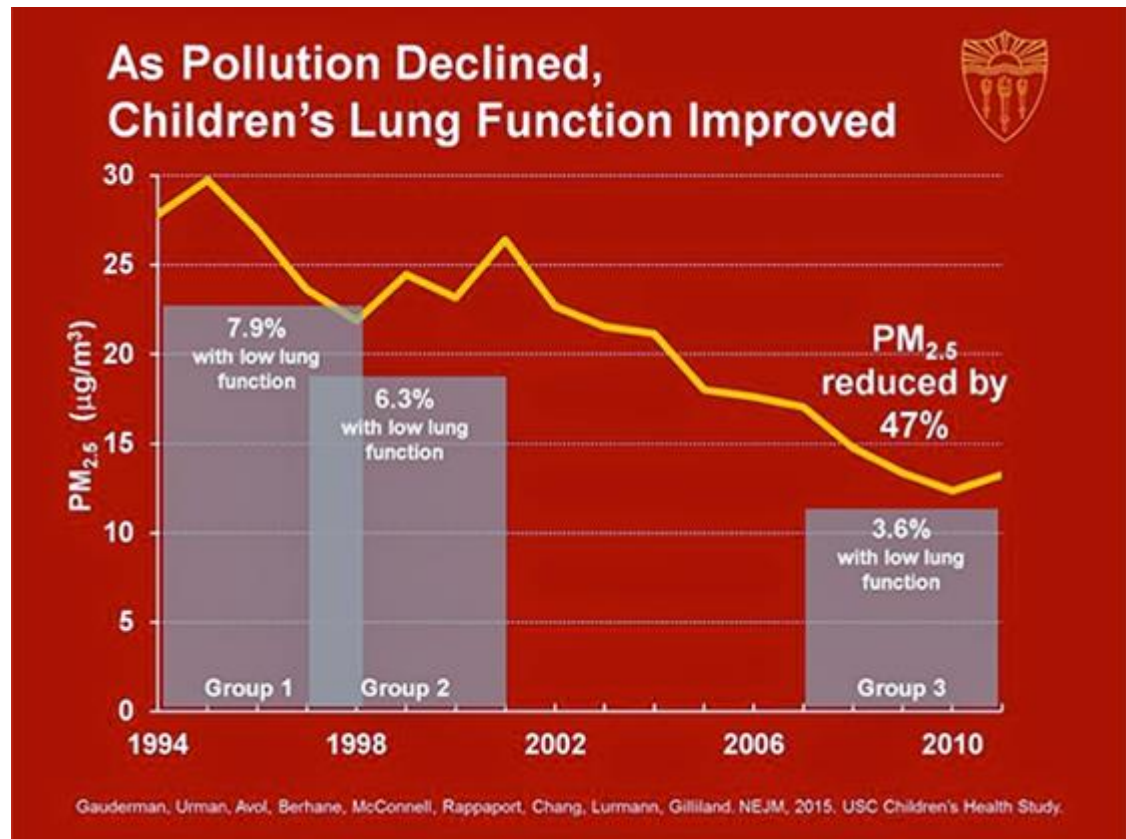


- Field studies have confirmed that noise barriers can reduced air pollution levels compared with a clearing
- Combining vegetation with solid noise barriers provided further pollution reductions, especially for airborne particles



