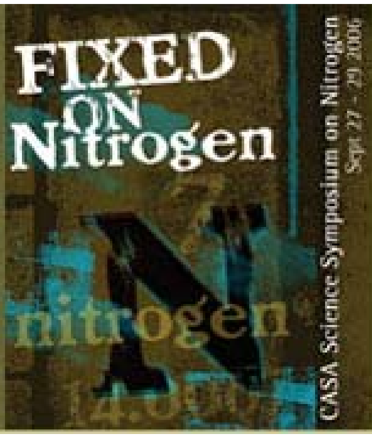


FIXED ON NITROGEN

CASA Science Symposium on Nitrogen

September 27 – 29, 2006
Fairmont Chateau Lake Louise
Lake Louise, Alberta

Abstract

Overview of CASA
Donna Tingley

The Clean Air Strategic Alliance (CASA) was formed in 1994 by the Government of Alberta to resolved outstanding air quality issues using a collaborative process. CASA is a multi-stakeholder partnership, composed of representatives selected by industry, government and non-government organizations. CASA's mission is to recommend strategies to assess and improve air quality in Alberta using a consensus process.

The goal of the CASA consensus process is to achieve a solution to a complex issue that everyone can "live with" because it reflects the interests of every person around the table. Consensus agreements amongst stakeholders have many beneficial outcomes: producing innovative solutions that meet both environmental and economic interests; long-lasting solutions that are supported by all stakeholders; and the application of resources and ideas from many sectors to resolve difficult issues.

Air quality management frameworks developed through the CASA consensus process have been recognized nationally and internationally. CASA has been the recipient of several awards for its innovative processes and outcomes. Some notable successes are: the Solution Gas Flaring and Venting Framework; Emissions Management Framework for the Alberta Electricity Sector; and Particulate Matter and Ozone Management Framework.

To provide CASA stakeholders with leading edge scientific information, two symposia have been held: Acidifying Emissions (1996) and Air Quality and Human Health (2002). The goals of the 2006 Scientific Symposium on Nitrogen are: one, to address issues related to the science of nitrogen emissions and their environmental effects, and two, to examine risks and management approaches for these issues in Alberta. The Scientific Symposium on Nitrogen has been organized by a multi-stakeholder committee who has worked to ensure that all topics and presentations are fair, balanced and meeting the information needs of CASA stakeholders.

Web Link: www.casahome.org

Overview on Nitrogen: Effects, fate and impact and issues for research and management

Dr. Bridget Emmett

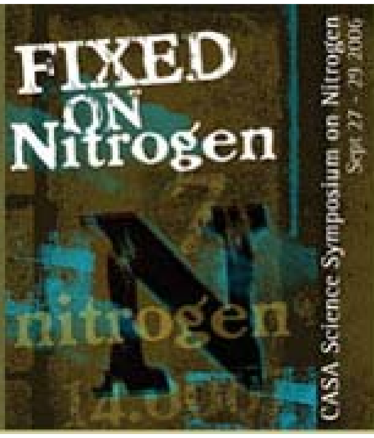
Through international agreements there has been some success in reducing emissions of nitrogen in Europe and N America. However, within specific regions such as Alberta, and in many other parts of the world, trends are increasing. Sources of this nitrogen are varied and include both dry and wet forms of oxidised and reduced nitrogen. Contributing sectors responsible for nitrogen oxide emissions include transport, energy industries and fertilizer applications and ammonia from animal husbandry activities and fertiliser applications. Impacts are also complex and varied and depend on the nitrogen species present. Areas of concern include species change of terrestrial systems, impacts on soil quality and tree growth, changes in water quality and species diversity of marine systems, adverse effects on human health both through water and air quality, and impacts on greenhouse gas fluxes. Significant advances have been made in our scientific understanding in many of these areas, which has helped inform policy development, but areas of uncertainty remain. These include accurate modelling of deposition, controls on soil nitrogen storage and links to above and below-ground species change, appropriate indicators/thresholds for ecosystem responses, relative importance of phosphorus and nitrogen enrichment in aquatic systems and appropriate air quality guidelines for nitrogen dioxide and ammonia due to their role in formation of particles ($PM_{2.5}$), to name but a few. Management approaches in Europe, whilst having some success, has perhaps not been as great as we could have been hoped for. Reasons for this are varied but include lack of scientific understanding and the complexity of the nitrogen cycle, lack of technologies to reduce emissions, conflicting policies (e.g. agricultural policy and emissions control), a focus on the wrong industries (industry instead of agriculture and omitting shipping) and cost.

