Secondary NAAQS for Oxides of Nitrogen and Sulfur

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Many contributors

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Overview

- Schedule and background
- Explaining the structure of the standard
- Role of critical loads
- Advantages of instituting a standard
- Discussion
Schedule

- EPA is under a court ordered schedule to sign a proposed rule by **July 12, 2011** and a final rule by **March 20, 2012**
  - Includes an extension of 18 months granted by the plaintiffs on the basis that we needed more time to develop an ecologically relevant standard

- Since review initiated in 2006, EPA has completed the following milestones:
  - Integrated Science Assessment (ISA, 2008)
  - Risk and Exposure Assessment (REA, 2009)
  - Staff Policy Assessment (PA, 2011)
Major points and challenges

Basics

- EPA staff’s Policy Assessment presents a new *multi-pollutant, multi-media* standard that is unique in that it depends on atmospheric and ecological modeling to specify the terms of an equation that characterizes the relationships between air concentrations, deposition, and aquatic acidification effects.

- The Clean Air Scientific Advisory Committee (CASAC) is supportive of setting a new standard as developed in the Policy Assessment.

Challenges

- Translating spatially variable effects into a national standard.
  - *recognizing research conducted at the individual watershed level*.

- Accepting spatially varying amounts of air concentrations (as well as deposition) fits into the definition of an air quality standard.

- Adequately accounting for the effects of reduced nitrogen, along with but separately from oxidized forms.
Conclusions in ORD’s Integrated Science Assessment (ISA)

ISA concludes that the evidence is sufficient to infer a causal relationship between:

- Gas-phase SO₂, NO₂, and direct injury to vegetation (basis for current standards)
- Acidifying deposition of nitrogen (N) and sulfur (S) and effects in aquatic and terrestrial ecosystems (e.g., decreased species diversity and fish mortality resulting from aquatic acidification)
- N deposition and effects on nutrient status in terrestrial, wetland, freshwater aquatic, and coastal marine ecosystems

With regard to aquatic acidification, ISA presents compelling evidence that oxides of N and S both cause ecosystem acidification in the U.S.

- Thousands of peer-reviewed scientific papers
- Several national assessments [e.g., National Acid Precipitation Assessment Program (NAPAP) reports (1980 to present)]
- Well-established water quality and biological indicators
- Well-established models that link deposition, water quality, and effects on biota

ISA concludes that aquatic acidification is a well-documented process caused by multiple chemical species that constitute N + S deposition, which occurs under current air quality conditions

- Ecosystem sensitivity to acidification varies across the nation according to present and historic N + S deposition, geologic/soil/hydrologic factors and vegetation type
Pollutants considered in ISA

- Oxides of nitrogen and sulfur -- the “criteria pollutants” -- include:
  - $\text{SO}_2$ and $\text{NO}_2$ – indicators for current secondary standard
  - Particulate sulfate, $\text{SO}_4$, combined with $\text{SO}_2$ is defined as $\text{SOx}$
  - $\text{NOy}$ – includes the transformation products from emissions of oxides of nitrogen (e.g., nitric acid and particulate nitrate)

- Forms of nitrogen which are not criteria pollutants, but that contribute to N deposition, include:
  - Ammonia gas, $\text{NH}_3$
  - Ammonium ion, $\text{NH}_4^+$
  - Together referred to as reduced nitrogen, NHx
Based on the ISA and the case-study analyses in the REA, the Policy Assessment and CASAC concluded it is appropriate to focus on aquatic acidification in this review:

- Science is more complete than for other effects
- Atmospheric inputs are the dominant contributions

Focus on aquatic acidification relies on two important concepts:

- Acid neutralizing capacity (ANC)
  - A water quality value that reflects ability of ecosystem to buffer acidifying inputs
  - Well related to effects on aquatic ecosystems and to deposition of N and S

- Critical Load
  - The amount of acidifying deposition (of N and S) that a water body can handle to maintain a specified ANC level, based on present knowledge
  - Critical loads are influenced by a system’s natural ability to neutralize acid inputs
Ecosystem sensitivity varies across the nation, predominantly due to variability of geologic material (bedrock and soils) which buffers acidifying deposition.

