Effectiveness of Sound Wall-Vegetation Combination Barriers as Near-Roadway Pollutant Mitigation Strategies

I. Objectives

The objectives of the project are to obtain field measurement data in California to evaluate the impact of different features of sound walls in combination with vegetation, on levels of traffic pollutants (fine particular matter, ultrafine particles, black carbon, oxides of nitrogen, carbon dioxide, and carbon monoxide) at varying distances from the roadways, including any potential increased concentrations resulting from the use of the barriers. The project will identify different features of sounds walls in combination with vegetation that minimize the exposures from roadway pollution in residential areas located near heavily trafficked roads and freeways under different physical and meteorological conditions. The goal of this research is to provide information that can be utilized by the Air Resources Board (ARB) to advise local planners, agencies, and developers on effective measures to mitigate exposures for residents near highly trafficked roadways.

II. Background

The Sustainable Communities and Climate Protection Act of 2008 (SB 375) and other State and local policies and programs are encouraging infill development in urban areas that may result in increased residential development near busy roadways. However, exposure to traffic emissions has been associated with a variety of serious health impacts in epidemiological studies, including exacerbations of respiratory and cardiovascular diseases, increased asthma and bronchitis in children, and increased risk of premature death. Children appear to be particularly vulnerable to the adverse effects of traffic emissions. Traffic pollutant concentrations near high traffic roadways have been found to be 2 to 10 times higher than levels at a distance from the roadways. Also, recent studies have shown elevated traffic pollutant levels at greater distances from the roadway than previously measured.

The State's current set-back requirement for schools (500 feet [ft.]; PRC 21151.8) and ARB's recommendations on siting for housing and other sensitive uses (e.g., 500 ft. from major roadways and 1000 ft. from busy distribution centers and rail yards; (CARB, 2500a)) are intended to help protect the public from exposure to traffic emissions. Various building and site mitigation approaches have been examined as potential additional means to further reduce exposure to traffic pollution near roadways in addition to the reductions in exposure achieved by set-backs. A review by ARB staff found that high efficiency filtration and reduction of indoor sources appeared to be effective measures.

Additionally, sound walls were found to reduce near roadway pollutant concentrations (within 15-20 m [49-66 ft.]) up to about 50 percent (Baldauf et al., 2008; Bowker et al., 2007; Hagler et al., 2012; Ning et al., 2010). However, higher levels of pollution were seen behind the barrier and at a distance from the sound walls and roadways, although in some of these studies the higher levels appeared to be related to other sources of pollution (Baldauf et al., 2008; Bowker et al., 2007; Hagler et al., 2012; Ning et al., 2010). In one of the few field measurement studies of sound walls, conducted along two Southern California freeways, Ning et al. (2010) found that concentrations at farther distances were typically greater for the portions of the roads with sound walls. Modeling and tracer studies (Finn et al., 2010; Heist et al., 2009) showed that barriers reduced air pollution downwind of the barrier, although in some cases trapping of pollution and increased levels on the road occurred (Finn et al., 2010; Hagler et al., 2011). Nearby buildings and structural barriers can also affect the attenuation and dispersion of pollution from roadways, but results vary with different meteorological conditions (Bowker et al., 2007; Hagler et al., 2012; Hagler et al., 2010).

Results for vegetation alone are more highly variable than those for sound walls, and reliable estimates of reductions have not been identified. Modeling studies have shown that vegetation may restrict dispersion and increase concentrations on-road in street canyons with closer spacing of trees, particularly in low wind conditions (Buccolieri et al., 2009; Gromke, 2011; Gromke & Ruck, 2007, 2009). In another study, investigators found different results depending on particle size and wind speed, and a non-linear increase of particle removal with increased leaf area density, which varies by tree species and season (Steffens et al, 2012). Gaps in vegetation barriers can have a significant negative impact on their effectiveness (Hagler et al., 2012), a critical factor in California because California roadside vegetation tends to be less dense than that in the eastern U.S., where most of the previous field studies have been conducted. Also, some types of vegetation can trigger asthma and allergy attacks, and some emit reactive volatile organic compounds (VOC) that contribute to the formation of ozone. These factors need to be considered in California if vegetation is to be considered for possible exposure reduction.

A combination of sound walls and vegetation used together has been shown to disperse pollutants more consistently and to greater distances than either alone, with up to about a 60 percent reduction in near roadway levels (Baldauf et al., 2008; Bowker et al., 2007).