Sources of Nitrogen in Alberta

David Niemi

Environment Canada in collaboration with Alberta Environment and other provincial / territorial experts prepare comprehensive emissions inventories and projections of Criteria Air Contaminants (CAC) and Greenhouse Gasses for the provinces / territories and Canada. Ammonia (NH_3), Nitrogen Oxides (NOx: NO & NO_2) and Nitrous Oxide (N_2O) are among the pollutant emissions inventoried. While Alberta NOx emissions from many sectors are relatively stable or decreasing there has been growth in the Energy sectors (Upstream Oil and Gas, Oil Sands, and Electricity Generation) leading to a 51% increase in emissions from 1990 to 2002 and 73% by 2015. Alberta ammonia emissions have been increasing somewhat mainly due to the agricultural sectors with other sources remaining relatively stable. Preliminary ammonia projections are predicting significant increases in NH3 from agriculture but these are currently under review by Environment Canada, Alberta Environment, Agriculture Canada, and other government departments to refine the emissions inventories and projections. Nitrous Oxide emissions for Alberta have increased from 1990 to 2004 by 29% due to increased emissions from agriculture and transportation. Work is in progress at Alberta Environment and various CASA teams to reduce the NOx emissions from many of the leading sectors.

Web Links:
Environment Canada's Clean Air on Line: http://www.ec.gc.ca/cleanair-airpur/ , Environment Canada's CAC Emissions Inventories : http://www.ec.gc.ca/pdb/cac/cac_home_e.cfm, Environment Canada's Greenhouse Gas Inventory: http://www.ec.gc.ca/pdb/ghg/inventory_e.cfm, Environment Canada's National Pollutant Release Inventory: http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm
Alberta Environment: http://environment.gov.ab.ca/default.aspx



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Abstract

Nitrogen Concentration and Deposition in Alberta
Dr. Karen McDonald

This presentation provides a brief contextual setting for the discussions to follow in the workshop. The state of information on atmospheric concentrations and deposition of nitrogen in the province of Alberta will be presented. Spatial distribution of NO and NO2 gas concentrations is displayed using monitored results from Alberta's airshed zones across the province. Alberta will be shown in context with other North American cities. Modeled results performed by Alberta Environment demonstrate the changes over time in air concentrations and deposition patterns. Model projections to emissions for the year 2010 will be presented. Hotspots and issues are identified. The nitrogen changes are demonstrated in contrast to the changes in sulphur over the same time frame to illustrate the relative affect on the overall potential acid input and proportion of critical load affecting the landscape.

Management Approaches for Nitrogen Emissions

Dr. Julian Aherne

Human activity during the last century has greatly increased the emissions of nitrogen to the environment. This dramatic increase has caused nitrogen to be ranked as a pressing environmental issue, owing to the concerns that excess nitrogen can lead to deterioration of air quality, disruption of forest processes, acidification of freshwaters, and over-enrichment of coastal waters. Nitrogen may be viewed as a pollutant when more reactive nitrogen (nitrate and ammonia) is released into the environment than can be assimilated (Driscoll et al. 2003). The principal sources of airborne emissions of reactive nitrogen are fossil fuel combustion by vehicles, industry and electric utilities, and agricultural practices.

Historic efforts to manage atmospheric emissions of airborne pollutants looked to dilution and dispersion through building higher smokestacks. More realistic efforts to reduce emissions during the mid-1980s and early 1990s focused on flat-rate reductions, with agreed percentage reductions in pollutant emissions relative to a fixed base year. Although they represented an initial positive action, flat rate reductions were considered neither economically nor environmentally efficient. Socolow (1999) suggested five principles to manage the human impacts on the nitrogen cycle: (i) reach agreement on goals relevant to sustainability; (ii) improve efficiency of producers and consumers; (iii) harness market forces; (iv) incorporate mechanisms to learn continuously from research; and (v) engage the consumer and the citizen. However, these require integration into a properly crafted management system. To achieve this, mathematical assessment models and other management tools must be developed and used to help environmental managers and stakeholders in government and industry (Galloway et al. 2002).

The UNECEs Convention on Long-Range Transboundary Air Pollution (LRTAP) provides an excellent case study on the development of emission controls. Since 1979, several protocols relating to sulphur and nitrogen emission reductions have been signed under the auspices of the UNECE. The Convention has been highly successful due in principal to five key elements: (i) an effective organisational structure; (ii) the formal creation of a body responsible for processing and analysing air-pollution data (iii); the set-up of a working group to provide scientific information on the effects of air pollution; (iv) the development of new effects-based protocols using the critical loads approach; and (v) the use of an integrated assessment model to link scientific data on damage with the political process under the critical loads approach (Gough et al. 1998, Siebenhüner 2002).

