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Comments Concerning the EPA Scope and Methods Plan for Urban Visibility Impact Assessment

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I have reviewed the US EPA document, *Particulate Matter National Ambient Air Quality Standards: Scope and Methods Plan for Urban Visibility Impact Assessment*, dated February 2009. This urban visibility assessment (UVA) planning document relies extensively on information in earlier EPA documents and often doesn't explain a concept or approach that has appeared in an earlier document, so I also read portions of the following reports:

- *Summary of Urban Visibility Workshop*. Memorandum by Stratus Consulting, Inc., 18 November 2008.

- *Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information*. OAQPS Staff Paper, EPA-452/R-05-005a, December 2005.

- *Integrated Science Assessment for Particulate Matter: First External Review Draft*. EPA/600/R-08/139, December 2008.

This memo comments on the UVA planning document in light of these other documents.

What is "Urban Visibility"

First, I find a fundamental problem with the EPA approach. I couldn't find a definition of "urban visibility" in any of these documents. Four types of seeing situations have been mentioned in these documents and in the photographs displayed at the Urban Visibility Workshop of October 2008:

1. Visibility within an urban area

2. Visibility looking from within an urban area at a scenic feature (usually mountains) outside of the urban area

3. Visibility looking at an urban area (typically the skyline) from a location outside the urban area.

4. Visibility looking at both an urban area and a prominent scenic feature from a location outside the urban area.

Each of these is a valid concept, but the relationship between the visibility and the PM concentration within the urban area is different for each of them, which means that there is no single level of PM in the urban area that corresponds with a specific visibility in all four situations. In particular, because of spatial gradients in PM mass concentration and species, types 2, 3, and 4 may have portions of the sight path traversing non-urban air that is likely to have different PM characteristics from those of the urban area. Consequently, the relationship between the observed visibility and the urban PM concentration will depend on what fraction of the sight path passes through urban air. (Even within the urban area, a sight path is likely to traverse varying concentrations of PM, with only one point characterized by a PM sampler.) If the relationships between visual conditions and the PM concentrations measured at an urban sampler differ for each of the four methods, it will be difficult to relate the findings of the planned visibility preference study to a single concentration level for a potential secondary PM standard.

The Relationship Between Preferred VAQ and PM Concentrations is Ambiguous

I also have another fundamental concern that relates to the linking between the preference study visual air quality (VAQ) findings and PM concentrations. The visibility depends greatly on the position of the sun relative to an observer's sight path. Suppose one of the pictures presented for the preference study is a picture in an urban street canyon or along a suburban street (examples were shown at the workshop), where the sunlight is coming from behind the camera/observer. The visibility will look greatly different if the camera is turned 180 degrees, so that it is now looking more toward the sun. Because forward scattering of light by fine particles is much greater than back scattering, the pictures will show that the visibility in the first direction is greater than that in the second even though the light extinction coefficient in both directions is the same. Correspondingly, then, the PM concentration that corresponds to an "acceptable" visibility in the first picture is likely to be different from the concentration that corresponds to an "acceptable" visibility in the second picture, even though both pictures were taken at the same location and time and in the same atmospheric aerosol.

This fact means that the pictures that are used in the visual air quality study should represent conditions at the time of day for which a secondary standard is being considered. Also, it would be best if the pictures displayed views in different directions relative to the position of the sun.

The two items mentioned above indicate that the definition of visibility in the UVA plan is not adequate for dealing with human perception of scenes or pictures. The UVA plan states, on lines 21-22 on page 1-5: "Visibility, which can be defined as the degree to which the atmosphere is transparent to visible light, is determined by the scattering and

absorption of light by particles and gases …." That statement is actually a definition of atmospheric transmittance, not visibility. Transmittance, which can be related to the atmospheric light extinction coefficient, is only one of the air pollution related factors that determines the VAQ of a scene. The UVA plan is concerned with determining the relationships between PM concentrations, the atmospheric light extinction coefficient, and human visibility preferences, but it hasn't fully met the challenge of coming up with a viable method for tying together the nonlinear (and sometimes non-unique) relationships between these three parameters.

