USDA Agricultural Air Quality Task Force
Comments on the Proposed Ozone Secondary Standard

(Officially Approved December 4, 2014)

Executive Summary

There should be a separate, biologically-relevant secondary ozone standard (not coupled with the primary ozone standard) that takes into account the full body of research related to ozone exposure impacts on plant growth. The W126 form of the secondary ozone standard proposed in EPA's final Policy Assessment bears no biological relevance to plant growth and, as such, should not be the basis for the secondary ozone standard. Furthermore, when establishing the level of a new ozone standard, EPA should quantify uncertainties in estimates of policy-relevant background (PRB) concentrations and the potential impacts of inaccurately estimating the PRB on potential non-attainment areas and the cost of implementation[1] for both a proposed primary and secondary standard.

Background

Ozone is not a pollutant emitted into the air. It is the product of chemical reactions among nitrogen oxides (NO_x) and volatile organic compounds (VOCs) and is predominantly formed in the summer when ambient temperatures are the hottest.

Under Section 109 of the Clean Air Act (CAA), EPA is required to issue national ambient air quality standards (NAAQS) for six air pollutants, one of which is ozone, and is required to review these standards every five years to ensure an adequate margin of safety. For each NAAQS, EPA is tasked to issue both primary and secondary standards. Protection of public health is the focus of the primary standard while protection of public welfare is the focus of the secondary standard.

The secondary standard is intended to protect ecosystems and sensitive plants. Currently, the secondary ozone standard is equal to the primary ozone standard, based on short-term (8-hour) average concentration measurements. However, plant growth and foliage damage are more sensitive to long-term ozone exposure rather than short-term episodic events. Scientists have shown that a cumulative index of exposure is better correlated with plant growth effects than the 8-hour average concentration used to measure human health effects. However, an appropriate cumulative index must consider not only ambient concentrations of ozone but ozone uptake by the plant through stomatal conductance.

Since the 1997 ozone NAAQS review, EPA Staff have considered implementing a secondary ozone standard having a cumulative form such as the W126 index. The W126 index form of the secondary standard is determined by multiplying a sigmoidal weighting value (W_i) at a specific

[1] It is recognized that the Administrator cannot consider costs in his or her decisions regarding establishment or revisions of NAAQS, but an accurate assessment of the costs associated with implementation of a standard provides important information to legislators and the public regarding the true costs associated with new air quality standards.

one-hour average concentration (C_i, ppm) by the one-hour average concentration and then summing over all concentrations. The sigmoidal weighting function takes the form:

$$W_i = \frac{1}{1 + M \times e^{-(A \times C_i)}} \quad (1)$$

where "M" and "A" are empirical constants of 4403 and 126 ppm^{-1}, respectively. The indicator is then calculated as:

$$\text{W126 Index} = \sum (W_i \times C_i) \quad (2)$$

EPA Staff decided it is appropriate to cumulate daily exposures for the 12-hour period from 8:00am to 8:00pm during the three-month period with the greatest index values (USEPA, 2014).

History of W126 in the EPA Regulatory Agenda

In June 2007, the EPA Administrator recommended the W126 exposure index as the form for a secondary standard to protect vegetation from ozone exposure (USEPA, 2007). However, in March 2008, the Administrator decided not to adopt the W126 exposure index based on advice from the White House (Washington Post, April 8, 2008; Page D02), the EPA Administrator made the secondary (i.e., vegetation) ozone standard the same as the primary (human health) 8-hour average standard (0.075 ppm)" (A.S.L. & Associates, 2010).

In 2010, EPA again proposed to establish a distinct, cumulative, seasonal secondary ozone standard having the form of the W126 index within the range of 7-15 ppm-hours (USEPA, 2010). In August 2010, EPA delayed its announcement of a final decision on the ozone NAAQS and has continued to do so until the present (A.S.L. & Associates, 2010). In 2013, the D.C. Circuit Court remanded the secondary standard to EPA, ruling that, in setting the secondary standard equal to the primary standard, EPA had failed to identify a level of air quality requisite to protect public welfare and, therefore, EPA's selection of a secondary standard equivalent to the primary standard was inherently arbitrary.

Scientific Support for the Secondary Ozone Standard

Ozone effects on plants are initiated in leaves when the gas enters through the stomates and disrupts cellular processes, resulting in suppression of growth and yield of many crops. Non-stomatal ozone deposition may be large, but its phytotoxic effects are likely small, although effects on epicuticular wax and subsequent interactions between leaves and the atmosphere are unknown.