Clearly during the last decade innovative concepts for emission control have been developed under the Convention on LRTAP. Air quality management is now understood as a multi-pollutant, multi-effect task within which integrated assessment models have proved useful

in developing cost-effective emission control strategies. An effects-based approach to emissions reductions is highly recommended for Alberta — incorporating scientific information on effects, consensus on the modelling of pollutant transport and linked to policy through an integrated assessment model.

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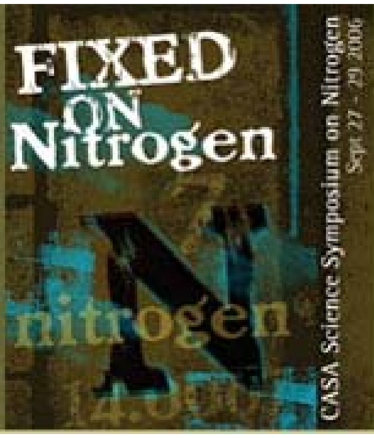
Updated Biography

Julian Aherne
Julian Aherne holds the Canada Research Chair in Environmental Modelling at Trent University in Peterborough, Ontario, Canada. His research interests are focused on the application of hydrological and hydrochemical models as a means of investigating the impacts of human perturbations on aquatic and terrestrial ecosystems and the consequences, both immediate and long-term, on their sustainability. His current research includes regional scale application of dynamic hydrochemical models to forested catchments across Canada and Europe, regional critical load mapping across North America, and site specific investigations on the impacts of sulphur and nitrogen deposition in Ontario, Alberta and British Columbia, Canada and Ireland. Previous research experience includes a critique of acid rain surface water acidification models; application of hydrological and hydrochemical models to Irish forests; determination and mapping of critical loads for sulphur and nitrogen and critical levels of ozone for Ireland; Irish acid-sensitive lake survey; mapping deposition of major ions in precipitation, SO_2 and NOx emissions, and ammonia emission and deposition in Ireland.

Atmospheric Chemistry of Nitrogen
Dr. Mary Anne Carroll

Human activities have greatly affected the atmospheric burden of reactive nitrogen species and N_2O, which play significant roles in oxidant photochemistry in the troposphere and stratosphere, respectively. In the troposphere, nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NOx, play a catalytic role in the production of ozone (O_3); a key role in the production of OH via production of O_3 and reaction with peroxy radicals (HO_2 and RO_2); and are precursors of alkyl nitrites and nitrates, peroxyalkyl and peroxyacetyl nitrates, nitrous, nitric and peroxynitric acids, ammonium nitrate, and secondary organic aerosols, many of which are irritants to humans and biological systems. In addition, the nitrate radical (NO_3) plays an important role in the oxidation of organic compounds. In the stratosphere, reaction of N_2O with excited oxygen atoms is a source of NO, which plays a direct catalytic role in O_3 destruction; reaction of NO_2 with chlorine and bromine monoxide (ClO and BrO) leads to a cessation of ozone destruction; and catalytic cycles involving NOx and both reactive and nonreactive forms of chlorine and bromine lead to ozone destruction. The photochemistry involving the transformation of NO to NO_2, NO_3, and N_2O_5, and further transformation of these compounds to inorganic acids, organic nitrates and ammonium nitrate and the catalytic roles played by NOx in ozone formation (troposphere) and loss (stratosphere) will be discussed.



Abstract

Soil, groundwater and surface water chemistry of nitrogen
Dr. Shaun Watmough

The behaviour of atmospherically-deposited nitrogen (N) in terrestrial and aquatic ecosystems in complex and a number of processes and internal and external factors ultimately affect the fate of N. Understanding these processes, the factors influencing them and their response to increased N loadings is of paramount importance for estimating acceptable levels of N deposition that will not adversely impact the environment. The basic processes affecting N transformation in soils and aquatic ecosystems are reviewed, highlighting results from short-term experimental studies and gradient studies that investigate chronic exposure to elevated N. Long-term trends in N export from calibrated catchments in Canada and Europe are described, and the complicating effect of climatic perturbations on chemical patterns is discussed.

