UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

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OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options – A Report of the EPA Science Advisory Board

Dear Administrator Jackson:

Excess reactive nitrogen compounds in the environment are associated with many large-scale environmental concerns, including eutrophication of surface waters, toxic algae blooms, hypoxia, acid rain, nitrogen saturation in forests, and global warming. In addition, reactive nitrogen is associated with harmful human health effects caused by air pollution and drinking water contamination. Reactive nitrogen (hereafter referred to as Nr) includes all biologically active, chemically reactive, and radiatively active nitrogen compounds in the atmosphere and biosphere of the earth, in contrast to non-reactive gaseous N_2. EPA and other federal and state agencies have implemented programs to reduce the risks posed by excessive Nr, but a more comprehensive and integrated approach is needed to manage the use of Nr in a way to achieve its benefits, such as fertilizer for food production, and mitigate its damages as it is introduced to and cycles repeatedly through the environment in different forms and media.

The Science Advisory Board (SAB) Integrated Nitrogen Committee has conducted a study to analyze sources and fate of Nr in the United States and provide advice to EPA on integrated nitrogen research and control strategies. We are pleased to submit the SAB report, *Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options.* Our objectives for this study were to:

- Identify and analyze from a scientific perspective the problems Nr presents in the environment and the links among them;
- Evaluate the contribution an integrated nitrogen management strategy could make to environmental protection;
- Identify additional risk management options for EPA's consideration; and
- Make recommendations to EPA concerning improvements in nitrogen research to support risk reduction.

The SAB report provides findings and recommendations addressing these study objectives. Assessment of the challenges and costs to the Agency of implementing the recommendations is beyond the scope of the report.

In general, the SAB finds that:

- In the United States, human activities across multiple sources currently introduce more than five times the Nr into the environment than natural processes. The largest U.S. sources of new Nr entering the U.S. environment include: the creation and use of synthetic fertilizers, Nr created by legumes, and the combustion of fossil fuels.
- Much of the Nr used to ensure a plentiful supply of food, fiber and biofuel is released to the environment, as is the Nr formed during fossil fuel combustion.
- The introduction of human created Nr into the environment degrades air and water quality, which can cause harmful algae blooms, hypoxia, fish kills, loss of drinking water potability, loss of biodiversity, forest declines, and human health problems resulting in losses of billions of dollars per year.

- Multiple strategies and actions exist to more effectively minimize the inputs of Nr to the environment and maximize nitrogen use efficiency.

The SAB provides the following overarching recommendations to improve the management of Nr.

- The framing of the movement of nitrogen among various environmental reservoirs in terms of the nitrogen cascade concept provides a means for tracking nitrogen as it changes form and passes through multiple ecosystems and media. Given this complexity, innovative management systems and regulatory structures reflecting these characteristics of Nr are required to address the significant environmental and human health damage caused by Nr. New institutional structures and relationships that also reflect the multi-media and multi-form character of Nr and its flows and transformations through the environment will have to be created for effective control and management.
- The SAB recommends an integrated approach to the management of Nr. This approach must use a combination of implementation mechanisms appropriate to the specific environmental and policy contexts and supported by critical research on the specific risks of Nr and on decreasing the risks of Nr. The approach must reflect an integrated policy that recognizes the complexity and trade-offs associated with the nitrogen cascade while recognizing that intervention points vary in terms of efficiency and cost effectiveness.
- EPA should form an intra-Agency Nr management task force that will build on the existing breadth of Nr research and management capabilities within the Agency. Its objective should be to increase scientific understanding of: (1) Nr impacts on terrestrial and aquatic ecosystems, human health, and climate; (2) Nr-relevant monitoring requirements; and (3) the most efficient and cost effective means by which to decrease various adverse impacts of Nr loads as they cascade through the environment.
- Successful Nr management will require changes in the way EPA interacts with other agencies. The SAB recommends that EPA convene a reactive nitrogen inter-agency management task force with broad representation from other agencies and departments involved with Nr control or utilization. This is essential to coordinate federal programs that address Nr concerns and would help ensure clear responsibilities for monitoring, modeling, researching, and managing Nr in the environment. Similar efforts at coordination and joint action need to be made among and between agencies at both the state and federal level.

In the context of addressing the specific study objectives, the SAB explored how an estimated 25 percent reduction in Nr introduced into the environment might be achieved with existing technology in the coming 10 to 20 years through actions that could be taken by EPA, other management authorities, and other public and private organizations. Specific actions include increased controls of oxides of nitrogen, improved reactive nitrogen uptake by agricultural crops, large-scale creation and restoration of wetlands for nitrogen removal in agricultural landscapes with high Nr in surface waters, decreased loss of reactive nitrogen from agricultural lands and animal feeding operations, and decreased discharge of reactive nitrogen from point sources and developed (urban) lands. However, dealing effectively with reactive nitrogen's cascade through air, water and land will require an integrated management approach that is multi-media and multi-stressor as suggested by recent initiatives by EPA's Office of Research and Development.

The most important task for EPA and allied agencies and departments will be to effectively inform the public of the costs and dangers of excess Nr. Without strong public support, the widespread efforts necessary to control Nr will not be possible.

In closing, we appreciate the opportunity to provide advice on this very important topic, and we look forward to receiving your response. The SAB stands ready to provide more information as it may be useful and would be pleased to assist EPA in the implementation of the report's recommendations, if the EPA would find such support valuable.

