11/7/2011

MEMORANDUM

SUBJECT: The Estimated Contribution of Ambient Lead (Pb) to Class I Area Visibility Impairment

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TO: File

Overview:

This memorandum provides rough estimates of Pb-associated visibility impairment levels in mandatory Class I Federal areas, and the corresponding proportions of those estimated levels to associated total visibility impairment. Pertinent background information, underlying analysis assumptions, and descriptions of the implemented analysis tasks are summarized in bullet form below:

- The Clean Air Act establishes a Regional Haze Program which is intended to improve and protect visibility in mandatory Class I Federal areas. Mandatory Class I Federal areas include certain national parks (larger than 6000 acres), wilderness areas (larger than 5000 acres), national memorial parks (over 500 acres) , and other areas of special national and cultural significance.
- The National Park Service operates an ambient air monitoring program called "IMPROVE" (Interagency Monitoring of Protected Visual Environments) with a primary objective of characterizing visibility impairment in Class 1 and other similar areas.
- The IMPROVE program has developed assorted equations for estimating visibility impairment in mostly non-urban environments. The original, and still widely accepted IMPROVE formula for estimating visibility impairment, calculates "24-hour average total light extinction" (in units of inverse megameters) from inputs of 1) 24-hour average concentrations of select speciated $PM_{2.5}$ components (some of which are used in reported form in the equation and others which are transformed to the explicit formula variables via additional simple equations; 2) 24-hour average concentration estimates of $PM_{10-2.5}$ (a.k.a., "PM-coarse"), and 3) estimates of the hygroscopic impacts of relative humidity on associated ambient inputs, specifically sulfate and nitrate. The calculated light extinction formula is:

$$PMb_{ext;_i} = (3 \times Sulfate_i \times f(RH)_i) + (3 \times Nitrate_i \times f(RH)_i) + (4 \times OM_i) + (10 \times EC_i) + (FS_i) + (0.6 \times PMc) + 10$$

Where:

$PMb_{ext:i}$	=	PM-related light extinction in Mm^{-1} for day *i*; and
$Sulfate_i$	=	ammonium sulfate (reported concentration of sulfate ion * 1.375) for day *i*; and
$Nitrate_i$	=	ammonium nitrate (reported concentration of nitrate ion * 1.29) for day *i*; and
OM_i	=	organic mass (blank-adjusted reported concentration of organic carbon * 1.4) for day *i*; and
EC_i	=	the reported concentration of elemental carbon for day *i*; and
FS_i	=	fine soil (reported concentration of Al * 2.20 + reported concentration of Si * 2.49 + reported concentration of Ca * 1.63 + reported concentration of Fe * 2.42 + reported concentration of Ti * 1.94) for day *i*; and
PMc_i	=	PM_coarse (reported PM_{10} concentration – reported $PM_{2.5}$ concentration) for day *i*; and
10	=	the "Rayleigh" factor which is assumed light reflection from gasses; and
$f(RH)_i$	=	the RH hygroscopic growth factor as determined from the EPA climatological f(RH) database corresponding to the month of day *i* for the grid point closest in distance to the monitoring site.

- In this analysis, the above formula was used to estimate 24-hour average <u>total</u> light extinction at all IMPROVE sites for days (containing all formula components) in years 2007-2009. The formula was also used to estimate 24-hour average <u>total</u> light extinction at all Chemical Speciation Network (CSN) sites for the same time-frame (for days containing all formula components). As opposed to the IMPROVE network which encompasses monitors in predominately non-urban areas, the CSN network is mostly urban-based. CSN sites were used in addition to IMPROVE sites in order to obtain more light extinction estimates (and make the anticipated conclusion more robust), but because sulfate, nitrate, and carbon concentrations are typically much higher in urban areas than in non-urban areas and because those light extinction formula components generally constitute the majority share of light extinction estimates (as opposed to the fine soil and PM-coarse concentrations), the light extinction estimates calculated at CSN sites are thought to be upper bound estimates of the absolute levels expected in Class 1 areas.
- To estimate the portion of light extinction associated with Pb, only two of the IMPROVE formula components were used as shown below. 24-hour average concentrations of $PM_{2.5}$_Pb were used as the fine soil factor, and 24-hour average concentrations of $PM_{10\text{-}2.5}$_Pb were used as the PM_coarse factor. Because PM_{10}_Pb is not monitored at many sites, but the larger size-cut TSP_Pb is (since the Pb NAAQS is based on that indicator), TSP_Pb 24-hour average concentrations were used as a conservative surrogate for 24-hour average PM_{10}_Pb in the computation of site-day 24-hour average $PM_{10\text{-}2.5}$_Pb. Only site-days (2007-2009) with both $PM_{2.5}$_Pb and $PM_{10\text{-}2.5}$_Pb estimates were used in the analysis.

