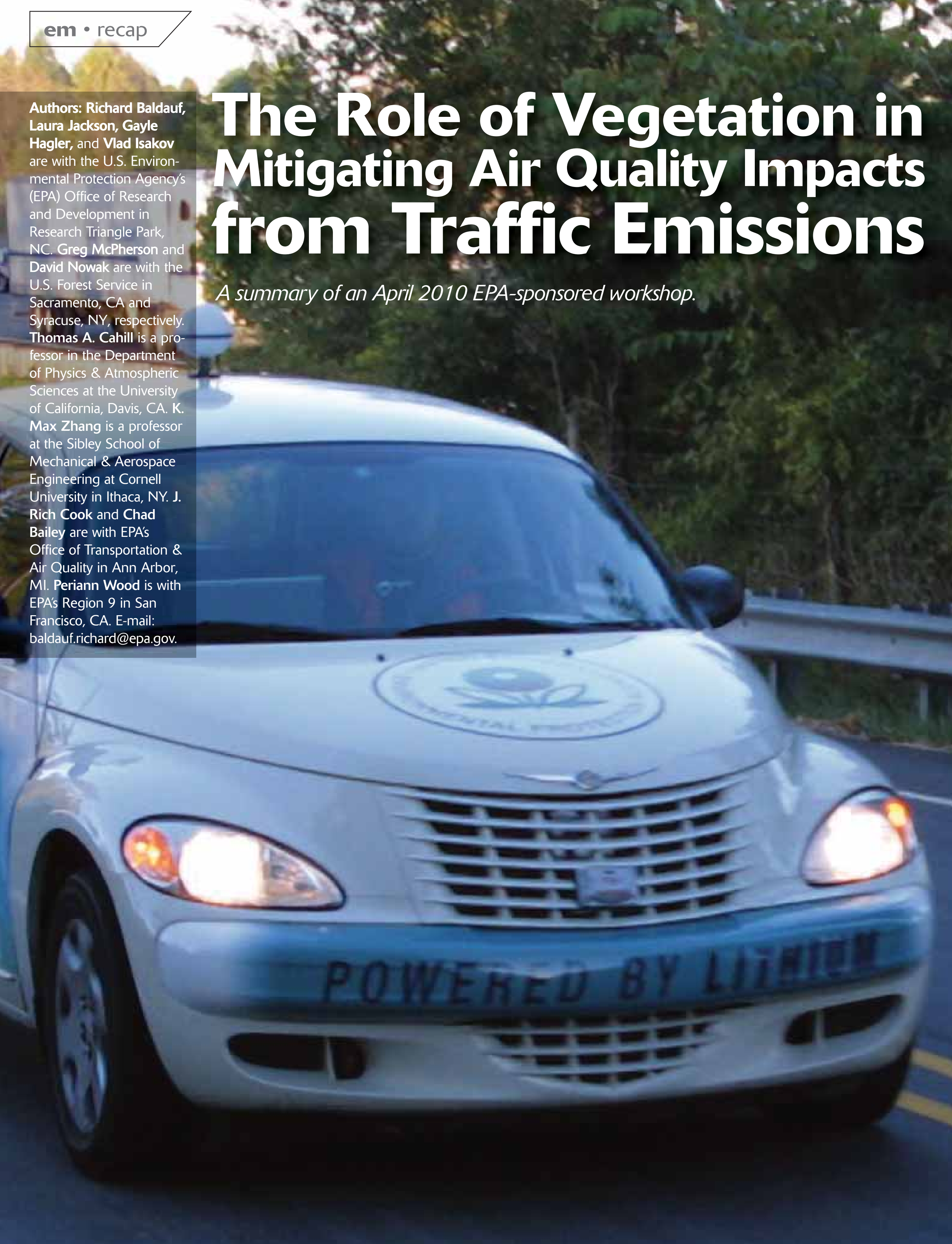

The Role of Vegetation in Mitigating Air Quality Impacts from Traffic Emissions

A summary of an April 2010 EPA-sponsored workshop.