Ozone impairs growth primarily by inhibiting net photosynthesis and perhaps translocation processes, which limit availability of photosynthate needed for biomass production. Ozone results in lower carbon fixation due to inhibition of ribulose bisphosphate carboxylase (Rubisco) activity in the chloroplasts of leaves with the result that:

- Allocation of carbon and energy resources to detoxification and repair processes in ozone-stressed plants likely detracts from growth as well.
- With less carbon available, plants produce fewer branches, leaves, roots, flowers and fruit.
- Ozone exposure also accelerates plant senescence, reduces leaf longevity, decreases water use efficiency, and inhibits pollen tube growth (Raymond Knighton, 2006).

EPA Staff have proposed using the W126 index and accumulating daily exposures for the 12-hour period from 8:00am to 8:00pm during the three-month period with the greatest index values. However, this approach is decoupled from known plant physiological responses in which plant stomata will close during the hottest parts of the day to minimize moisture loss, effectively limiting gaseous exchange between plants and the atmosphere. During the peak ozone season, plants will often experience exposure during off-peak concentration hours. In experiments on permanent grasslands, Grünhage and Jäger (1994) found that, "atmospheric conditions that facilitate the daily occurrences of peak (highest) O_3 concentrations in general do not coincide with the conditions that promote plant uptake." In fact, Krupa et al. (1998) reported that "…daily peak (highest) hourly O_3 values not as important as moderate to higher concentrations in eliciting negative crop biomass responses." Later, Krupa et al. (1995) reported that cumulative frequencies of occurrences of hourly ozone concentrations in the range of 50-87 ppb were the best predictors of negative crop biomass responses rather than the statistically forced W126 index. As can be seen in Pinto et al. (2007), highest rates of ozone conductance often coincide with the lowest O_3 concentrations, particularly in rural locations where a protective secondary standard would be most desirable for protecting ozone-sensitive species. As pointed out by Manning (2004), "Ground proofing [of ozone uptake metrics] must be done to verify and validate plant injury predictions. If this is not done, then the standards have no biological significance and are only exercises in air quality assessment."

Based on three years of physiological measurements on ponderosa pine, Panek (2004) documented that stomatal conductance of ozone was strongly correlated with leaf water potential ($R^2 = 0.82$) which closely followed the dynamics of stomatal conductance. Peak ozone update occurred in early summer and did not correspond to periods of peak ozone concentration. Panek (2004) therefore concluded that cumulative metrics based on ozone concentrations, including the W126 index, were <u>not</u> appropriate for plants in the studied region.

The USDA has funded or conducted specific studies and results that should be corroborated into the consideration of a secondary ozone standard. Below are just a few.

- The Aspen FACE (Free-Air Carbon Dioxide Enrichment) Experiment – A multi-disciplinary study to assess effects of increasing tropospheric ozone and carbon dioxide levels on the structure and function of northern forest ecosystems: results suggest that:
  - Moderate levels of O_3 will offset elevated CO_2 responses projected for the year 2100;
  - Carbon sequestration under elevated CO_2 is being overestimated by modelers who do not consider O_3 in areas with periodic episodic O_3;
  - Elevated CO_2 delays normal autumn leaf senescence, predisposing some aspen genotypes to winter dieback;
  - Aspen and birch insects and disease may increase under elevated CO_2 and O_3. (Free-Air Carbon Dioxide Enrichment (FACE), 2014)

- SoyFACE (Soybean Free Air Concentration Enrichment) – An innovative facility for growing crops completely in open-air conditions within an agricultural field. The facility allows researchers to evaluate the influence of natural variability of meteorological factors such as drought and temperature in conjunction with imposed atmospheric composition (elevated CO_2 and O_3) on naturally occurring soybean diseases across several growing seasons. An increase in the daytime ozone concentration from 60 ppb to 72 ppb led to a 15% decrease in yield from 2002 to 2003. (University of Illinois/USDA ARS, 2014).

  SoyFACE is mentioned in EPA's most recent Policy Assessment, but it is the only new study included related to ozone effects on crop production since the previous review. In fact, EPA relies heavily on the 1980's crop yield study in its assessment. Given that different species (and even cultivars within a species) vary tremendously in their sensitivity to ozone, transference of effects from soybeans to other crops is inappropriate. Instead, additional research is needed to elucidate the effects of ozone on other crop species and cultivars.

- Through collaborative research between Minnesota and Alberta scientists, a natural field exposure study in Alberta was conducted that included ambient air quality and meteorological data. Those two elements accounted for two thirds of the variability in alfalfa yield; air quality influenced half of the accounted variation, with O_3 accounting for 25%. (Raymond Knighton, 2006).

- Research at Auburn University to understand the combined effects of elevated O_3 and N deposition on productivity and nutritive quality of grazing lands will assist policymakers and resource managers concerned with forage-based production systems.