$$\text{PM\_Pb}b_{\text{ext;}_i} = (FS_i) + (0.6 \times PM\_\text{coarse})$$

Where:

$PM\_Pb\, b_{\text{ext: i}}$	=	PM_Pb-related light extinction in Mm^{-1} for day *i*; and
FS_i	=	fine soil (reported concentration of PM2.5_Pb) for day *i*; and
PMc_i	=	PM_Pb_coarse (reported PM_{10}_Pb concentration – reported $PM_{2.5}$_Pb concentration) for day *i*. If

- As with the processing of calculated <u>total</u> light extinction, the above equation for calculated <u>Pb-associated</u> light extinction was applied to data for both IMPROVE and CSN sites. As with the total extinction estimates, the CSN Pb-associated extinction estimates are thought to be an upper bound as to what would be expected in Class I areas.
- The site-day estimates of total light extinction and Pb-associated light extinction were then matched by site-day and only site-days with both estimates present (total and Pb-associated) were used in the subsequent summarizations. For each site-day in the matched file, the ratio of Pb-associated light extinction to total light extinction was computed.
- Consistent with the Regional Haze Program, the implemented summarizations focused on the 20 percent best and worst visibility days (as determined with regard to site-level <u>total</u> calculated PM-light extinction). For each site in the matched file, the 20^{th} and 80^{th} percentiles for total calculated PM- light extinction were determined. No data completeness cutoff was imposed. The daily extinction estimates and corresponding ratio were then averaged by site-category (i.e., those where the total extinction was >= the 80^{th} percentile, those where the total extinction was <= the 20^{th} percentile, and those where the total extinction was in between the 20^{th} and 80^{th} percentiles). The site-category averages for total extinction and for Pb-associated extinction were then averaged nationally by network-category.

Results and Conclusion:

- The results of the described analysis are shown below. Although the CSN estimates for total light extinction and Pb-associated light extinction are significantly higher than the corresponding estimates at IMPROVE sites, the ratios of the two extinction estimates were quite comparable for both networks. For the high extinction days (best 20% based on site-level total extinction), ambient Pb contributed 0.01 percent, on average, to total light extinction in both networks. For the low extinction days (worst 20% based on site-level total extinction), ambient Pb contributed 0.03 percent, on average, to total light extinction in both networks. For the "other" days (where total extinction was between the 20th and 80th percentiles), ambient Pb contributed around 0.02 percent, on average, to total light extinction in both networks.
- In conclusion, it appears that the Pb-related visibility effects (in Class I and other areas) are insignificant in comparison to those associated with sulfate, nitrate, and carbon PM.

IMPROVE: 164 sites (with all components)

	Bext24_total	Bext24_Pb	ratio of Bext24_Pb to Bext24_total
average of high days	59.10879	0.00783	0.00013
median of high days	44.10702	0.00551	0.00011

	Bext24_total	Bext24_Pb	ratio of Bext24_Pb to Bext24_total
average of low days	10.42402	0.00255	0.00026
median of low days	7.20448	0.00162	0.00023

	Bext24_total	Bext24_Pb	ratio of Bext24_Pb to Bext24_total
average of other days	25.45386	0.00472	0.00020
median of other days	18.49656	0.00350	0.00018

CSN: 117 sites (with all components)

	Bext24_total	Bext24_Pb	ratio of Bext24_Pb to Bext24_total
average of high days	140.93796	0.01998	0.00013
median of high days	135.79025	0.01216	0.00010

	Bext24_total	Bext24_Pb	ratio of Bext24_Pb to Bext24_total
average of low days	32.14398	0.00820	0.00027
median of low days	32.25639	0.00756	0.00025

	Bext24_total	Bext24_Pb	ratio of Bext24_Pb to Bext24_total
average of other days	68.02410	0.01185	0.00017
median of other days	68.00097	0.00876	0.00014