UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Update to the 24 Hour $PM_{2.5}$ NAAQS Modeled Attainment Test

FROM: Tyler Fox, Leader
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TO: Regional Air Program Managers

This memorandum describes updates to the 24-hour $PM_{2.5}$ attainment test that is contained in EPA's $PM_{2.5}$ and ozone photochemical modeling guidance document[1]. The revised test described in this memorandum supersedes the version of the test in the current guidance. The revised test will be included in the updated version of the guidance when it is released in draft form later this year[2].

As described in section 5.2 of the modeling guidance, the 24-hour $PM_{2.5}$ attainment test uses model predictions in a relative sense to project site-specific ambient observations to the future. The current guidance refers only to the 1997 24-hour NAAQS of 65 ug/m^3. The revised procedures contained in this memorandum reflect an attainment test that is applicable to either the 1997 NAAQS or the 2006 NAAQS of 35 ug/m^3.

The updates to the attainment test are intended to make the projection methodology more consistent with the procedures for calculating ambient 24-hour $PM_{2.5}$ design values. In the previous 24-hour attainment test, for each $PM_{2.5}$ monitor, we recommended projecting the measured 98th percentile concentrations to the future. A basic assumption in that methodology was that the overall distribution of high measured days in the future case will be the same as in the base period. However, additional analysis of recent future year modeling scenarios has shown that in some areas, the highest modeled $PM_{2.5}$ days switch from the summer in the base period to the winter in the future period. As a result, the distribution of days can shift across seasons between the base and future periods and result in an overestimation of the future year 98th percentile values. This is especially true in areas which experience both high summer and winter $PM_{2.5}$ episodes.

[1] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze", available at: http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf

[2] The current version of the ozone and $PM_{2.5}$ modeling guidance was released in 2007. EPA is currently working on revisions to the document which will include, among other things, updates to the ozone attainment test which will reflect the revised ozone NAAQS, when finalized. We expect the revised draft of the modeling guidance to be released later this calendar year.

The revised methodology does not assume that the temporal distribution of high days in the base and future periods will remain the same. In order to more formally and appropriately examine the full distribution of days, we recommend projecting a larger set of ambient days from the base period to the future and then re-rank the entire set of days to find the new future year 98^{th} percentile value (for each year). This update to the methodology ensures that the future 98^{th} percentile day is not over-estimated or under-estimated due to changes in the temporal distribution of high days between the base and future days. In practice we have found that in almost all cases, the revised methodology leads to either lower or unchanged future year 98^{th} percentile values and therefore, lower or unchanged projected future year 24-hour design values.

Attachment A contains detailed background information on the updated procedures for calculating projected 24-hour $PM_{2.5}$ design values while Attachment B contains the revised guidance language that replaces section 5.2 of the current modeling guidance. Please contact Brian Timin of my staff at 919-541-1850 or timin.brian@epa.gov for more information.

Attachments (2)

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Attachment A

This memorandum addresses updates to section 5 of the ozone, $PM_{2.5}$, and regional haze modeling guidance that describes the annual and 24 hour $PM_{2.5}$ attainment test. Section 5.1 outlines the annual $PM_{2.5}$ NAAQS attainment test, including definitions of the $PM_{2.5}$ species that are used in the speciated model attainment test (SMAT). We are not recommending any updates to the annual attainment test at this time. The annual $PM_{2.5}$ monitor based attainment test is codified in EPA's Model Attainment Test Software (MATS)[1] which is available on EPA's SCRAM website: http://www.epa.gov/scram001/modelingapps_mats.htm.

Section 5.2 of the modeling guidance contains the 24-hour $PM_{2.5}$ NAAQS attainment test. The procedures for calculating the future year 24-hour $PM_{2.5}$ design values are being updated to make the projection methodology more consistent with the procedures for calculating ambient design values. In the current 24-hour attainment test, for each $PM_{2.5}$ monitor, the measured 98th percentile concentration from each year of the five year base period is projected to the future. As an additional check, the next highest concentrations from the other calendar quarters for each year (the three quarters when the 98th percentile did not occur) are also projected to the future to ensure that the future year 98th percentile did not switch seasons in the future year compared to the base year. The methodology effectively dropped the highest days (99th and 100th percentile days) from consideration in the test. A basic assumption was that the overall temporal distribution of high measured days in the base period will be the same as in the future.

