API Comments on EPA's Second Draft of the NO_2 NAAQS Review REA: Part 2

Chapter 8: Exposure Assessment and Health Risk Characterization

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Introduction

On behalf of the American Petroleum Institute (API), ENSR reviewed Chapter 8 of the Second Draft of the REA for the primary NAAQS for nitrogen dioxide (NO_2). ENSR's review focuses on the modeling and statistical methods to estimate ambient concentrations in the context of evaluating human exposure. The major findings of our review are as follows:

- EPA has not demonstrated that the AERMOD modeling methodology it applied in either the Atlanta or Philadelphia studies can reliably estimate peak 1-hour NO_2 concentrations, especially from the key outdoor source category involving roadway emissions.
    - Comparison of the frequency distribution of modeled and measured concentrations indicate a consistent and substantial bias toward overestimation of peak and high percentile NO_2 1-hour concentrations near roadways.
    - Comparison of diurnal patterns establishes that overprediction occurs on a daily basis in the early morning and early evening and that the model compares well with ambient measurements only during mid-day hours when NO_2 concentrations are lowest.
    - AERMOD still needs development and enhancements to be able to reliably predict peak short-term NO_2 concentrations near roadways.
    - Based on Chapter 8 evaluation results, the EPA modeling procedures were found to predict ambient peak 1-hour NO_2 concentrations that are on the order of a factor of 2 too high. Peak annual averages are overpredicted by at least 50%.
    - The application of AERMOD to estimate peak short-term NO_2 concentrations on roadways, i.e., with receptors within the simulated line sources, has no evaluation history.
    - Comparison of the AERMOD roadway estimates with estimates based on empirical extrapolation of NO_2 measurements indicate consistent overestimation.

- As noted previously by API, it is incorrect and unrealistically conservative to apply the roll-up method in the exposure assessment to estimate 1-hour NO_2 exposure when the present annual NAAQS is just met.

- The consistent overpredictions resulting from the AERMOD modeling EPA used to estimate 1-hour NO_2 concentrations on roadways and the ambient air and the problems with the use of the simple roll-up method for NO_2 create serious implications for the adequacy of the computations in Chapter 8 related to exposure and risk due to outdoor sources of NO_x.

Specific Comments

8.1 Overview (Page 1, Line 15)

Chapter 8 describes an exposure assessment for Atlanta, but includes the first case study for the Philadelphia area from the first draft REA is in Appendix B. CASAC members and ENSR's May 29, 2008 review of the first draft REA identified substantial flaws in the Philadelphia modeling assessment, to the extent that it is unsuitable for evaluating exposure to short-term NO_2 concentrations. Among the issues identified for the Philadelphia study were the roadway emissions modeling procedures and the underestimates of airport emissions. Given that it does not appear that material changes, if any, were made to try to correct the Philadelphia exposure study, documentation of that flawed study should either be removed from the appendices of the second draft final REA or be flagged with the limitations associated with the modeling issues noted above.

8.3.1 Study Area Selection (Page 4, Line 15)

The REA text should note that Atlanta, with an annual average concentration of only 26.6 ppb, has only the16th highest annual NO_2 concentration among the metropolitan areas in the U.S. We have found that the extrapolation of annual to peak 1-hour NO_2 concentrations is least reliable for low annual averages. The fact that the present concentration is only about half of the present NAAQS makes extrapolation of 1-hour concentrations when the annual concentration just matches the NAAQS quite uncertain. ENSR's previous reviews of the first draft and the initial second draft REA (May 29, 2008 and September 26, 2008) indicated that the application of a roll-up technique to the annual average concentration substantially overestimates 1-hour concentrations in areas such as Atlanta where the ambient air quality is well below the present NAAQS. Thus, the evaluation of 1-hour exposures for the case where modeled air quality in Atlanta just-meets the NAAQS is subject to considerable error through overestimates of the resulting peak 1-hour concentrations.