Focus of this secondary standard is on aquatic systems located in relatively pristine, rural environments – typically, high elevation clear water bodies supporting trout fisheries.

Map based on water quality data available through EPA monitoring programs.
Unlike most other NAAQS that are based on the direct relationship between pollutant concentrations in the air and effects on health or welfare, this standard necessarily involves multiple linkages, since aquatic effects are not directly related to concentrations of oxides of N and S in the ambient air.

- Linkage between ecological effects and deposition of oxides of N and S is characterized by critical load modeling.

- Linkage between deposition and air concentrations of oxides of N and S is characterized by atmospheric modeling that translates emissions of N and S into ambient concentrations and deposition.

- Model also takes into account deposition of N from reduced forms of nitrogen (e.g., ammonia) that contributes to the aquatic effects but is not part of the “criteria” pollutants addressed by this standard.
**Elements of an aquatic acidification standard**

*Elements of the standard – analogous to all NAAQS:*

- **Indicators:** NOy and SOx to be measured to determine if the standard is met

- **Form:** Aquatic Acidification Index (AAI) equation that relates a target ANC value to air concentrations as mediated by other deposition-related environmental factors …*next slide*

- **Level:** the target AAI value, based on ANC, that, in combination with the other elements of the standard, is judged to provide requisite protection

- **Averaging time:** annual standard, averaged over 3 to 5 years

*Standard would be met when measured values of NOy and SOx are such that the calculated value of the AAI, averaged over 3 - 5 years, is greater than or equal to the level of the standard*
Critical Load modeling
(J. Lynch guidance)

- A modified version that incorporates attributes of SSWC and FAB steady state models
  - \( CL= (BC_0^* - ANC_{\text{lim}})Q + N_{\text{eco}} \)
    - Where \( N_{\text{eco}} \) represents all N loss terms (uptake, denitrification, immobilization); estimated as N deposition – NO\(_3\) leaching (not strictly ss)
    - \( BC_0^* = [BC^*]_t - F([AA]_t^* - [AA]_0^*), \) based on water quality data
    - National water quality data base of over 9,000 water bodies (J. Lynch)
Critical Load modeling to AAI

AAI equation is derived from the CL expression by (1) separating out NHx, (2) defining a deposition exceedance, (3) defining an ANClim exceedance, (4) translating an ANClim exceedance to a calculated AAI as the air quality/deposition below that to achieve and ANClim:

1) \( CL \ (N + S) = ([BC]_0^* - [ANC_{lim}])Q + N_{eco} = [NOy]T_{NOy} + [SOx]T_{SOx} + NHx; \)
   note: T's are aggregated deposition velocities

2) \( DEP_{ex} = [NOy]T_{NOy} + [SOx]T_{SOx} + NHx - CL \)

3) \( ANC_{lim_{ex}} = DEP_{ex}/Q_r = \{[NOy]T_{NOy} + [SOx]T_{SOx} + NHx - CL\}/Q_r \)
   note: Qr is a representative runoff rate to balance units

4) \( ANC_{calc} = ANC_{lim} - \{[NOy]T_{NOy} + [SOx]T_{SOx} + NHx - CL\}/Q_r \)

Rearranging:

\[ AAI = (ANC_{lim} + CL_r/Q_r) - NHx_{dep}/Q_r - T_{NOy}[NOy]/Q_r - T_{SOx}[SOx]/Q_r \]

Condition \( N_{dep} < N_{eco}, \) \( CL \ (N + S) = ([BC]_0^* - [ANC_{lim}])Q \) and NHx and \( T_{NOy} = 0 \)
Form of the standard

Aquatic Acidification Index (AAI) = F₁ – F₂ – F₃ [NOy] – F₄ [SOx]

AAI = (ANClim + CL_r/Q_r) – NHxdep/Q_r – T_{NOy}[NOy]/Q_r – T_{SOx}[SOx]/Q_r

Components of the form:
- AAI: calculated ANC expected to result over time from deposition associated with monitored NOy and SOx concentrations
- F₁ = (ANClim + CL_r/Q_r)
  - natural ability of an ecosystem to neutralize deposition
  - CL_r = (BC₀* - ANClim)Q_{wb}
  - Q_r = median runoff rate of sampled water bodies
- F₂ = NHx deposition/Q_r
  - reduced nitrogen (ammonia gas and ammonium ion) deposition
- F₃, F₄ are transference ratios; T_{SOx} = SOx deposition/[SOx]; T_{NOy} = NOy deposition/NOy
  - factors that convert measured NOy and SOx in the ambient air to NOy and SOx deposition
Defining appropriate ecoregions