More recently, EPA examined several future year nationwide modeling scenarios. The results showed that many of the highest base year $PM_{2.5}$ days switched from the summer in the base period to the winter in the future period. As a result, the distribution of days shifted between the base and future periods. This is especially true in areas such as the upper Midwest which experience both high summer and winter $PM_{2.5}$ episodes. A consequence of this shift is that a base year 98th percentile winter day may end up having a higher concentration in the future than a summer day that started with a higher concentration in the base year. In this case, a 99th or 100th percentile day in the base year may end up being the 98th percentile day in the future. Consequently, the projected 98th percentile base year day may end up being the highest projected day in the future (100th percentile). Since we are trying to estimate a future year 98th percentile value, the old methodology could in some cases, clearly lead to overestimated future 98th percentile values and design values[2].

The revised methodology does not assume that the temporal distribution of high days in the base and future periods will remain the same. We recommend projecting a larger set of ambient days from the base period to the future and then re-rank the entire set of days to find the new future year 98th percentile value (for each year).

Similar to the annual $PM_{2.5}$ calculations, we continue to recommend using the $PM_{2.5}$ species (defined in section 5.1) to calculate individual species relative response factors (RRF). The 24-hour

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[1] The 24-hour attainment test that is in the 2007 guidance is also codified in the current version of MATS (2.3.1). A new updated version of MATS will be released which will incorporate the changes outlined in this memo.

[2] The old methodology could lead to either over-predictions or under-predictions of the future design value. However in the specific cases examined, the future year design values were almost always over-predicted by the old methodology.

$PM_{2.5}$ calculations are computationally similar to the annual average calculations. The main difference is that the base period "high day" 24-hour $PM_{2.5}$ concentrations are projected to the future year, instead of the annual average concentrations. Also, the $PM_{2.5}$ species fractions and RRFs are calculated from observed and modeled high concentration days for the 24-hour $PM_{2.5}$ attainment test, instead of from quarterly average data for the annual $PM_{2.5}$ attainment test.

Both the annual $PM_{2.5}$ and 24-hour $PM_{2.5}$ calculations are performed on a calendar quarter basis. Since all years and quarters are averaged together in the annual $PM_{2.5}$ calculations, the individual years can be averaged together early in the calculations. However, in the 24-hour $PM_{2.5}$ calculations, the 98th percentile value from each year is used in the final calculations. Since the 98th percentile value can come from any day in the year, all quarters and years must be carried through to near the end of the calculations. To calculate final future year design values, the 98th percentile for each year is identified and then a five year weighted average of the 98th percentile values for each site is calculated to derive the future year design value.

In the revised 24-hour attainment test methodology, the eight highest ambient $PM_{2.5}$ days in each quarter at each site are projected to the future (32 days per year) using species specific quarterly relative response factors[3]. After all 32 days are projected to the future, the days are re-ranked to determine the future year 98th percentile day. The rank of the future year 98th percentile day is selected based on the rank of the 98th percentile day in the base year ambient data. For example, at monitoring site A, if there are 120 observations in year 1 then the 98th percentile day is the 3rd high day for the year. In that case, the future year 98th percentile day is selected as the 3rd high future day for the year (out of the 32 days).

This update to the methodology ensures that the 98th percentile day is not over-estimated (or under-estimated) due to changes in the temporal distribution of high days between the base and future days.

[3] The observed 98th percentile day is always between the 1st and 8th high for the year, depending on the sampling schedule. Therefore, projecting the 8 highest days in each quarter ensures that the observed 98th percentile day is always captured. More days could be projected, but a maximum of 32 days per year is needed to guarantee that the 98th percentile day is projected.

Attachment B

<u>The following is the revised language that replaces the text from section 5.2 of the ozone, $PM_{2.5}$, and regional haze modeling guidance:</u>

Our recommended modeled attainment test for the 24-hour NAAQS for $PM_{2.5}$ is similar to the previously described test for the annual NAAQS in that it uses model predictions in a relative sense to reduce site-specific *observations* (averaged over 5 years). In the test, we are interested in reducing the current design values[1] at each site to $\leq 35\ \mu g/m^3$ (the 2006 24 hour $PM_{2.5}$ NAAQS).

Ideally, the modeled attainment test should reflect model results obtained for days in each season having observed $PM_{2.5}$ concentrations above the design value. Even though the 24-hour NAAQS is based on the single 98th percentile value of all days in the year, it is important to perform the test on a seasonal basis. The underlying reasons are that $PM_{2.5}$ consists of a mixture of pollutants whose composition can vary substantially from season to season. Second, there could be a substantial amount of uncertainty associated with predictions on any single day. Thus, our test is most likely to be reliable when relative response factors (RRFs) reflect composite responses from many days. Therefore, we recommend modeling as many days as feasible where observed $PM_{2.5}$ is greater than 35 $\mu g/m^3$. Alternatively, the test can focus on the high end of the distribution of days in each quarter, (e.g. the top 10% of $PM_{2.5}$ days[2]) assuming that the high days are representative of days that violate the NAAQS. As with the annual NAAQS (and for the same reasons), the preferred approach is to develop RRFs which are season (i.e., quarter) specific[3].