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In April 2010, a multidisciplinary group of researchers and policy-makers met to discuss the state-of-the-science regarding the potential of roadside vegetation to mitigate near-road air quality impacts. Concerns over population exposures 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. A recent *EM* article described how roadway design, including the presence of roadside vegetation, may be a means of mitigating air pollutant concentrations near roads.[1] As a first step in evaluating this concept, representatives from government agencies, academia, state and local agencies, and nongovernmental environmental organizations with expertise in air quality, urban forestry, ecosystem services, and environmental policy reviewed the current science and identified future activities in evaluating the potential role of vegetation in mitigating near-road air pollutant concentrations.

Current State of the Science

General consensus exists that populations spending significant amounts of time near major roads face increased risks for several adverse health effects.[2] These effects may be attributable to particulate matter (PM), gaseous criteria pollutants, and air toxics. For PM, notable constituents of concern include ultrafine particles, coarse particles, metal constituents, and organic compounds.

Scientists discussed several studies that have measured and modeled the impacts of vegetative barriers on near-road air quality. Field and wind tunnel studies have observed trends of inert gases (e.g., carbon monoxide, CO) in the presence of a barrier to quantify dispersion-only-based impacts on near-road pollutant concentrations. For research on solid barrier impacts, which are assumed to have similar effects as dense vegetation, wind tunnel studies and a field tracer study revealed consistent reductions in ground-level concentrations behind barriers relative to a clearing with no barriers.[3,4] The presence of a barrier led to an increase in vertical mixing, resulting in lower behind-barrier concentrations at the ground level. In addition, field and wind tunnel studies investigated the potential for enhanced capture of PM by vegetation. Generally, these studies have shown decreases in concentrations of ultrafine[5,6] and coarse[7] mode PM, with limited reductions measured for $PM_{2.5}$ mass. PM concentrations under certain meteorological conditions could be higher behind a vegetative barrier than on the roadside as identified for CO concentrations behind a solid noise barrier.[5]

Current Gaussian-based atmospheric dispersion models (e.g., AERMOD) are not parameterized to resolving the complex flow patterns introduced by roadside barriers. Researchers have used Computational Fluid Dynamic (CFD) models to simulate the impacts of vegetation barriers on plume dispersion near roads. CFD models use finite difference and volume methods in two- (2D) or three-dimensions (3D), and vegetative barriers are typically treated as porous media. Two modeling studies simulated the impact of roadside vegetation on near-road air quality: a 3D model developed to match a wind tunnel model[3] and a 2D model with meteorology inputs matching a past field study in Los Angeles.[8]

Initial simulations for these two models produced differing results—for a solid barrier case study, the 3D model revealed significant reductions in downwind inert pollutant concentrations in the presence of the barrier due to enhanced turbulence and mixing. The 2D model suggested that, under low wind speed conditions, concentrations can be higher on the downwind side of a vegetative or solid barrier, at further distances from the road, than would have occurred without a barrier. For this modeling, the traffic emissions were forced up and over the barrier, with the plume remaining mainly intact until the plume returns to ground-level, leading to higher concentrations further downwind. Thus, the 2D model suggested that, under certain meteorological conditions, near-road barriers may result in higher exposures for populations at further distances from the road than would occur if a barrier was not present. In addition, the 3D model showed that behind-barrier emissions, such as from vehicles on an access road, can lead to high concentrations immediately behind the barrier.

EPA's mobile monitoring vehicle collects air quality measurements behind a stand of vegetation located adjacent to a large highway.

Finally, modeling vegetation in extremely dense development, such as street canyons, has also shown generally lower concentrations on the windward side, but higher concentrations on the leeward side of the street canyon.[9,10] Overall, CFD modeling generally agreed that local meteorology and site design were critical factors affecting air quality impacts around roadside vegetative barriers.