- Adaptation of agricultural and commercial forest species to air pollution and climate change can take advantage of modern breeding and genetics approaches but requires an understanding of the mechanisms controlling plant response as a step toward identifying genes of interest and developing screening protocols. Research on the physiological and molecular basis of O_3 tolerance is being conducted on multiple species by the Northeast Coordinating Committee 1013 (NECC-1013) members (Raymond Knighton, 2006).

- Ozone-sensitive and -tolerant snap beans developed by USDA-ARS in Raleigh, NC, were used in ozone gardens at Harvard University, the St. Louis Science Center and two other locations in St. Louis, and the Goddard Science Center, Greenbelt, MD. The snap beans were also grown by a University of Illinois, Urbana-Champaign graduate students' urban agriculture project in Chicago and are being tested as an ozone bio-indicator system at a number of locations in Europe and Asia by the ICP-Vegetation program (United States Department of Agriculture, 2010).

In the 2014 Policy Assessment, EPA Staff assert that the W126 is the "more biologically relevant cumulative, seasonal form" of a long-term exposure index, but the W126 index was compared only to the threshold metrics such as the SUM06 metric, ignoring other possible metrics such as 1-hour maximum concentrations, AOT40, N100, flux methods, or even the EPA primary standard with modified averaging time and co-factors. In fact, based on a five-year study at the Aspen FACE facility using aspen and birch trees, a plant growth model of mean basal area was well predicted (adjusted R^2 from 61.5 to 94.6%; $p < 0.0005$) by the 4th highest daily maximum 8-hour O_3 concentration along with six other meteorological and agronomic predictors (i.e., wind speed, precipitation, growing-degree days, relative humidity, soil moisture, and solar radiation) (Percy et al., 2009). Reducing the regression to a more usable form, mean basal area can be predicted using 4th highest daily maximum 8-hour concentration (the primary standard form), wind speed and growing degree days (adjusted R^2 from 68 to 89%; $p < 0.0005$), and the regression model makes biological sense, unlike the W126 index, which is purely a statistical regression with no basis in plant physiology (Percy et al., 2007).

Unlike the W126 index, a standard based on the 4th highest daily maximum 8-hour average ozone concentration has a high degree of statistical significance and goodness of fit while also having greater biological association with the economically and ecologically relevant endpoint of plant growth. Furthermore, unlike the W126 index, for which there has been no empirical response evidenced demonstrating a biological association outside of chambered studies[2], a standard incorporating daily maximum 8-hour average concentrations, wind speed, and growing degree days has been shown to have significant biological association with two species (and five genotypes) of trees over five years, under free-air conditions characterized by large inter-annual climate variation, stand dynamics, and pest activity (Percy et al., 2007, 2009).

RECOMMENDATION: The AAQTF Air Quality Standards Committee recommends that the USDA Staff work with EPA Staff to identify a secondary ozone standard form that is more biologically-relevant than the W126 index and to consider the full suite of agricultural ozone effects research that may affect the level of a proposed standard.

Setting Levels for the Primary and Secondary Standards

Once the forms of the primary and secondary ozone standards have been determined, EPA must establish levels for each of these standards. In the Policy Assessment, EPA proposes a W126 value in the range of 7–15 ppm-hours for a new secondary ozone standard. Standard levels should consider not only the health and welfare effects of ambient concentrations but also the portion of measured concentrations originating from background conditions, international transport and stratospheric ozone (i.e., “policy-relevant background” or “PRB”).

There is confusion among EPA staff and CASAC as to the relevance of the policy level background and how it is to be used in the independent scientific process in the setting of new standards. On December 3, 2009, CASAC member, Dr. Michelle Bell, Associate Professor, School of Forestry and Environmental Studies, Yale University, New Haven, CT, offered the following to then Administrator Jackson about establishing policy relevant background (PRB) levels:

[2] Grunhage and Jager (1994) found that dose-response relationships established using chamber experiments overestimate negative impacts of ozone exposure relative to open-air experiments that better mimic ambient conditions.

"Establishing the policy relevant background (PRB) level [see page 39] is by no means trivial, and the draft Review Plan acknowledges some of these limitations. The Plan notes that greater emphasis will be placed on understanding the contribution of different components that contribute to PRB [see page 40]. However, given the complexities of establishing a PRB and the wide range of approaches available, it would be helpful to have more information on how the PRB will be determined and how sensitivity analyses might be conducted."