- Omernik Ecoregion III classification scheme (developed in the 1980s by EPA) divides the U.S. into ecologically relevant regions (84 regions cover the continental U.S.)
  - Based on common vegetation, geology, soils, and hydrological characteristics
Acid sensitive and non-sensitive ecoregions

- While the standard would apply nationwide, categorizing ecoregions as relatively acid-sensitive (22 areas) or non-sensitive (~62 areas) serves to identify areas that will benefit most from reductions in NOy and SOx deposition (similar to “susceptible populations” for health-based standards)

- Categorization based on water quality data and land use categories (naturally acidic and managed areas categorized as relatively non-sensitive)
2006 NLCD land use data by ECO III

% Coverage

- Atlantic Coastal Plain Barrens
- Southern Coastal Plain
- Middle Atlantic Coastal Plain
- Southwestern Appalachians
- Ouachita Mountains
- Arkansas Valley
- Boston Mountains
- Blue Ridge
- Western Allegheny Plateau
- Central Appalachians
- Ridge & Valley
- South Central Appalachians
- Southeastern Plains
- Piedmont
- Maine/New Brunswick Plains & Hills
- Northeastern Coastal Zone
- Northern Appalachian Plateau & Uplands
- Cascades
- North Cascades
- Canadian Rockies
- Columbia Mountains/Northern Rockies
- Idaho Batholith
- Southern Rockies
- Wasatch & Uinta Mountains
- Sierra Nevada
- Middle Rockies
- North Central Appalachians
- Northern Appalachian & Atlantic Maritime Highlands
- Northern Lakes & Forests

Dev  Ag

Land Use Category
Ecoregion-specific factors (F1 – F4)

- Each ecoregion has a unique set of factors, F1 – F4, based on data averaged across the ecoregion
  - F1 is determined based on selecting a representative critical load of sampled water bodies for each ecoregion
    - For acid sensitive regions, a representative critical load is defined in terms of a specific percentile of the distribution of critical loads that have been calculated for each ecoregion
      - Use of a higher percentile (e.g., 90th percentile) would be more protective than a lower percentile (e.g., 70th percentile)
    - For relatively non acid-sensitive ecoregions, consider using a national default critical load based on averaging the 50th percentile values from all such ecoregions
      - This different approach is intended to avoid potential for over protection in relatively non acid-sensitive ecoregions
  - F2, F3, and F4 are based on CMAQ (Community Multi-scale Air Quality Model) modeling, which translates emissions of N and S into ambient concentrations and deposition

- EPA would calculate and codify (as part of NAAQS rulemaking) F values for each ecoregion and provide tables – update every 5 years
Level of the standard

- Policy Assessment focused on a range of values from 20 – 75 µeq/L
  - Range would afford some degree of protection from long-term, chronic aquatic acidification
  - Upper part of range would afford:
    - Added protection for episodic acidification (e.g., spring snowmelt)
    - Shorter time frame for some water bodies to reach a target ANC
Alternative Standards

- Level and form together determine the degree of protection afforded by standard
- Alternative levels (20 – 75 µeq/l) and forms (F1 based on 70th to 90th percentile) were assessed in terms of whether acid-sensitive ecoregions would likely not meet alternative standards
  - Anticipate that all non acid-sensitive ecoregions would meet this range of standards

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**Legend:**
- **northeast mtns.**
- **central/southern Appalachians**
- **northern Piedmont**
- **Ozark region**
- **northern midwest Lakes**
- **western mountains**
Example maps of ecoregions not likely to meet alternative standards – current and future conditions

ANC 50, 80%

Policy assessment results
Emissions sensitivity run:
42% and 48% SOx, NOx reduction

ANC 35, 80%

2005

2016 projection with Toxics rule
39% NOx and 73% SOx reductions
Key Uncertainties

Data gaps:

- Limited ambient measurements of NOy
  - National multiple-pollutant network (NCORE), but monitors are not located in targeted locations in sensitive ecoregions

- Relatively sparse coverage in mountainous west, including measurements of:
  - Air concentrations
  - Water quality
    - Water quality values determine ecoregion sensitivity
    - Small sample sizes impair our ability to characterize the “representativeness” of the available data

- Limited measurements of reduced forms of N (ammonia and ammonium)
  - Only a small new ammonia network (AMON) exists
  - Emission inventories are subject to considerable uncertainty
Reliance on critical load and atmospheric modeling inherently introduces additional uncertainties, for example:

- Model results difficult to evaluate due to lack of relevant observations
  - Critical load modeling requires evaluation of pre-industrial conditions (e.g., in terms of base cation supply)
  - Atmospheric modeling (CMAQ) involves evaluation of relationship between N and S in ambient air and associated deposition (i.e., transference ratios)
  - Modeled dry deposition
- Air quality models exhibit over-prediction of SO$_2$ concentrations
  - Although analyses indicate that this does not bias the use of CMAQ in the AAI expression
- Use of steady state critical load models results in a simplification of key biogeochemical processes

There is no obvious directional bias that would suggest uncertainties lead to under- or over-protection.
What are the benefits of a secondary N/S standard?

• Why bother if other programs (PM and ozone rules) solve the problem?
• Accountability
  – Title IV only provided an emissions test
    • Does not allow for any diagnosis
  – An air quality based “indicator” is one step closer …source-effects perspective
    • At least conceptually links further to deposition and water quality.
• An air quality standard draws attention
  – periodic reviews
  – a catalyst and resource? for more research
  – And more data collection
• Establishes a template for refinements
  – Additional effects (terrestrial acidification, nutrient enrichment)
  – Additional interactions…e.g, Hg methylation
  – Improved modeling…gradual transition to dynamic CL models
What help is needed? (note: the FOCUS effort is already is thinking or has considered much of the same)

- Key needs ,,separate from atmospheric modeling and data
  - Characterizing critical load distributions
    - Increase Mountainous West sampling
    - Define “representativeness”
      » Nth percentile???
    - Screen or not
  - Refining land use data
    - Adding “protected lands”
    - Recently “mined” areas
    - Defining plantation forests for harvest
  - To lag or not, SS or dynamic
    - Not just science
      » Semantic component
        » Do we need a CL that is effects and time based?
    - How does the exclusion or simplification of key processes affect results?
Monitoring considerations

- CASTNET provides a solid infrastructure
  - Largely rural location, originally designed to support acidification assessments – greater coverage in eastern U.S.
    - Most acid sensitive ecoregions have 1 - 3 sites
  - Provides measurements of 2 of 3 indicators (SO$_2$, SO$_4$), and supplementary data (nitrate, ammonium, ammonia – limited locations)

- Monitoring approaches would be specified in the final rule

- Approved federal reference or equivalent methods (FRM/FEM) are not available for sulfate and NOy
  - EPA-ORD is working to approve an NOy method and other required CASTNET SO$_2$ and SO$_4$ methods; these methods would be adopted by rule upon ORD approval

- A staged deployment synchronized with options outcomes is recommended
  - Stage 1 – methods development design and approval (on-going)
  - Stage 2 - initial “pilot” deployment in 3 - 5 ecoregions (opportunity to use observed data to evaluate the standard)
  - Stage 3 – complete deployment in all sensitive ecoregions
1. Methods approval and network design 10/2010 to 6/2013
   - CASTNET methods – documentation of methodology and historical performance.
     - For indicator SOx – includes SO₂ and SO₄
   - NOy – controlled site testing in RTP, NC and 1-2 additional locations
   - Design includes:
     - Siting criteria, spatial coverage
     - Developing partnership across CASTNET, EPA, States

2. Pilot program (2013 - 2016) to evaluate monitoring network design and implementation issues, and to generate data to calculate AAI values (see next slide)

3. Complete deployment in all ecoregions by 1/2017
A 2 - 4 year transition program to develop a monitoring network and to work out logistics of implementing the new standard