Using Fine PM Concentration as a "General" Surrogate for Visibility Needs Further Evaluation

The UVA states, on lines 13-15 on page 1-6: "In the last review, EPA concluded that fine particle mass concentrations could be used as a general surrogate for visibility impairment (EPA, 2005a [sic][1], p. 2-74." Actually, the cited statement in the staff paper is not a conclusion, but rather an assertion that is not supported very well by EPA's own analyses. As displayed in the scatter plots in Figures 6-3 and 6-5 on pages 6-10 and 6-12 of the staff paper (reference EPA, 2005b in the UVA plan), there is large amount of scatter (and only fair correlation) in the relationship between light extinction estimated using the original IMPROVE algorithm (labeled RE in the staff paper) and urban $PM_{2.5}$ concentration. For the four-hour period from noon to 4 pm that EPA favors, Figure 6-5b shows, for example, that a $PM_{2.5}$ concentration of 20 $\mu g/m^3$ corresponds, over the seasons and locations considered, to values of RE ranging mostly from about 60 Mm^{-1} to more than 200 Mm^{-1} (and with a large number of data points up to and above 300 Mm^{-1}) – a range of more than a factor of 3. Clearly the lumping together of East and West into the same secondary standard, even for this limited four-hour period, is problematic, and further subdivision of the data by geography, season of year, or other factors is likely to be needed to produce robust relationships.

Actually, there is even more scatter in the data than that which appears in Figure 6-5 of the staff paper. The relationship plotted in that figure relates RE with $PM_{2.5}$. However, the relevant relationship is the one between measured light extinction and $PM_{2.5}$. As IMPROVE studies have shown,[2] the RE calculated with the original IMPROVE algorithm is not a perfect representation of measured extinction, which means that the relationship between measured light extinction and $PM_{2.5}$ is likely to have even more scatter than that shown in Figure 6-5 for RE and $PM_{2.5}$. In order to arrive at a meaningful secondary standard for $PM_{2.5}$, the UVA plan needs to resolve such uncertainty in any relationship between extinction and $PM_{2.5}$ mass concentration that strives to represent multiple locations and times.

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[1] Citations to (EPA, 2005a) in the UVA plan should actually be to (EPA, 2005b), i.e., the December 2005 staff paper.

[2] Pitchford, M.; Malm, W.; Schichtel, B.; Kumar, N.; Lowenthal, D.; Hand, J. Revised Algorithm for Estimating Light Extinction from IMPROVE Particle Speciation Data. *J. Air & Waste. Manage. Assoc.* **2007**, 57, 1337-1350.

Estimating Current Visibility

According to Section 2.1.2 on page 2-4, hourly light extinction will be estimated for a variety of urban areas as follows (emphasis is mine):

1. Start with 24-hr measurements of $PM_{2.5}$ mass;
2. Estimate hourly mass concentrations by developing and applying *diurnal profiles*;
3. Estimate hourly concentrations of each species by developing and applying *hourly speciation factors*; and
4. Estimate hourly light extinction levels using an *urban-optimized algorithm*.

Carrying out these steps in the limited time available is an ambitious effort, if the results of the analyses are to be sufficiently comprehensive to truly be representative throughout the nation. The four steps above are dependent on the development of the data and algorithms that are highlighted in italics, but the development process for each is not described in any detail in the UVA plan.

Presumably the diurnal mass concentration profiles will be derived from TEOM measurements, but extrapolating them to other locations without TEOM measurements will be challenging and uncertain. The diurnal mass concentration profiles will vary with diurnal variations in emissions, the season of the year, and the latitude (e.g., temperature and solar insolation) of the urban area. The geographic distribution of sources in and around the urban area, relative to wind directions, will matter. The magnitude of background concentrations, which sets a base for the local impacts, needs to be taken into consideration at each location. Coastal and mountain areas can have flow reversals in which the air mass in the afternoon differs greatly from the one in the morning. Day-to-day or hour-to-hour changes in weather, especially precipitation, can dramatically alter the diurnal variation; how will weather be reflected in the profiles?

Hourly speciation factors are even more challenging. They are influenced by most of the same factors, but they also have to account for differing rates of formation (and removal) of secondary particles.

When all is done, how credible will the final extinction estimates be in light of the many assumptions and approximations that were made in the process? That uncertainty should be assessed.

Assessing the Implications of Just Meeting the Secondary PM NAAQS

The first paragraph Section 2.1.3 on page 2-5 describes a method for adjusting current hourly PM concentrations to create a hypothetical case with the concentration just at the level of the potential NAAQS. This exercise promises to be as difficult as the multi-step process just discussed for estimating hourly light extinction, a fact that is acknowledged in the sentence on lines 23-24 on that page: “Thus, it may be necessary to assume that each

hour in a day experiences the same adjustment (possibly by species) as does the day as a whole." Such an assumption might be acceptable if the change in concentration is assumed to be due to a change in wind speed or turbulence, but it is not a good assumption if the alteration might be because of emissions or wind direction changes. It will be important to evaluate the implications of such an assumption on the credibility of the assessment.