Co-Benefits and Dis-Benefits

Urban forestry and landscape ecology considerations offer insights on potential additional advantages and disadvantages of implementing vegetation to mitigate near-road air quality impacts. Vegetation in urban settings can provide numerous benefits beyond air quality improvements, including temperature[11] and stormwater[12] regulation, noise reduction,[13] aesthetic improvements, and opportunities for physical exercise[14] and nature experience.[15] These co-benefits, known as ecosystem services, have been associated with improved physical[16] and mental[17] health and community vitality.[18] Positive associations between physical or visual access to green space and personal health have been observed particularly in children,[19] the elderly,[20] populations with limited mobility,[21] and families in military[22] and low-income housing.[18] The services provided by urban vegetation can yield significant concomitant economic returns, such as energy and medical costs averted, increased worker productivity, and increased property values.

The U.S. Forest Service has developed tools called "i-Tree" (www.itreetools.org) to quantify multiple benefits of urban vegetation, including the filtration of air pollutants. The algorithms for this benefit address atmospheric pollutants transported and deposited upon the tree canopy at the urban-scale, and not the horizontal capture of localized roadway emissions. Nevertheless, the Forest Service can apply information about the filtration capacity of vegetation types to near-road dispersion models. Additional benefits addressed with i-Tree include carbon storage and energy savings at the urban-scale, and water filtration and storage at the watershed-scale.

Potential dis-benefits may also be associated with near-road vegetation. Issues of concern include pollen production, water demand, channeling of invasive pests and fire into the urban environment, and exacerbation of sprawl by distancing buildings and other land use activities from roadways. Trees may also obstruct visibility on the road, cause damage or injury by falling, and create slippery conditions from dropped debris. Consideration of environmental and landscape contexts is critical to minimizing dis-benefits related to barrier design and vegetation type. Ideally, a large suite of costs and benefits would be evaluated in concert to optimize the use of urban vegetation to protect human health and promote sustainable, vibrant communities.

Policy Considerations

Workshop participants agreed that further exploration of the use of vegetative barriers to mitigate adverse air quality is worth pursuing; however, care must be taken in both communicating the potential benefits of such a program and implementing this approach as a mitigation strategy. This approach should be viewed as one component of a set of mitigation strategies that need to be considered in addressing near-road health concerns. Caution was expressed that near-road vegetation may be used for "green-washing," justifying road expansion over transportation and urban design alternatives and reducing efforts to control vehicular emissions.

Participants also agreed that planting vegetation as a mitigation strategy may be most useful along existing roadways. For new and widened roadways, retaining existing vegetation is an important consideration. While vegetation within a highway's right-of-way is frequently restricted for safety reasons, state departments of transportation use planting for other aims (e.g., erosion control) and measures on adjacent land may be feasible alternatives.

For More Information: The Web site, www.epa.gov/nrmrl/appcd/nearroadway/workshop.html, contains files of the presentations from this workshop that provide more detail on the issues and next steps summarized in this article. The Web site also contains a list of participants and contacts for more information.

Next Steps

Workshop participants identified a broad range of research needs and activities to further assess the role of vegetation in mitigating air quality impacts from traffic emissions. These included steps to refine current research programs and methods to evaluate long-term trends under variable conditions (e.g., seasons, meteorology, vegetation state) using standardized methods; understand traffic emission behavior and pollutant interactions with varying vegetation types and characteristics; determine the effectiveness of vegetation barriers with different roadway sources (e.g., highways, arterials, intersections, freight movement); identify how receptor issues affect vegetation's effectiveness at mitigating pollutant impacts; determine the potential for inclusion of roadside vegetation in near-road studies of exposure and health; and evaluate overall near-road effects on urban agriculture.

Actions to support assessments were also discussed, including identifying audiences, partners, and initiatives to steer future research and implementation; developing best-practices documents; enhancing existing air quality assessment tools with the ability to account for vegetation effects; quantifying co-benefits and dis-benefits of vegetative barriers; documenting mitigation effectiveness with accountability studies; and quantifying optimal physical design of near-road vegetative barriers for varying site conditions. **em**

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