During the May 19-20, 2011 Clean Air Scientific Advisory Committee (CASAC) meeting, EPA stated that by its using GEOS-Chem Model, background ozone is in the range of 15-35 ppb. A number of researchers contend that frequent occurrences of ozone greater than or equal to 50 ppb occur at both high- and low-elevation monitoring sites across the United States due to transport from the stratosphere to the lower troposphere, thereby increasing the background levels of ozone. These ozone concentrations appear to be related to stratospheric transport occurring during the springtime and sometimes in the summertime. Also missing in EPA's equation is the impact of the long-range transport of Eurasian biomass burning and wildfires in the US and the ability to affect background ozone concentrations. (A.S.L. & Associates, 2010)

If the actual background level of ozone is higher than EPA estimates with the GEOS-Chem model (or another tool used to establish PRB), results may overestimate human health and vegetation risks and present inaccurate information to the public and policymakers. The range of background concentrations is used in the EPA's risk assessment for both humans and vegetation and provides the baseline for assessing the amount of emission reductions required to attain a specific ozone level within the standard.

RECOMMENDATION: The AAQTF Air Quality Standards Committee recommends that the USDA Secretary requests EPA to quantify uncertainties in PRB estimates and the potential impacts of inaccurately estimating the PRB on potential non-attainment areas and the cost of implementation for both a proposed primary and secondary standard.

Conclusions

In August 2014, the EPA released its policy assessment for review of the ozone NAAQS in which it recommended an independent secondary standard for ozone having the form of the W126 index in order to protect sensitive ecosystems from damage caused by high levels of ozone exposure. The W126 form of the secondary ozone standard proposed in EPA's final Policy Assessment bears no biological relevance to plant exposure as ozone uptake is highly dependent on stomatal activity. As such, the W126 index should not be the basis for the secondary ozone standard.

Furthermore, when establishing the level of a new ozone standard, EPA should quantify uncertainties in estimates of policy-relevant background (PRB) concentrations and the potential impacts of inaccurately estimating the PRB on potential non-attainment areas and the cost of implementation for both a proposed primary and secondary standard.

References

A.S.L. & Associates. (2010). *How the W126 Ozone Exposure Index was Developed*. Retrieved October 24, 2014, from A.S.L. & Associates: http://www.asl-associates.com/w126.htm

Free-Air Carbon Dioxide Enrichment (FACE). (2014). *ASPEN FACE*. Retrieved October 28, 2014, from Free-Air Carbon Dioxide Enrichment: http://facedata.ornl.gov/aspen/

Grünhage, L. and H.-J. Jager. 1994. Influence of the atmospheric conductivity on the ozone exposure of plants under ambient conditions: considerations for establishing ozone standards to protect vegetation. Environmental Pollution 85, 125-129

Krupa, Nosal, Legge 1998. *Environmental Pollution* 101, 157-160.

Krupa et al. 1995. *Environmental Pollution* 87, 119-126.

Manning, W.J.. 2003. Detecting plant effects is necessary to give biological significance to ambient ozone monitoring data and predictive ozone standards. *Environmental Pollution* 126: 375-379.

Panek, J.A. 2004. Ozone uptake, water loss and carbon exchange dynamics in annually drought-stressed *Pinus ponderosa* forests: measured trends and parameters for uptake modeling. *Tree Physiology* 24: 277-290.

Percy et al. 2007. *Environmental Pollution* 147: 554-566.

Percy, Nosal, Heilman, Sober, Dann, Karnosky 2009. Ozone Exposure-Based Growth Response Models for Trembling Aspen and White Birch. pp 263- 287 In A.H. Legge (ed.) *Developments in Environmental Science*, Volume 9, Elsevier.

Pinto *et al*. 2007. Characterization of surface ozone concentrations in the United States. Ninth Conference on Atmospheric Chemistry, AMS.87th Annual Meeting, San Antonio.

Raymond Knighton, P. (2006, November 29). *Ozone Research and Vegetative Impacts.* Retrieved October 28, 2014, from Mechanisms of Plant Responses to Ozone in the Northeastern U.S.: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143

U. S. Environmental Protection Agency. (2007, July). *Ozone Standards Documents From Review Completed in 2008.* Retrieved October 28, 2014, from Final Staff Paper, Updated July 2007, EPA report No. EPA-452/R-07-007a: http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_cr_sp.html

U. S. EPA. (2010, January 19). National Ambient Air Quality Standards for Ozone (Proposed). *Federal Register*, pp. 2938-3052.

U.S. EPA. (2014, August). *Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards*. EPA report No. EPA-452/R-14-006.

United States Department of Agriculture. (2010, July 8). *Ozone Biomonitoring Project* . Retrieved October 28, 2014, from Agriculture Research Service: http://www.ars.usda.gov/Main/docs.htm?docid=18279&page=1

University of Illinois/USDA ARS. (2014). *SoyFACE*. Retrieved October 28, 2014, from SoyFACE: http://www.igb.illinois.edu/soyface/