The Urban Optimized Linear Algorithm

Lines 21-24 on page 2-7 state that the performance of the IMPROVE algorithm in predicting urban light extinction will be evaluated and changes will be made "as necessary" to create a new urban optimized linear algorithm. How will the algorithm be evaluated? Are there sufficient optical measurements in a variety of urban areas to use as "ground truth" against which the algorithm estimates can be evaluated? Will the starting point be the original or new IMPROVE algorithm. If adjustments are needed, will they be empirical ones to improve the fit compared to optical measurements or ones based on scientific principles (an example of the latter being the organic PM discussion in the preceding paragraph of the UVA plan)?

One comment in the UVA plan raises concern that the algorithm will not be usable in urban locations, such as in southern California, where nitrates contribute significantly to visibility impairment. In Appendix B, on page B-3, an entry in the first column states, "EPA does not consider any available continuous nitrate data to be suitable for use in the risk assessment." If the continuous nitrate measurements are not considered acceptable, then it will not be possible to develop and use the optimized linear algorithm for short periods, such as the four hours mentioned in the UVA plan.

Uncertainty

The processes described in the UVA plan break new ground with untested assumptions and approximations. An uncertainty analysis that evaluates whether the end results are credible, and estimates their level of uncertainty, is an absolute necessity for a viable secondary NAAQS.

Scene Selection for the Assessment

The paragraph that occupies the upper half of page 3-4 mentions some scene-specific considerations. Representing changes in scene appearance with images created by WinHaze has some limitations that could influence the preference study and should be accounted for in the assessment. First, the synthetic haze created by WinHaze is too blue, so that pictures of hazy days are too blue and may be perceived by some as being hazier than they actually are. Also, for good reasons, the current version of WinHaze only works for images with cloudless skies. The distance from the camera/observer to every pixel in the scene has to be specified before the radiative transfer calculations in WinHaze take place, but the distance to all points in a cloud is unknown. Using the wrong distance will cause changes to the appearance of the cloud in increasing haze to be over- or under-

emphasized. These factors also need to be considered when evaluating new WinHaze photos that include clouds, as mentioned in lines 13-15.

The same paragraph on page 3-4 also shows a preference for long-distance views because their appearance is considered to be more sensitive to changes in haziness. However, page 11 in the memorandum that summarizes the October 2008 Urban Visibility Workshop[3] points out that the concept of perceptual transparency[4] has not received enough attention in previous urban visibility studies, and that it can affect how a person responds to a hazy scene and perceives changes in visibility. Consideration of the effect of perceptual transparency is particularly important when viewing a scene through a long distance of haze. Two-dimensional printed photographs, projected slides, and computer monitors cannot display this phenomenon – the actual 3-dimensional scene is required. This limitation of 2-dimensional views is an argument against using long distance views, especially ones with noticeable haze.

Representativeness

Line 19 on page 3-6 states that color blind individuals will be excluded from the focus groups. Color blind individuals may perceive effects of haze or changes in haze differently from individuals with normal vision. Since between 5 and 8% of males are color blind to some degree, the visual experience of a substantial minority of the population is not reflected in the focus groups. Unless the focus groups include a sufficiently large number of people that they can represent the population at large, selectively excluding individuals with all of the various forms of color blindness will make the focus group results hard to interpret for the general population. If color blind individuals are excluded, thought should be given to how the focus group conclusions might be biased by those exclusions.

Errors

There are a few errors in the UVA plan. The incorrect use on several pages of EPA (2008a) as a citation instead of the correct EPA (2008b) has already been mentioned in Footnote 1.

On page 1-1, line 22, there is a reference to U.S. EPA (2009b), but no such document is listed in the References section.

On page 2-2, line 15, in accordance with logic and consistent with page 2-66 of the EPA staff paper, “underestimate” should be replaced by “overestimate”.

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[3] Deck, L., Chestnut, L., and Donovan, C., *Summary of Urban Visibility Workshop*. Memorandum to Vicki Sandiford, EPA-OAQPS, 18 November 2008.

[4] Perceptual transparency describes the 3-dimensional phenomenon that, when viewing a scene through haze, the human eye-brain system can perceive the presence and appearance of the haze separately from the properties of the scene being viewed through the haze. Among other things, perceptual transparency alters the human judgment of the degree of haziness or visibility impairment..