The General Science of Nitrogen Eutrophication:

Dr. Bridget Emmett

Nitrogen eutrophication can be considered as the unintended enrichment of terrestrial and aquatic systems by nitrogen such that changes are observed which are considered harmful or undesirable in the long term. Many factors can influence the impact and fate of nitrogen deposited to an ecosystem and therefore sensitivity can vary between different ecosystem types. Considering depositional factors first, the form of nitrogen deposited is known to affect the responses observed. In general, dry deposition is considered more damaging and some recent evidence from a large scale field experiment will be presented to illustrate this. Reduced nitrogen is also often considered more damaging than oxidised nitrogen due to its acidification potential and effective retention in the soil. However, this may be system specific as some studies suggest oxidised forms of nitrogen can result in faster species change in some habitats. The rate nitrogen enters the system may also be important although syntheses of experimental studies indicate surprising robustness of response to nitrogen load irrespective of frequency of dose. Once deposited, a range of responses are observed some of which are specific to ecosystem type. These include changes in foliage chemistry and nutritional imbalances, loss of sensitive species and vegetation composition change, increased incidence of pathogen and herbivory attack, and enhanced nitrate leaching. Uncertainties remain including controls on soil nitrogen storage and links to vegetation change, underlying mechanisms leading to increased sensitivity to stresses, impacts on animal populations and changes in soil biodiversity and implications for soil function including carbon turnover and storage. Major emphasis in Europe is now being placed on the development of dynamic ecosystem models to help determine the timing of changes forecast as this can be an important factor to consider for policy makers.

Specific Nitrogen Eutrophication Issues
Dr. Per Gundersen

Nitrogen fate, cycling and loss in forest ecosystems

Based on experimental and observational data from boreal forests in Scandinavia as well as from temperate forests in general the fate of deposition N in the forest ecosystem will be discussed. Components of the N balance will be examined particularly N accumulation in the plants (trees) and the soil. The development of nitrogen saturation and the controls on N leaching will be considered. Possible indicators of the N status of forest ecosystems (and thereby the susceptibility to N saturation) will be presented. This presentation will be based on the report 'Nitrogen Sinks in Boreal Ecosystems' by Callesen & Gundersen (2004), which is part of the information package.

The Direct Health Effects of Various Common Nitrogen Species
Dr. Kathleen Belanger

Abstract n/a

Abstract

Direct Effects of Common Atmospheric Nitrogen (N) Species on Vegetation
Dr. Sagar Krupa

Nitrogen (N) is an essential element for plants. All plants have a natural range of N requirements and when deficiencies or excesses occur, plants suffer from adverse effects. Aside from the soil, atmosphere is a major source of N and can contribute to its overload in plants. Gaseous N compounds such as ammonia (NH_3) and oxides of N (NO_x) are absorbed directly from the atmosphere through the foliage. In comparison, plants take up wet and dry deposited particulate N compounds primarily from the soil. Thus, there are both direct and indirect effects of N deposition on plants and their individual contributions can be apportioned by analytical and computational methods.

Among the gaseous N species, NH_3 is the most phytotoxic, but within short distances of its sources. Acute NH_3 exposures will lead to visible foliar injury symptoms very similar to sulfur dioxide (SO_2) toxicity. In comparison, generally at ambient concentrations, oxides of N do not produce visible foliar injury in plants, but their presence is extremely important for the production of ozone (O_3), the most important phytotoxic air pollutant world-wide.

Effects of NH_3 on plants include: visible foliar injury; changes in: growth, flowering, yield and responses to other stresses. Excess regional scale N loading can lead to changes in plant reproduction, species fitness and diversity and thus, ecosystem structure and function. A number of forbs, lichens, mosses and liverworts are extremely sensitive to excess N deposition. In contrast, grasses are tolerant, leading to changes in inter-species competition and plant

Abstract

Odours and their effects on residents – How to measure and regulate odour impact

Dr. Ralf Both

When evaluating odour emissions or odour impacts the measurement of single substances is often not useful, as a mixture of a lot of different and often unknown chemical substances causes odour. Only in very unusual cases is odour impact related to a single substance. The parameters used to describe the effects of odours are odour quality, odour frequency, odour concentration, odour intensity, hedonic tone and odour annoyance including health effects caused by odours. An overview of the different odour measurement (olfactometry, field measurements) and calculation methods (dispersion modelling) with respect to practical experiences will be given.
In addition exposure-response relationships, results of field investigations in residential areas near industrial installations and livestock operations, and the evaluation of odour limit values will be explored.

For industrial odours the strongest annoyance potential is found for unpleasant and neutral odours. Pleasant odours have a much less annoyance potential. For odours caused by livestock farming it is found that hedonic tone has no effect on the annoyance response of residents. Due to different odour qualities poultry odour has the strongest, pig odour a less strong and diary cow odour a very low annoyance potential. The dominating parameter found in all investigations is odour frequency. It was determined that odour frequency is suitable and sufficient to predict the annoyance response of residents.