- **Monitoring component** - evaluation period to work out design issues
  - Deployment of 2-3 sites in each of 3-5 high priority ecoregions – beginning in 6/2013
  - Add NOy monitors to existing CASTNET methods
  - CASTNET includes SOx (SO2 and SO4), as well as ammonium and total nitrate
  - Use CASTNET sites that measure ammonia and add ammonia measurements at sites lacking
  - Provide actual observed data to use in the AAI equation
  - Would afford an opportunity to work out network design and process issues
    - Would provide data to analyze spatial variability within an ecoregion – assist network design
    - Explore the partnership across CASTNET, EPA and the states

- **Data analysis component**
  - In parallel with monitoring, use source apportionment modeling to explain which sources (sectors and location) are contributing – reinforce the multiple pollutant similarities with ozone, PM and haze
  - Information would be used to support the implementation strategy
    - For example, illustrate how PSD/NSR and interstate transport (110a2d) requirements are met through other conditions related to existing programs, including the primary SO2 and NO2 NAAQS
  - Would provide data to evaluate modeled characterization of reduced nitrogen deposition

- **Stakeholder component**
  - Provide time to work in concert with state program administrators and other stakeholders to use the data to help develop an implementation strategy
Monitoring timeline

Staged approach – using existing CASTNET infrastructure

1. 10/2010 - 6/2013 methods approval by ORD and network design
2. 6/2013 – gather and evaluate data at 3-5 sites in priority sensitive areas
   - Initial set of 3 years of complete data available in 2017
3. 1/2017 - complete deployment in all 22 areas (if new standard promulgated)

Stage 1
FRM/FEM
Testing/design
CFP
NOy

Stage 2
Priority
Sites deployed

Stage 3
Full deployment

For any of the standard options
CASAC Conclusions and Recommendations

- **With regard to adequacy of current standards** (Dec. 9, 2010 letter):
  - Current standards “should be retained to protect direct adverse impacts to vegetation”
  - The ISA, REA, and PA demonstrate that adverse impacts to aquatic acidification are also occurring due to deposition of oxides of N and S
  - “Levels [of current standards] are not sufficient, nor the forms of those standards appropriate, to protect against adverse depositional effects; thus a revised NAAQS is warranted”

- **With regard to a new aquatic acidification standard** (April 12, 2001 draft letter):
  - “The PA develops a framework for a multi-pollutant, multimedia standard that is ecologically relevant and reflects the combined impacts of these two pollutants....”
  - “CASAC generally supports the potential choices/ranges presented by EPA staff on the indicators, form, averaging time, and level that should be considered . . . “
  - Combinations of levels and percentiles in the Policy Assessment “provide the Administrator with a broad but reasonable range of minimally to substantially protective options for the standard.”

- **CASAC noted important uncertainties that should be considered in this review and addressed in future analyses and reviews**
  - “. . . a more rigorous model evaluation should have been conducted to provide more confidence in the use of the models.”
Stakeholder views

- **Industry** – highly critical of any change to standards
  - Power generation (UARG, EPRI)
  - Fuels (API)
  - Agriculture – hasn’t yet engaged, but likely to be critical due to role of ammonia

- **Environmental groups** - strongly supportive of new standard
  - Have also argued for direct inclusion of reduced nitrogen as a regulated pollutant
  - Have also encouraged extending standard to address nutrient enrichment effects
    (Chesapeake Bay Foundation)

- **Other government organizations**
  - NPS, USFWS – strongly supportive
    - Encouraged extending standard to address nutrient enrichment effects
  - Individual States – expect mixed reactions, with some supportive and others concerned about implementation burdens
  - NESCAUM – strongly supportive
  - Tribes – not engaged to this point
## Estimated Monitoring Costs

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<td>Stage 1</td>
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<td>100K S&amp;T/EPM&lt;br&gt;Complete methods development &amp; evaluation&lt;br&gt;OAQPS/ORD</td>
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<td>Priority deployment phase&lt;br&gt;2 existing CASTNET - $0&lt;br&gt;2 new CASTNET - $190K*&lt;br&gt;*Additional OAP funds</td>
<td>O&amp;M - $60K&lt;br&gt;(for 2 additional CASTNET sites)</td>
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<td>$80K</td>
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** Additional operating costs above current CASTNET O&M operating costs
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