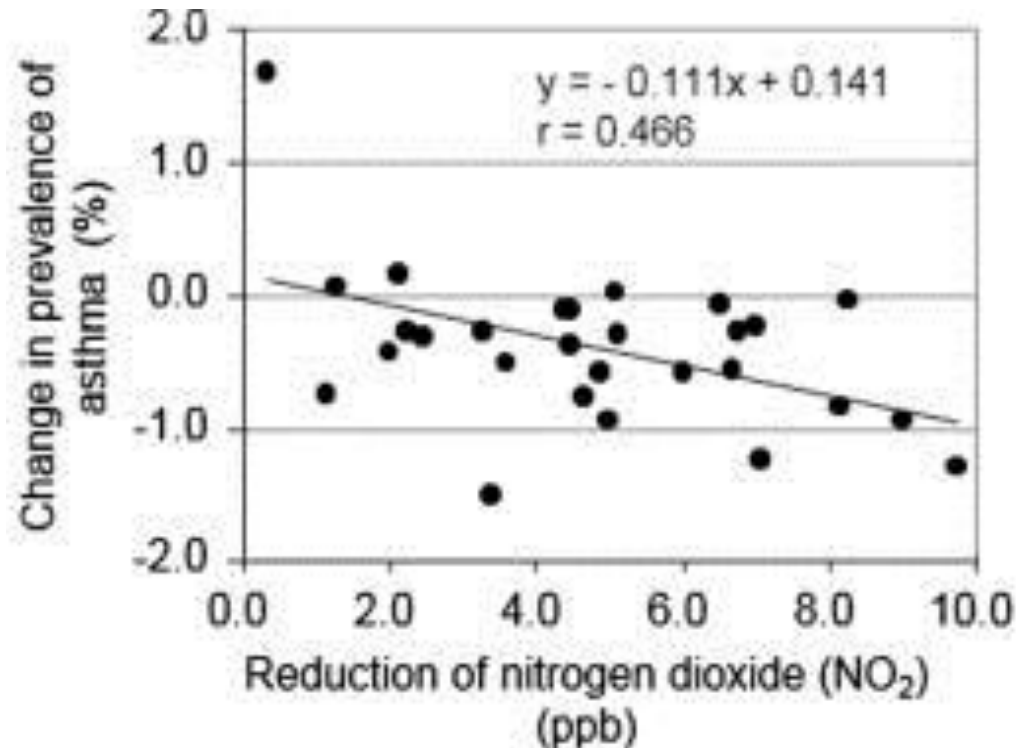
Observed Health Benefits of Mitigation

- 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

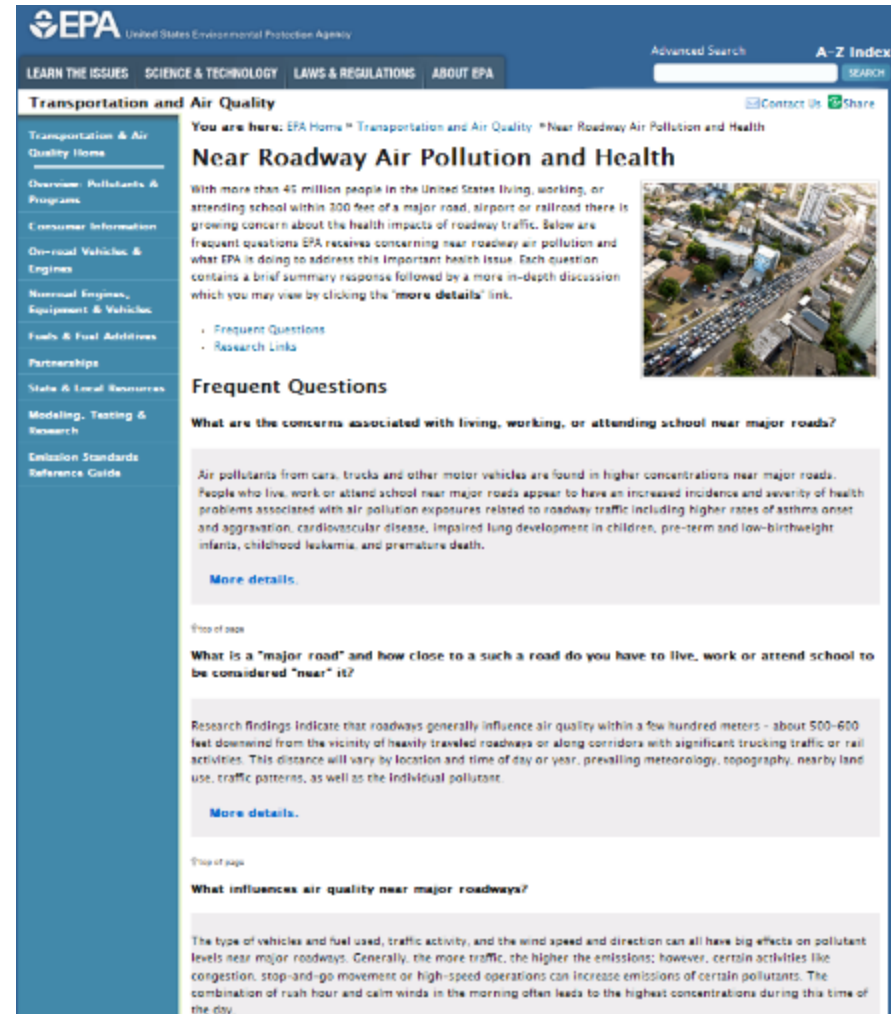


EPA Programs Relevant to Near-Road Air Quality

- 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

Near-Road Q&A Web Page

- 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



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

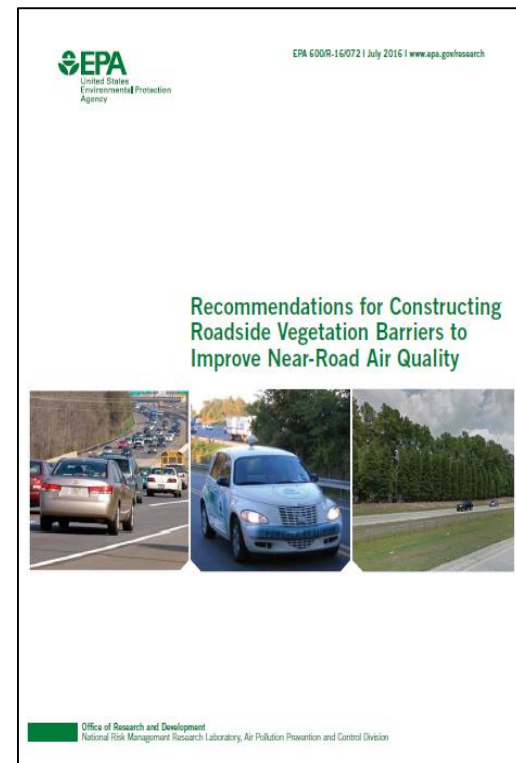
<https://www.epa.gov/schools/best-practices-reducing-near-road-air-pollution-exposure-schools>

- 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



Recommendations for the Design of Roadside Features

- 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
 - Avoid 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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