Finally the well-established odour regulation system of Germany will be presented where different limit values for residential and industrial areas, based on odour frequencies, have been established to avoid significant nuisances.

Atmospheric and Depositional Nitrogen Monitoring

Dr. John Neil Cape

The sources of the different forms of nitrogen-containing air pollutants are described as a prelude to asking how and why such pollutants should be measured. Problems of spatial heterogeneity are dealt with by illustrating ways in which concentrations and deposition data can be interpolated and extrapolated from point measurements across a region. New techniques for directly measuring dry deposition fluxes are described, and more appropriate approximate techniques for dry deposition monitoring, based on conditional sampling, are introduced. Inferential modelling of dry deposition, using monitored air concentrations and modelled or measured estimates of atmospheric and surface transport processes, can be used as an alternative to expensive deposition monitoring. The development of low-cost active samplers for trace gases and particles has provided practical approaches to both conditional flux measurements, and improved spatial measurements of air concentrations for use in inferential modelling. The different forms of nitrogen pollutants in the atmosphere are deposited by different processes and at different rates to different vegetation types. For typical concentrations in Alberta, annual dry deposition of nitrogen oxides and ammonia is likely to be at least as important as wet deposition of nitrogen in terms of the overall transfer of nitrogen from the atmosphere to the surface. Estimates of the likely relative magnitude of the different pathways of nitrogen deposition allow priorities to be set for addressing current and future emissions, and indicate where the largest and most important uncertainties currently lie.

Modelling of Atmospheric Nitrogen

Dr. Paul A. Makar

The comprehensive modelling of atmospheric nitrogen in regional 3-D reaction transport models is discussed in this presentation. The focus of the talk are the linkages between reactive nitrogen emitted in the form of gaseous nitrogen oxides and ammonia, and product species such as ozone and particulate matter. The discussion is divided into three sections. The first section consists of a description of the processes that must be considered in advanced computational models of atmospheric chemistry and transport. The discussion is a non-mathematical overview of how processes such as emissions, advection (pollutant transport by winds), vertical diffusion (turbulent mixing of pollutants), gas and particle chemistry, etc., must be described as algorithms in computer models. The section is intended to familiarize the audience with the construction, limitations and potential uses of models of this type. The second section is a more detailed description of the processes that are specific to atmospheric nitrogen – smog formation, main reaction pathways and loss mechanisms. Here the focus is on the NOx/Ozone cycle, and the formation of particles from ammonia and NOx-derived reaction products. The final section describes the use of air-quality models within the context of government policy making, with a focus on model “scenario runs”, and how they are used to provide scientific support for government policy. The talk closes with some example uses of air-quality models from the recent Canada – US Transboundary PM Science Assessment.

The General Science of Nitrogen Acidification

Dr. Julian Aherne

The role of nitrogen in acidification has been long recognised. Ducros (1845) is credited with being the first to use the term ‘acid rain’ in the scientific literature owing to the observation that natural sources of nitric acid (produced by lightning) acidified rainfall. Some years later, Likens et al. (1972) were the first to indicate that nitric acid from atmospheric transport of anthropogenic NO_x contributed to the acidity of rainfall in the eastern United States. Since that time, nitrogen has become the dominant pollutant in rainfall in many regions of the industrial world due in part to the significant reduction in sulphur emissions during the last decade.

The acidity of soil is determined by the relationship between the amounts of basic cations and acid aluminium species on the soil exchange complex. Processes that would tend to acidify a soil include those that remove basic cations, such as leaching in association with an acid anion (Reuss and Johnson 1986). The potential of nitrogen to acidify the soil through base leaching depends entirely on the fraction of nitrogen that is leached as nitrate. In general, forest ecosystems are nitrogen-limited and will not be subject to nitrate leaching. However, nitrogen inputs may cause acidification as a result of increased growth and consequent increase in demand for base cations from the soil.

The potential of atmospheric nitrogen to acidify surface waters depends to a large extent on the characteristics of the surrounding land. Surface water that is surrounded by soil that does not weather easily usually has limited buffering capacity. It has been suggested that increased nitrate concentrations in stream water draining forested catchments are an early indicator of nitrogen saturation. However, a number of different climate parameters and physical chatchments characteristics, such as soil temperature, soil moisture, proportion of thin soils, bare rock and wetlands within the catchment, are strong predictors of nitrogen leaching. Further, nitrate is recognised as an important driver in seasonal or episodic acidification following spring snowmelt and large rain events in the spring and fall (Driscoll et al. 2001). These short term increases in acidity can reach levels detrimental to fish and aquatic organisms.