8.4.2.4 Other AERMOD Specifications (Page 8, Lines 11-13)

EPA applied two conservative methods to simulate near-field conversion of NO to NO_2; for transportation sources, the Ozone Limiting Method (OLM), and for point sources, the Plume Volume Molar Ratio Method (PVMRM). Both methods compute transformed NO_2 based on coincident measured hourly ozone measurements. There are two basic reasons why these mechanisms overestimate hourly NO_2 concentrations in urban air sheds.

1) *Ozone Availability:* A portion of the ambient ozone concentration may have already been involved in the oxidation of NO to NO_2 due to NO emissions from other sources. In a standard AERMOD application, the NO emitted from individual sources all are assumed to come in contact with the measured ozone concentration. For this application, at least for transportation sources, an attempt was made to address this effect by grouping concentrations from multiple sources before applying OLM. However, the extent that this method was effective was not stated in the REA. The PVMRM was used for point sources, but these sources have a much smaller role in the Risk Exposure Assessment impact.

2) *Photochemistry:* Both the OLM and PVMRM are simplified parameterizations that do not account for the complex photochemical reactions that affect NO_2 concentrations. The implication is that NO_2, which is reactive, can be rapidly consumed in these reactions, especially in the presence of sunlight, hydrocarbons, ozone and other photochemical oxidants. During the night, the ambient ozone reacts with newly emitted and ambient NO to form NO_2. These complex reactions are not accounted for in dispersion models such as AERMOD which have simplified mechanisms. It is also likely from other field study findings (e.g., see Mulik and Philbrick, 2001 at http://lidar1.ee.psu.edu/neopsWeb/publicSite/papersandpresentations/ilrc2-km.pdf) that the available ozone in roadway areas is different spatially and temporally than that at ambient monitors placed away from roadways. Due to the continuous NO_x emissions from roadway sources, the available ozone for reacting with fresh NO_x emissions is depleted due to past NO_x emissions, especially in situations where the wind is along the roadway, so that fresh ozone is not being advected into the roadway. Therefore, the assumed ozone concentration used in AERMOD's OLM treatment may often be overestimated, which could (and did) lead to substantial overpredictions of NO_2 concentrations from roadway sources, especially for peak short-term impacts.

The combination of diurnally varying emissions, dispersion and atmospheric chemistry results in a typical diurnal pattern of the measured NO_2 concentrations shown in Figure 8-6 of Chapter 8, which, as indicated, AERMOD is not able to properly simulate.

8.4.5 Adjustment of On-road Mobile Source Strengths to 2002 NEI Vehicle Emissions (Page 15, Lines 15-23)

Emissions of vehicles from roadways were computed based on 2005 TDM data from ARC rather than 2001–2003 target years for the exposure assessment. Using these data with 2002 emission factors would inherently assume that traffic level and patterns for 2005 are also representative of the earlier period. Given the multitude levels of uncertainty in the assessment, this assumption is unlikely to invalidate the assessment. However, various methods could have been employed to spot check the validity of this assumption, for example, trends in measured traffic volumes, vehicle registrations, tolls, etc. Instead, EPA compared the modeled NO_x emissions for 2005 and then compared it with 2002 NEI NO_x emissions estimate to develop a correction factor of 0.78. The premise of this approach is that differences are accounted for by the difference in traffic counts, vehicle mix, speeds, etc. However, it is probably as likely that the difference is associated with intrinsic differences in how the 2002 NEI estimates were made versus the present approach. A more thorough review of how the 2002 NEI estimates were generated should be undertaken to assure that this method of adjustment is valid. If applying this method underestimates emissions from mobile sources, then the relative importance of point sources to ambient NO_2 concentrations would be overstated.

8.4.5 Stationary Sources Emissions Preparation (Page 17, Line 4)

EPA applied SCC-base temporal emission profiles to for six of the seven facilities to scale the 2002 NEI data. Given the small number of facilities involved, it would be better if more site-specific information could be readily obtained to ensure the accuracy of the assessment.

