1.5 NOAA EPA Near-Roadway Sound Barrier Atmospheric Tracer Study 2008

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Abstract A roadway toxics dispersion study was conducted at the Idaho National Laboratory to document the effects on concentrations of roadway emissions behind a roadside sound barrier in various conditions of atmospheric stability. The key finding was that reduced concentrations were measured behind the barrier in all stability conditions. It was also found that the magnitude of the concentration footprint behind the barrier was tied to atmospheric stability and that the roadway tended to trap high concentrations during light wind speed conditions.

1. Introduction

Numerous studies have found that living and working near roadways are associated with a wide range of pathologies arising from the elevated levels of pollution associated with vehicular emissions (e.g. Baldauf et al. 2008a). Given that noise barriers and vegetation are now common roadside features it is pertinent to ask what effect they might have on pollution levels adjacent to roadways. Many studies have examined this issue. Some of these studies suggest that a barrier results in a well-mixed zone with lower concentration extending downwind behind the barrier (e.g. Baldauf et al. 2008b; Nokes and Benson, 1984; Bowker et al. 2007).

Some uncertainties persist, however, regarding the effects of roadside noise barriers on pollutant concentrations in surrounding areas. Specifically, the role of atmospheric stability has not been investigated in any systematic manner. Wind tunnel studies are done in neutral stability conditions and most of the field experimental work has been done during the daytime. Furthermore, much of the field work has been done in "natural" settings featuring moving traffic and the associated turbulence, potential variation in source strength, and irregular distributions of canopy elements and flow obstructions. All of these can considerably complicate the interpretation of results.

The Field Research Division (FRD) of the Air Resources Laboratory (ARL) of the National Oceanic Atmospheric Administration (NOAA) conducted the Near Roadway Tracer Study (NRTS08) experiment during October 2008. NRTS08 was designed to quantify the effects of roadside barriers on the downwind dispersion of atmospheric pollutants emitted by roadway sources (e.g. vehicular transport). Pollutant transport and dispersion were measured during the field tests using sulfur hexafluoride (SF_6) tracer gas as a pollutant surrogate. The goal of the study was to produce a roadside barrier dataset that (1) covered a range of atmospheric stabilities, (2) minimized factors that could complicate data interpretation, and (3) could be used to guide model development.

2. Methods

Roadway emissions were simulated by release of an atmospheric tracer (SF_6) from two 54 m long line sources in unstable, neutral, and stable conditions. A 90 m long, 6 m high mock sound barrier constructed of straw bales (Fig. 1) was installed on one grid while the other grid had no barrier. Simultaneous tracer concentration measurements were made with real-time and bag samplers on the identical sampling grids downwind from the line sources at 1.5 m above ground level. An array of 6 sonic anemometers was employed to measure the barrier-induced turbulence. The pristine environment of the INL enabled a clearer and less ambiguous interpretation of the data.

3. Results

Figure 2 compares barrier and non-barrier normalized tracer concentrations for a 15-min period in neutral conditions. Figure 3 is a contour map of the ratio between barrier and non-barrier concentrations at corresponding grid locations for the same neutral case. The barrier had the effect of reducing downwind concentrations by more than 50%. This pattern was repeated consistently in all stability conditions.

Briefly, other key findings of the study include: (1) the magnitude of the concentration footprint expanded or contracted in stable and unstable conditions, respectively, and (2) very high concentrations were measured in the roadway upwind of the barrier in stable, light wind speed conditions.

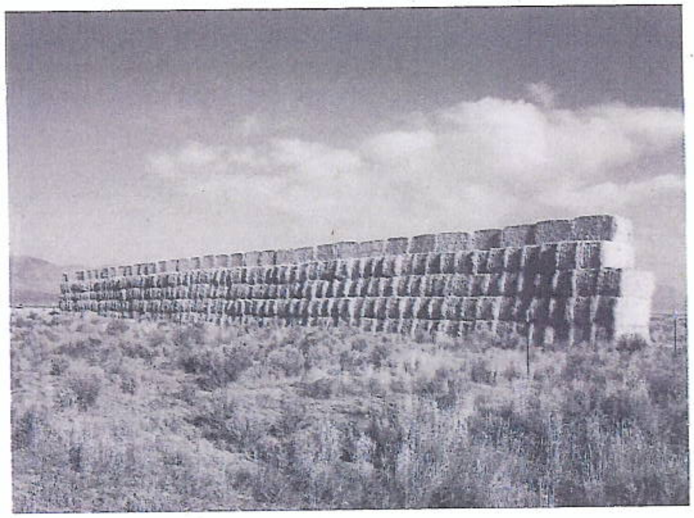

Fig. 1. Straw bale mock roadside sound barrier.