In summary, nitrate is an important contributor to the acidity of rainfall. Atmospherically deposited nitrogen can contribute to the acidification of soils and surface waters; however, nitrate leaching is highly variable and dependant on a number of factors. As such, an important further research need is the development of methods for predicting the nitrogen retention capacity in forest soils (Fenn et al. 1998). Nonetheless, nitrate plays an important role in episodic acidification.

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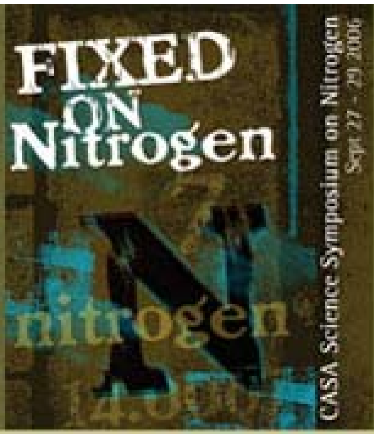
Specific Nitrogen Acidification Issues

Dr. Per Gundersen

The proton exchange in the processes of the N cycle will be described and the conclusion that actual acidification only occurs when nitrate is leached from the system will be discussed. However, accumulation of N in the system has the potential to acidify if it eventually leaves the system as nitrate. As N accumulates in the ecosystem other nutrients (or water) may become limiting and nutritional imbalance may develop; this particularly in acidified systems with low nutrient availability. The potential effect of N on the uptake of other elements directly, by changes in growth, or indirectly by ion competition will be discussed.



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The Role of Nitrogen in PM and O_3 Formation

Dr. Mary Anne Carroll

Peroxy radicals (HO_2 and RO_2) are formed when carbon monoxide (CO) and volatile organic compounds (VOCs) react with the hydroxyl radical (OH). Peroxy radicals readily react with nitric oxide (NO), creating a mechanism for conversion of NO to nitrogen dioxide (NO_2) that does not consume O_3, and the oxygen atoms created during subsequent photolysis of NO_2 undergo rapid reaction with molecular oxygen to form O_3. Thus, net ozone formation occurs when CO and VOCs undergo oxidation in NOx-rich environments. Solid or aqueous ammonium nitrate (NH_4NO_3) and ammonium sulfate (NH_4HSO_4, $(NH_4)_2SO_4$) is formed via an equilibrium reaction involving gas phase ammonia (NH_3) and nitric (HNO_3) or sulfuric (H_2SO_4) acid.
Sodium nitrate salts ($NaNO_3$(s)) are formed when gaseous NO_2 and HNO_3 react with salt particles (NaCl and NaBr). Secondary organic aerosols (containing organic nitrates) can form by gas-phase photooxidation reactions involving higher molecular weight (low volatility) hydrocarbons (or hydrocarbon oxidation products), O_3 and nitrogen oxides in both urban and rural areas. Finally, photolysis of deposited nitrate (NO_3^-) in snow, ice, and dew appears to lead to the revolution of gaseous NO and HONO. The role played by reactive nitrogen species in the production of ozone and particulates will be reviewed.

The Environmental Effects of Particulate Matter (PM) and Ozone (0;)

Dr. Sagar Krupa

Coarse particles are important close to their sources, their deposition resulting in water insoluble encrustations, changes in leaf surface pH, reductions in incident sunlight, nutrient imbalances, chlorosis and leaf defoliation. In comparison, regional scale deposition of fine particle acid sulfate increases the direct phytotoxicity of ozone (O_3). Overall, deposition of particulate matter to the soil has an important indirect effect on plants by: acidification, altering the plant nutrient balance, inducing foliar toxicity, causing joint effects with other stresses and altering plant community structure and diversity.

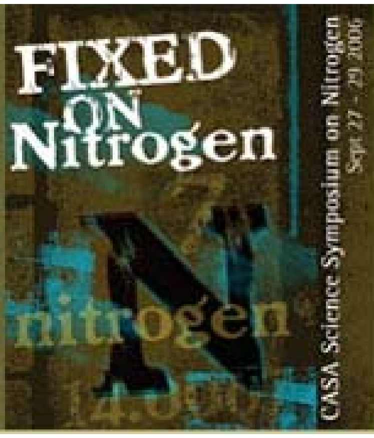
Ozone is the most important phytotoxic air pollutant worldwide. Acute effects result in visible, typical foliar injury on broad leafed plants. On conifers such symptoms are non-specific. Chronic effects (with or without injury symptoms) can result in changes in: growth, yield, nutrient quality for ruminant herbivores, inter-species competition, species fitness, biodiversity and ecosystem structure and function. In addition, chronic exposures can alter plant response to other stresses (biotic and abiotic) and can result in more than additive combined effects.