8.4.6 Airport Emissions Preparation (Page 17, Lines 11-29)

The characterization of the airport as a NO_x emission source is highly simplified and insufficiently resolved temporally and spatially to simulate 1-hour NO_2 concentrations near the airport. NO_x emissions from jet aircraft are highest and most relevant for ground-level impacts during take-off and climb-out, and during engine reversal upon landing when high thrust is required. Thus, as simulated by the FAA's Emissions and Dispersion Modeling System (EDMS), airport sources involving aircraft are simulated as a series of line sources, and emissions are typically accounted for within a 3000 ft mixing depth. Locations directly downwind of the runways will therefore experience the highest short-term concentrations. Receptors located in the vicinity of Atlanta-Hartsfield Airport are not likely to be accurately characterized by EPA's representation of the airport as a single area source.

8.4.7 Receptor Locations (Page 20, Line 1)

The analysis used 1/3 of the census blocks to represent ambient air and receptors on the roadway segments to represent the on-road environment. The estimation of hourly pollutant concentrations on a highway is highly complex and affected by the localized turbulent structure, which is affected by a variety of factors such as absolute and differential vehicle speed, traffic density and number of lanes as well as wind speed and direction relative to the roadway. Given that the near-field dispersion in AERMOD is simulated as an elongated area source with a Gaussian vertical structure, it is not clear that this idealized treatment is suitable to accurately estimate 1-hour average concentrations. To our knowledge, there have been no studies that have validated concentrations *in situ* , i.e., at receptors placed *within* an emission source. It is likely that such a simplified treatment could result in a substantial overestimation of concentrations because it is unlikely that the concentrations in the mixing zone conform to the idealized Gaussian structure. As stated above, another factor that is not considered is that the application of the OLM to simulate NO to NO_2 conversion inherently assumed that the plume of emissions is well mixed with the ambient atmosphere and that reactions occur instantaneously. Neither of these premises have been tested or verified in the REA. We would expect the ozone concentrations within the roadway envelope to be depressed compared to areas outside this region because of the continuous depletion of ozone by roadway sources. This situation is most important for large roadways with many lanes and high NO_x emissions. It follows that the OLM algorithm without an adjustment in the ozone concentration within the roadway envelope can substantially overestimate on-road concentrations of NO_2.

8.4.8.1 Comparison of Hourly Cumulative Density Functions (Pages 21-23)

EPA applied AERMOD to independently estimate NO_2 concentrations from four source categories and then added the modeled results together to estimate total NO_2. As noted above in the discussion of Section 8.4.2.4, conversion of NO to NO_2 through reaction with ambient ozone needs to evaluate the combined NO emissions form various sources to avoid “double-counting” the available ozone. For instance, because some of the ambient ozone is consumed to convert NO concentrations from major roadways to NO_2, there would be less ozone available to convert NO emissions from smaller adjacent roadways.

Another issue that we are concerned with is that the modeled results for all receptors within 4 km of each monitor were compared with monitoring data, which spans an unnecessarily large area and adds considerable uncertainty to the results. We are focusing our review upon the receptor placed at the actual location of the monitor as the appropriate means to evaluate the model’s performance. With this approach, the comparison of the hourly concentration distributions indicates that AERMOD overpredicts peak observed 1-hour concentrations by a wide margin. Even at the low-end estimate (2.5th percentile) receptor, the modeled concentration exceeds the monitored concentration.

8.4.8.2 Comparison of annual average diurnal concentration profiles (Pages 21-24)

The diurnal distributions point to the fact that AERMOD overestimates hourly concentrations on a daily basis, especially in the early morning and evening. To better diagnose this issue, a seasonal diurnal plot would be helpful because the timing of sunrise and sunset can mask the diurnal trends if results from a full year are shown. The comparison by season may also show that the model performance is better in winter with low ozone concentrations and worse in summer. Our concern with that possibility is that there is a higher likelihood for outdoor exposure to roadway emissions in summer rather than winter, but AERMOD’s overpredictions could be the highest in summer when the mischaracterization of the ozone concentration could potentially be maximized.