The 24-hour $PM_{2.5}$ attainment test should be based on the same 5 year weighted average methodology that was used for the annual standard, with some slight modifications. The 24-hour design values are calculated from the 98th percentile value for each year. In the 24-hour $PM_{2.5}$ calculations, the 98th percentile value from each year is used in the final calculations. Since the 98th percentile value can come from any day in the year, all quarters and years should be carried through to near the end of the calculations. To calculate final future year design values, the 98th percentile day for each year is identified and then a five year weighted average of the 98th percentile values for each site is calculated to derive the future year design value[4].

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[1]The $PM_{2.5}$ 24-hour standard was lowered to 35 ug/m3 in 2006 (71 FR 61224) (40 CFR 50.13).

[2]The top 10% of days may seem like a large number of days per quarter to use for an annual 98th percentile based standard, but for sites with a 1 in 3 day sampling schedule, the top 10% of days is only 3 days per quarter. For most sites, the top 10% of monitored days per quarter will represent between 3 and 8 days.

[3]In some areas it may not be necessary to model and evaluate the 24-hour NAAQS for all quarters. For example, if $PM_{2.5}$ concentrations only exceed the NAAQS in the 1st and 4th quarters, and concentrations in the 2nd and 3rd quarters are very low, then it may not be necessary to model the full year. But for areas that have monitored violations (or high values that are close to the NAAQS) in all 4 seasons, the entire year should be evaluated.

[4]Similar to the annual average $PM_{2.5}$ attainment test, design values are calculated for consecutive three year periods. From the five year base period, three design values are calculated and then averaged together to create a five year weighted average.

Similar to the annual $PM_{2.5}$ attainment test, we recommend interpolation techniques for FRM monitors that do not have co-located speciation data. Because the 24-hour standard is a 98th percentile based value, the species composition on high concentration days may be highly variable from day to day and from site to site. Therefore, while interpolation techniques may need to be used, we strongly recommend collecting speciation data at all FRM sites that violate the 24-hour NAAQS. A precise estimate of the $PM_{2.5}$ components at violating sites will help reduce uncertainty in projecting the future year concentration estimates.

We recommend a modeled attainment test for the 24-hour $PM_{2.5}$ NAAQS with the following 9 steps.

Step 1. Identify the high observed $PM_{2.5}$ days at each FRM monitoring site for each year.

The first step in projecting the daily design value is to identify at each FRM site, the eight highest observed 24-hour $PM_{2.5}$ concentration days in each quarter for each year of the base period (up to 5 years), and identify the day rank of the observed 98th percentile value for each year based on the number of collected ambient samples (i.e. 3rd highest day of the year). This results in a data set containing 32 days of data for each year (for up to 5 years) for each site.

The test should be performed for each monitoring site that meets the data completeness criteria for calculating a design value under the 24-hour NAAQS. There may not always be data available for all four quarters and all five years. We recommend using eight days per quarter because the 98th percentile day for a year is always one of the 8 highest days of the year[5]. If all of the high days occur in a single quarter, then using the 8 highest days from each quarter will ensure that the actual 98th percentile day is always captured. This may result in processing more days than necessary, but effectively limits the design value calculations to a reasonably small number of days.

Step 2. Calculate "high days" species fractions for each quarter for each FRM monitor.

In this step, quarterly ambient species fractions on "high" days are calculated for each of the major component species of $PM_{2.5}$ (i.e. sulfate, nitrate, ammonium, elemental carbon, organic carbon mass, particle bound water, salt, and blank mass). This calculation is performed by multiplying the monitored concentrations of FRM-derived total $PM_{2.5}$ mass on the high $PM_{2.5}$ days at each site for each quarter, by the average monitored species composition on the high $PM_{2.5}$ days for each quarter[6]. The default recommendation for identification of "high" days is the top 10% of days in each quarter. This results in a relatively robust calculation which typically uses between 3 and 9 days per quarter (depending on the sampling frequency). The end result is a set of quarterly species fractions for each FRM site.

Step 3. Calculate species concentrations for each of the high ambient days.

Multiply the quarterly "high day" species fractions from step 2 by the $PM_{2.5}$ mass concentration for the 8 high days per quarter identified in step 1. This results in a set of species concentrations for each of the 32 days per year identified in step 1.