Sincerely,

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List of Chemical Abbreviations

C	Carbon
CFC	Chlorofluorocarbon
DIN	Dissolved inorganic nitrogen
DO	Dissolved oxygen
Fe	Iron
H	Hydrogen
HNO_3	Nitric acid
HONO	Nitrous acid
N	Nitrogen
N_2	Diatomic (molecular) nitrogen
N_2O	Nitrous oxide,
N_2O_5	Dinitrogen pentoxide (nitric acid anhydride)
NH_3	Ammonia
NH_4^+	Ammonium
NH_x	NH_3 NH_4^+
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_3^-	Nitrate ion
NO_3	Nitrate radical
N_{org}	Organic nitrogen
NO_x	Nitrogen oxides (NO + NO_2)
NO_y	Total reactive oxidized nitrogen (NO, NO_2, NO_3, $2xN_2O_5$, HONO, HNO_3, NO_3^-, PAN and other organo-nitrates, $RONO_2$)
Nr	Reactive nitrogen
O_2	Oxygen
OH	Hydroxyl radical
P	Phosphorus
PAN	Peroxy acetyl nitrate
PM	Particulate matter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
PM_{10}	Particulate matter less than 10 microns in diameter
$RONO_2$	Organic nitrates
Si	Silicon
SO_2	Sulfur dioxide
SO_4^{2-}	Sulfate
TAN	Total ammonical nitrogen

List of Acronyms and Abbreviations

AAPFCO	Association of American Plant Food Control Officials
AARA	American Reinvestment and Recovery Act
AIRMON	Atmospheric and Integrated Research Monitoring Network
AOB	Ammonia oxidizing bacteria
BL	Boundary layer
BMP	Best management practice
BNF	Biological nitrogen fixation
BNR	Biological nutrient (or nitrogen) removal
CAA	Clean Air Act
CAFO	Concentrated animal feeding operation
CAIR	Clean Air Interstate Rule
CALM	Consolidated Assessment and Listing Methodology
CAST	Council for Agricultural Science and Technology
CASTNET	Clean Air Standards and Trends Network
C-BNF	Cultivation-induced biological nitrogen fixation
CCC	Criterion continuous concentration
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
CL	Critical load (threshold of Nr loading at which negative impacts have been documented)
CLAD	Critical Loads Ad-Hoc Committee
CMAQ	Community multiscale air quality
CMC	Criterion maximum concentration
CRP	Conservation Reserve Program
CSO	Combined sewer overflow
CTM	Chemical Transport Models
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund (construction grants program under the Clean Water Act)
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EGU	Electricity generating units
EFD	Essential Facilities Doctrine
EGR	Exhaust gas recirculation
EISA	Energy Independence and Security Act
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization Statistical Database
FGR	Flue-gas recirculation

ha	Hectare
GHG	Greenhouse gas
GPS	Geographic Positioning System
HAB	Harmful algal bloom
IPCC	Intergovernmental Panel on Climate Change
ISA	Integrated Science Assessments
ITQ	Individual transferable quota
kg	Kilogram
L	Liter
LA	Load allocation
LCA	Life cycle analysis
LISS	Long Island Sound Study
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
mg	Milligrams
MGD	Million gallons per day
MJ	Megajoule (one million joules)
Mmt	Million metric tons
MT	metric tons
MOM	Mississippi-Ohio-Missouri
MRB	Mississippi River Basin
MS4	Municipal separate storm sewer system
NAAQS	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
NASS	National Agricultural Statistics Service Information
NCA	National Coastal Assessment
NCE	Nitrogen Credit Exchange
NCCR	National Coastal Condition Report
NEEA	National Estuarine Eutrophication Assessment
NESCAUM	Northeast States for Coordinated Air Use Management
NFUE	Nitrogen fertilizer use efficiency. Calculated as the ratio of grain yield to the quantity of applied N fertilizer (kg grain/kg applied N).
NMP	Nutrient management plan
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint source
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRD	Natural Resource District
NRI	National Resources Inventory
NTN	National Trends Network

NUE	Nitrogen use efficiency. NUE is defined as the kg grain produced per kg of total N used by the crop, where total N includes N from fertilizer, biological N fixation, and soil organic matter mineralization
OTAG	Ozone Transport Assessment Group
OTC	Ozone Transport Commission
PE	Physiological efficiency (physiological efficiency with which the N taken up by the crop is used to produce economic yield such as grain or fruit, quantified by kg increase in economic yield per kg of N accumulation in above ground crop biomass)
PFP	Partial factor productivity
POTW	Publicly owned treatment works
PSD	Prevention of significant deterioration
RE	Recovery efficiency (kg N uptake per kg N applied)
SAV	Submerged aquatic vegetation
SNCR	Selective non-catalytic reduction
SCR	Selective catalytic reduction
SIP	State Implementation Plan
SOM	Soil organic matter
SPARROW	Spatially Referenced Regressions on Watershed Attributes Model
STP	Sewage treatment plant
SW	Storm water
SWAT	Storm Water Assessment Tool
SWPPP	Stormwater Pollution Prevention Plan
T	Temperature
Tg	Teragram (million metric tons or 10^{12} grams)
TMDL	Total maximum daily load
TN	Total nitrogen
UFTRS	Uniform Fertilizer Tonnage Reporting System
UNECE	United Nations Economic Commission for Europe
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WLA	Wasteload allocation
WPCA	Water pollution control authorities
WRI	World Resources Institute
WRP	Wetland Reserve Program
WSA	Wadeable Stream Assessment