The agreement between measurements and modeling is better during midday probably because of the higher ventilation rate and atmospheric mixing. The high modeled concentrations near sunrise and sunset may reflect inadequate simulation of urban dispersion under stable conditions in addition to the highly conservative methods by which NO to NO_2 conversion is simulated. To separate the NO to NO_2 conversion from the total dispersion, EPA should consider showing evaluation results for full NO_x.

Figure 8-5 results show that for the highest cumulative percentiles, the short-term NO_2 predictions at the monitor location approach a value that is a factor of 2 higher than the corresponding ranked observation (the form of the plot makes this hard to see for the reader, however). Figure 8-6 shows that even on an annual average basis, there are sharp predicted diurnal peaks that are not matched by the observed diurnal pattern. While this overprediction trend is protective of air quality by a large margin, the figures in this section point to areas of improvement that are needed with AERMOD before it can be reliably used to predict peak short-term NO_2 concentrations near roadways.

We are very concerned that these model-monitor comparisons result in routine overestimation of peak hourly ambient NO_2 concentrations. On Page 24, Line 9 of the REA EPA nevertheless *"determined that adjustment of the modeled air quality based on these monitors was not necessary."* We believe that further development is AERMOD is needed in this area due to the concerns noted above. This cannot be done until field studies are conducted near roadways to determine the ozone profiles across roadways, the extent of mixing and turbulence caused by the moving vehicles, and the gradient of concentrations near roadways under a variety of meteorological conditions. Until those studies are done, we contend that EPA does not have an acceptable modeling procedure to reliably predict short-term NO_2 concentrations from roadway sources. We conclude that the exposure assessment's results for roadway emissions using AERMOD are biased because the model substantially overestimates those short-term ambient NO_2 concentrations. We also conclude that at this time, EPA does not have a reliable modeling tool to use for predicting 1-hour NO_2 concentrations, especially for the important roadway emissions source category.

8.4.8.3 Comparison of estimated on-road NO_2 Concentrations (Page 24-27)

In this section of the REA, a comparison is made between the AERMOD on-road receptor concentrations and independent empirical estimates made from measurement studies. The comparison shows that AERMOD predicts much higher concentrations than the empirical method. Rather than analyzing the reasons for these differences for the critical peak impacts, the REA (Page 25, Line 25) notes that for the ratio of on-road to off-road concentrations, AERMOD values far exceed those from measurements for the high percentile frequencies. Rather than believing the measurements, the EPA report instead relies upon the AERMOD predictions and concludes that *"this could indicate that the AERMOD approach is better accounting for locally high NO_2 concentrations…"* Based on the monitor-model comparisons presented in the REA, we have no confidence in AERMOD's ability to reliably predict NO_2 concentrations for roadway emissions, and cannot dismiss the evidence of observations, however limited, in favor of unproven AERMOD predictions. As noted previously, the probable reasons for the disparity between AERMOD and measurements is that AERMOD's simulation of near-field NO_2 impacts is highly idealized and that with the available ozone input data, the OLM overestimates the near-field conversion of NO to NO_2. Higher ozone availability away from the roadway sources would change the ratio of the on-road to off-road concentrations. EPA does not have evidence on the gradient of concentrations between on-road and off-roadway locations to be able to validate the AERMOD predictions. (EPA should make sure for Figure 8-7 that the data being used for the ratios is not from values that are close to zero, because those ratios could contaminate the overall results. Also, the sentence on lines 20-21 on page 25 is incomplete and needs to be reworded.)

The overall implication from our review is that the modeled results for areas within and very close to roadways could be substantially overestimated with the current AERMOD approach. The available model versus modeling data indicates a potential for significant overprediction, especially for 1-hour NO_2 concentrations. Therefore, the REA's results for roadway sources are highly likely to be substantially biased toward overpredictions of short-term concentrations and any interpretation of results from this study should account for this bias.