Thus, while sound walls alone and sound walls combined with vegetation show promise, the increase in concentrations on-road and at a distance seen in some studies can result in increased exposures in those areas. Thus, these measures can redistribute, rather than remove, pollutants. Research is needed that identifies the specific conditions under which sound walls in combination with vegetation can consistently provide a reliable exposure reduction benefit while not increasing the burden of exposures to those living at a greater distance from the barrier. In particular, California field studies are needed because of the significant differences in California meteorology, building practices, and types of vegetation used, compared to those of the eastern U.S., and to confirm and refine validated models in literature estimates.

III. Scope of Work

This project will build on the sparse existing literature of the effects of sound walls with vegetation in California by obtaining measurement data that identify features which impact the level of exposures for residents near heavily trafficked roads. The study will provide reliable information on ambient pollutant concentrations for residents living near-road and at a distance from the roadway. In order to achieve these objectives the investigators will develop a detailed work plan in consultation with ARB staff, which will contain the following elements:

- A literature review on the impacts of sound walls and sound walls in combination with vegetation on near-roadway pollution and health. The different methods and techniques used to study the impacts of sound walls and sound walls in combination with vegetation should be investigated to aid in developing the final study design.

- Identification of the properties of roadways and roadside sound wall-vegetation combinations near residential areas, under different physical and meteorological conditions. Structural details of sound wall-vegetation combinations and roadway configurations, such as elevated and below grade roadways, will be examined to determine that the sites selected for study are representative of sound wall-vegetation combination and roadway properties in the air basin.

- Identification of at least three sites in different geographical areas of California. Ideally the combination of sound wall and vegetation buffer, as well as an adjacent roadside area without a barrier for comparison, will be located along the same roadway with similar traffic patterns and physical features. Sites with sound walls alone can be included for comparison purposes, if funding is available.

At a minimum, the factors listed below need to be considered during site selection:

  - Sites should be selected to be representative of roadside barriers likely to be feasible in residential areas. Sites will be selected in consultation with ARB.
  - The presence of a nearby high traffic volume freeway with well-characterized, reasonably predictable traffic volume flow characteristics is needed.
  - Avoid sites that have nearby structures or additional sources that will impact the transport and dispersion of pollutants emitted by the nearby traffic.
  - A suitable nearby fixed site for multiday meteorological monitoring is needed.
  - A suitable freeway orientation roughly perpendicular to consistent prevailing wind direction is needed for repeatable day to day exposure impacts.
  - Suitable sampling sites at varying distances from the freeway must be available.

- A pilot study of at least one of the candidate sites to test and finalize sampling methods and protocols. The selected site will be monitored under similar meteorological conditions for multiple pollutants in the multi-day pilot field study. The results of the pilot study must be reviewed and the final standard operating procedures (SOP) and sampling plan must be approved by ARB before conducting the study at the selected sites.

- The sampling must include, at a minimum, the following real-time field measurement data on multiple days, and during different commute periods for (1) Traffic-related pollutants: fine particular matter (PM2.5), ultrafine particles, black carbon, oxides of nitrogen, carbon dioxide, and carbon monoxide; (2) Meteorology data: wind speed and direction, temperature, and humidity; (3) Traffic activity patterns: traffic volume and speed, and fleet mix; and (4) Noise measurements to ensure that the sound walls are achieving their intended purpose. An additional option is the real-time measurement of polycyclic aromatic hydrocarbons, elemental carbon and organic carbon, and PM10.

- Development of a detailed sampling approach that includes upwind and downwind sampling. The downwind sampling must cover a range of distances from the freeway. Also, the investigators will develop a QA/QC plan and a data analysis plan that fully utilizes the data obtained to identify the sound wall-vegetation barrier characteristics that effectively reduce nearby concentrations and those that lead to increased concentrations.

- A field study at the selected and approved sites using the SOPs developed and tested in the pilot study, including data preparation and validation of the measurement data.

- Data analysis and preparation of draft and final reports.

IV. Deliverables

- Quarterly progress reports
- Final report
- Validated measurement data collected from this study and other related factors will be provided to ARB by the end of the study.

V. Timeline

It is anticipated this project will be completed in 36 months from the start date. Note that this allows 30 months for completion of all work through delivery of a draft final report; the last 6 months are for ARB and RSC review of the draft final report and delivery of a revised final report and data files to the ARB.

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