Because of the spatial and temporal variability in atmospheric processes governing the O_3 concentrations, there is considerable randomness in plant responses. Therefore, multi-year studies will have to be conducted to document reproducibility of the effects. Inexpensive passive samplers are in great demand to quantify time-integrated (weekly, bi-weekly etc.) ambient O_3 concentrations. However, such data can not directly explain the critical O_3 exposure dynamics that elicit plant responses. There are computational methods for converting passive sampler data to mimic hourly ambient O_3 concentrations and the exposure dynamics.

The Health Effects of PM and O_3

Dr. Barry Jessiman

The international perspectives on the health effects of particulate matter and ozone will be presented, as well as the most recent research results, which give insight into the interpretations of the entire body of evidence on this subject, as well as some sense of future directions. The perspectives and evidence on the health effects of NO_2, and the implications of the science for the interpretation of results on different aspects of the air pollution mix will also be presented.



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Nitrogen and Climate Change

Dr. Chris Evans

Since the 19th century, CO_2 from fossil fuel burning has been accumulating in the atmosphere, and is the major driver of anthropogenic climate change. Over a similar period, the production of man-made ‘reactive nitrogen’ has also increased hugely, potentially also influencing global climate. However the transportation, cycling and accumulation of reactive N in the atmosphere, terrestrial and aquatic ecosystems (the ‘nitrogen cascade’) is complex, and as a result N may impact on climate in a number of ways, some negative and some positive. In soils, particularly oxygen-poor areas such as wetlands, a proportion of N deposited from the atmosphere may be re-released as nitrous oxide, a greenhouse gas 296 times more powerful than CO_2. On the other hand, because nitrogen is the limiting nutrient for growth in most terrestrial ecosystems, adding moderate amounts of man-made N to these systems can lead to an increase in productivity, potentially sequestering CO_2 from the atmosphere into plant and soil organic matter. In addition, higher CO_2 in the atmosphere may itself lead to increased plant growth, but this can only occur where sufficient nitrogen is present. Finally, nitrogen oxides are a key precursor for ozone formation, and due to the detrimental effects of ozone on plant growth, this could act to reduce or even negate any beneficial effects of elevated N and CO_2. Overall, therefore, the complexity of the nitrogen cycle is such that it is difficult to categorise the influence of nitrogen on climate as either ‘good’ or ‘bad’. In reality nitrogen may well be ‘good’ (in terms of climate change) for some ecosystems, but ‘bad’ for others, and much work is required to quantify its overall role.

Approaches to the management of Industrial and Agricultural Nitrogen Emissions and Impacts in Alberta

Dr. Ahmed Idriss (Industrial), Len Kryzanowski (Agriculture)

This presentation presents an overview of Alberta Environment's regulatory approach to air quality management. This approach was initially developed and implemented in the late 1960's/early 1970's. Alberta Environment's air quality management system has evolved over time and shifted from being a "command and control" style approach, to a mix between regulatory approaches of "command and control" and stewardship; within the context of a broad stakeholder strategic planning framework. The current system approach is outcome focused and the broad air quality issues are addressed through the Clean Air Strategic Alliance (CASA), which was established in 1994. This new role for Alberta Environment will be achieved by strategically shifting to a systems manager approach where our role is one of policy development and not necessarily implementation.

Currently, Alberta regulates the NO_x emissions using the Industrial Air Quality Management System which includes ambient objectives, source emission standards, plume dispersion modelling, ambient and source emissions monitoring, environmental reporting, emission inventories, approvals, inspections/abatement, enforcement and research. The system was designed to ensure that emissions are minimized through implementing Best Available Technology Economically Achievable (BATEA) and to ensure that ambient air quality meets Alberta's objectives. Alberta Environment has worked with CASA to develop the acid deposition framework that considered NO_x and SO_2 as acidifying emissions. Cumulative Environmental Management Association (CEMA) is currently reviewing BATEA for oil sands burners and AENV will review the Code of Practice for Compressor and Pumping Stations and Sweet Gas Processing Plants.