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[5] If there are 365 samples in a year, then the 98th percentile is the eighth high day.

[6] Similar to the annual average calculations, for FRM sites that do not have co-located species data, we recommend calculating the quarterly species fractions using interpolated species data. For the 24-hour species interpolations, we recommend interpolating the average of the highest 10% of monitor days in each quarter.

Step 4. Calculate component specific RRFs for the high days in each quarter.

For each quarter, calculate the ratio of future year to base year modeled predictions for sulfate, nitrate, elemental carbon, organic carbon, salt, and other primary $PM_{2.5}$ for the top 10 percent of modeled $PM_{2.5}$ days based on predicted concentrations of 24-hour average $PM_{2.5}$. The result is a set of species-specific "high day" relative response factors (RRF) for each quarter.

The relative response factor for component j at a site i is given by the following expression:

$(RRF)_{ij} = ([C_{j,\ projected}]/[C_{j,\ base}])_i$

where $C_{j,\ current}$ is the base year mean species concentration (for the high modeled PM2.5 days for each quarter) predicted at the grid cell which contains monitoring $site_i$.

$C_{j,\ projected}$ is the future year mean species concentration (for the high modeled days for each quarter) predicted at the grid cell which contains monitoring $site_i$.

For example, assume that base year predicted sulfate mass on the 10 percent highest $PM_{2.5}$ days for quarter 3 for a particular location is 20 $\mu g/m^3$ and the future year modeled sulfate concentration is 16 $\mu g/m^3$, then the RRF for sulfate for quarter 3 is 16/20 or 0.80. For the 24-hour NAAQS, we recommend RRFs to be calculated based on the modeled concentrations at the single grid cell where the monitor is located.

Step 5. Apply the component specific RRFs to observed air quality by quarter.

For each of the 8 days in each quarter, multiply the daily species concentrations from step 3 by the quarterly species-specific RRFs obtained in step 4. If there is one modeled base year, then there are four quarterly RRFs at each monitor. The modeled quarterly RRF for quarter 1 is multiplied by the ambient data for quarter 1 (8 days in each year) for each of the 5 years of ambient data. The same procedure is applied for the 8 high days per quarter in the other 3 quarters. This leads to an estimated future concentration for each component for each day. For example, for day A, 21.0 $\mu g/m^3$ nitrate x 0.75 = future nitrate of 15.75 $\mu g/m^3$.

Step 6. Calculate remaining future year PM2.5 species.

The future year concentrations for the remaining species are then calculated for each of the days[7]. We recommend that the future year ammonium is calculated based on the calculated future year sulfate and nitrate concentrations, using a constant value for the degree of neutralization of sulfate (from the ambient data). The future year particle bound water concentration is then calculated from an empirical formula derived from the AIM model. The inputs to the formula are the calculated future year concentrations of sulfate, nitrate, and ammonium from step 5.

[7] If salt is not explicitly modeled, then the salt RRF should be held constant. Blank mass is assumed to be constant between the base and future year.

Step 7. Sum the species components to get total PM2.5 concentrations for each day.

Sum the species concentrations for each day to obtain total $PM_{2.5}$ values for the 32 days per year per site.

Step 8. Determine future year 98th percentile concentrations for each site year.

Sort the 32 days for each site for each year by total $PM_{2.5}$ concentration. For each site year, the monitored 98th percentile rank (for each year) is used to identify the 98th percentile rank for each year. For example, if the base year 98th percentile value for year 1 was the 3rd high concentration, then the future year 98th percentile concentration is identified as the 3rd high future year $PM_{2.5}$ concentration (out of the 32 days).

Step 9. Calculate future 5 year weighted average 24-hour design values and compare to the NAAQS.

The estimated 98th percentile values for each of the 5 years are averaged over 3 year intervals to create 3 year average design values (e.g. the 98th percentile values from year 1, year 2, and year 3 are averaged. Then the 98th percentile values from year 2, year 3, and year 4 are averaged, etc.). These design values (up to 3) are then averaged to create a 5 year weighted average design value for each monitoring site.

The preceding steps for determining future year 24-hour $PM_{2.5}$ concentrations are applied for each FRM site. The 24-hour $PM_{2.5}$ design values are truncated after the first decimal place. This approach is consistent with the truncation and rounding procedures for the 24-hour $PM_{2.5}$ NAAQS. Any value that is greater than or equal to 35.5 $\mu g/m^3$ is rounded to 36 $\mu g/m^3$ and is violating the NAAQS.