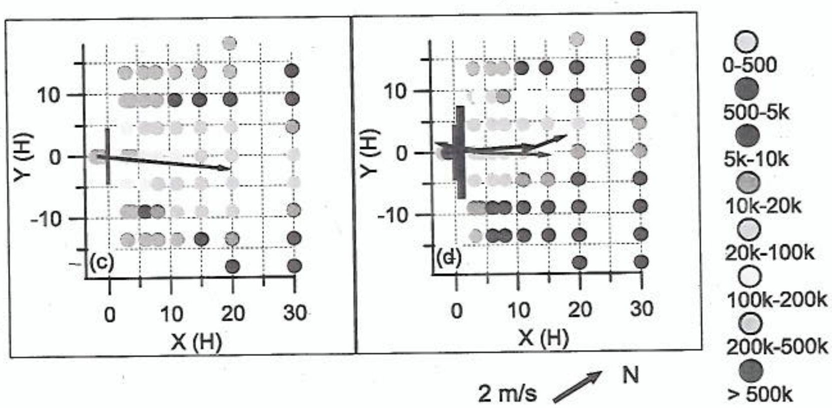

Fig. 2. Corresponding non-barrier (left) and barrier (right) normalized concentration/wind vector maps for an example neutral stability case. The tracer release line is indicated in bright red; the barrier in bold black.

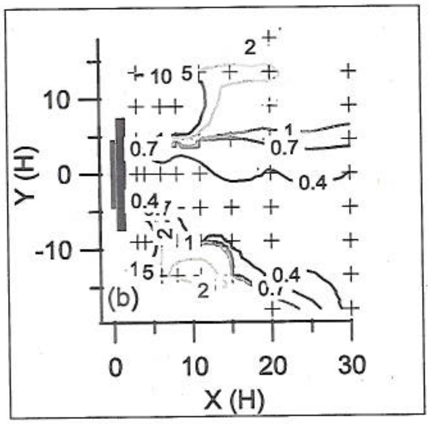

Fig. 3. Contour map of the ratio between barrier and non-barrier concentrations at corresponding grid locations for the neutral stability case shown in Fig 2.

Acknowledgments and Disclaimer We wish to thank Alan Vette and S.T. Rao from the EPA and Shane Beard, Tom Strong, and Neil Hukari from FRD for the contributions they made to the study. This work was completed under Interagency Agreement DW-13-92274201-0 between the National Oceanic and Atmospheric Administration and the U.S. Environmental Protection Agency. Although it has been reviewed by EPA and NOAA and approved for publication, it does not necessarily reflect their policies or views. U.S. Government right to retain a non-exclusive royalty-free license in and to any copyright is acknowledged.

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4. Questions and Answers

Steve Hanna: How did you decide on how long the barrier would be, and wouldn't the results depend on this length? Was this investigated by the EPA wind tunnel tests?

Answer: We were concerned about having a barrier long enough to ensure that edge effects would be minimal or nonexistent. We used the EPA wind tunnel study to guide us in determining the length of the barrier. Obviously, an infinite length barrier would have been ideal. Construction costs ultimately limited the length to 90m. In some of the test periods, edge effects were visible when the data were plotted as shown in Figure 2 above. However, in the majority of individual tests periods, which is when the wind was essentially perpendicular to barrier, edge effects were usually negligible. This is demonstrated by the fact that the areas of peak concentrations were located behind the barrier, even if not directly centered. It was when the peak concentrations were clearly located outside the y-bounds of the barrier that edge effects became more of a factor. In summary, the barrier proved to be long enough that several sampler locations on each crosswind sampling line in the direct downwind influence of the barrier did not show edge effects. The next step is to knit the concentration fields together to produce a result that would be expected from an infinitely long barrier. Our EPA colleagues demonstrated this technique in the wind tunnel study report.

Peter Builtjes: The effect found of the barrier is larger than I recall from CFD calculations. What is your experience with that?

Answer: The decreases in tracer concentration we measured behind the barrier were in the upper range of decreases reported in previous field studies, which was typically 50-60%. In some of our individual experiments we observed decreases greater than that although this was often associated with clear edge effects. We commonly observed decreases of 50-60% even when there was little evidence of any significant edge effects. The EPA wind tunnel results were also similar to our results. Therefore, it seems reasonable to conclude that the tracer concentrations from our field study are accurate.

Clemens Mensink: Some CFD models do show an increase of concentrations in the vertical direction behind the barrier. Do you have any information on the concentration distribution in the vertical direction?

Answer: We desired to investigate the tracer concentration distribution in the vertical direction, but were limited by funding constraints to only ground-level concentrations, i.e., 1.5 m AGL.