Agriculture n/a

Critical Loads for the Management of Nitrogen Acidification and Eutrophication
Dr. Chris Evans

Critical loads have been extensively used, particularly in Europe, as a tool for managing nitrogen emissions. Critical loads define the acceptable pollutant loading to an ecosystem. If the critical load is exceeded, long-term ecosystem damage is expected. Nitrogen deposition is relevant to: i) critical loads for acidity, which define the acceptable combined loading of sulphur and nitrogen deposition, beyond which acidification damage occurs in terrestrial or freshwater ecosystems; and ii) critical loads for nitrogen as a nutrient, which define the specific nitrogen loading beyond which biodiversity loss will occur due to eutrophication. Critical loads vary according to the sensitivity of the ecosystem. They have been used at large (e.g. European) scales to define the most cost-effective strategy for emissions reductions (i.e. that which will lead to the greatest reduction in critical load exceedance for the amount spent), and are also now being used at smaller scales, e.g. to protect and manage individual sites of conservation importance. Although they have proven effective as a policy tool, critical loads nonetheless have a number of limitations. Most importantly, they predict damage to the ecosystem at long-term steady state. Since many ecosystems have the capacity to accumulate nitrogen over very long periods, the lag between critical load exceedance and observable ecosystem damage (or indeed deposition reductions and ecosystem recovery) may be long. New approaches, which overcome some of these limitations using dynamic models, and more detailed vegetation models, are described.

FIXED ON NITROGEN
CASA Science Symposium on Nitrogen
September 27 – 29, 2006
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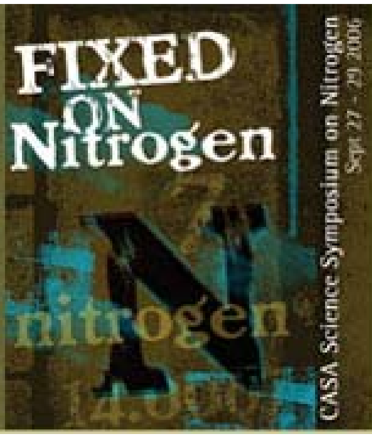
Lake Louise, Alberta

Abstract

Industrial and mobile NO_x Control Practices and Options

Tim Smith

There has been much attention to industrial and mobile source NO_x control practices in the United States in recent years.   Regulatory drivers for this include: programs to reduce regional NOx to help address ozone concerns in the Eastern US, new source emissions standards for stationary and mobile sources of NOx, and permitting of new major and minor NOx sources. Studies are emerging on the benefits of regional NOx reductions from the "SIP call aimed at addressing ozone in the Eastern US.   Further reductions are expected from EPA's Clean Air Interstate Rule. EPA has undertaken work on emissions standards for industrial NOx sources such as boilers, turbines, and cement kilns. EPA has developed technical tools for use in developing cost estimates for application of NOx technologies in ozone non-attainment areas. Additionally, permitting decisions for these sources have also been ongoing with a continuing review of best available controls and emissions limit capabilities.   Finally, EPA has developed mobile source NOx emissions standards for both onroad and nonroad engines. Technical feasibility issues remain on use of high-efficiency after treatment in large engines used in mobile machinery. Further activities are underway to address controls for locomotives, marine engines and other large diesel engines. All of these programs contribute to an overall picture of the state-of-the-art for NOx emissions control practices for the various source categories.



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Abstract

Agricultural Nitrogen Control Practices and Options

Dr. Brent W. Auvermann

Intensive agriculture in developed nations is responsible for a great deal of the accelerating, atmospheric accumulation of reactive, gaseous nitrogen (RGN) species produced for intensive crop and livestock production. Recent estimates from Texas, for example, suggest that RGN emissions, which include ammonia (NH_3), nitrogen oxides (N_xO_y) and some VOCs, are on the order of 42-48% of the total nitrogen fed to beef cattle in feedyards (Todd et al., 2006). Abatement measures to reduce RNG emissions to the atmosphere by intensive livestock operations (ILOs) include (a) manipulation of feeds and feeding systems, (b) intensive management of corrals, open lots and barn floors, (c) capture, treatment and internal recycling of RNG emissions from barns, manure and wastewater storages and composting operations and (d) scrubbing RNG from the wind or exhaust air before it crosses the ILO boundary. Aside from obvious economic considerations of capital and operational costs, the selection of RNG abatement measures, however, depends largely on whether the primary performance objective is related to greenhouse-gas (GHG) equivalents, surface-water eutrophication, acid precipitation, secondary formation of fine particles or photochemical ozone (O_3) formation. An additional selection criterion emerging over the past few years is the amount of fossil-fuel energy required to achieve a unit reduction in RNG emissions. Because not all RNG have an equivalent effect on ecosystems, and because nitrogen mass balance is a zero-sum enterprise, researchers and policy makers must rigorously identify the key performance objectives and the multi-media interactions among soil, water and air to inform their recommendations.