FINAL DRAFT

A Primer on Nitrogen Emission Issues

Prepared for CEMA

June 18, 2007

Contents

1 Introduction

Nitrogen emissions are increasing in Canada and Alberta, as well as globally, and have the potential to adversely affect the environment and human health. In late 2006, the Clean Air Strategic Alliance held a conference to explore the impacts of nitrogen emissions and how they can be better managed in Alberta. This is a very important issue in north-eastern Alberta, which is why CEMA was a major sponsor of the conference. A copy of the conference program is included in the appendix.

This short document, entitled *A Primer on Nitrogen Emission Issues*, summarizes the information and advice provided by scientists and other experts at that conference. It focuses on nitrogen oxide (NOx) emissions and their environmental and health impacts, as these are of the most concern in the Wood Buffalo area. Ammonia emissions associated with the fertilizer industry and the agricultural sector were also discussed at the conference, but issues associated with these emissions are not so relevant to the Wood Buffalo area.

In the context of north-eastern Alberta, this summary report:

- provides a short overview of nitrogen and why it is important
- describes the direct and indirect effects of nitrogen
- looks at the sources and management strategies for nitrogen

2 Why does nitrogen matter?

- Nitrogen is a very important element, both chemically and biologically. It is cycled through the environment in complex processes and is an essential nutrient for plants, animals and humans.

  Essential nutrient

- Human activities are affecting the nitrogen cycle, particularly through emissions to the atmosphere by burning of fossil fuels and use of fertilizers.

  Affected by human activities

- Nitrogen comes out of the atmosphere with rain and snow (called "wet" deposition), and in gas form or as tiny particles such as dust (called "dry" deposition).

  Wet and dry deposition

- Nitrogen can exist in many forms. The forms of most interest and concern in the oil sands region (OSR) are what scientists call "reactive" nitrogen. There are many different reactive forms of nitrogen and the form determines how the chemical will react in the environment and what effects it will have.

  Many chemical forms

- Nitrogen is the major gas in the atmosphere (78% of air is nitrogen) but this form of nitrogen is non-reactive and has no environmental or health impacts.

  78% of the atmosphere

- At high temperatures such as those in boilers and vehicle engines, nitrogen and oxygen in the air combine to produce nitrogen oxides (also called oxides of nitrogen, or NOx). This is a reactive form of nitrogen.

  Nitrogen oxides

- Reactive nitrogen can have positive effects, such as increasing crop production when it is used as a fertilizer. Too much can have negative impacts by adding too many nutrients to soils and water (eutrophication), by acidifying soil and water, by triggering respiratory problems for humans, and by directly damaging trees, crops and other vegetation. It can even affect which plants will grow in a particular area.

  Positive and negative effects

- Nitrogen can also combine with other chemicals in the air to create new substances such as fine particulate matter and ground level ozone, which can affect human health and vegetation.

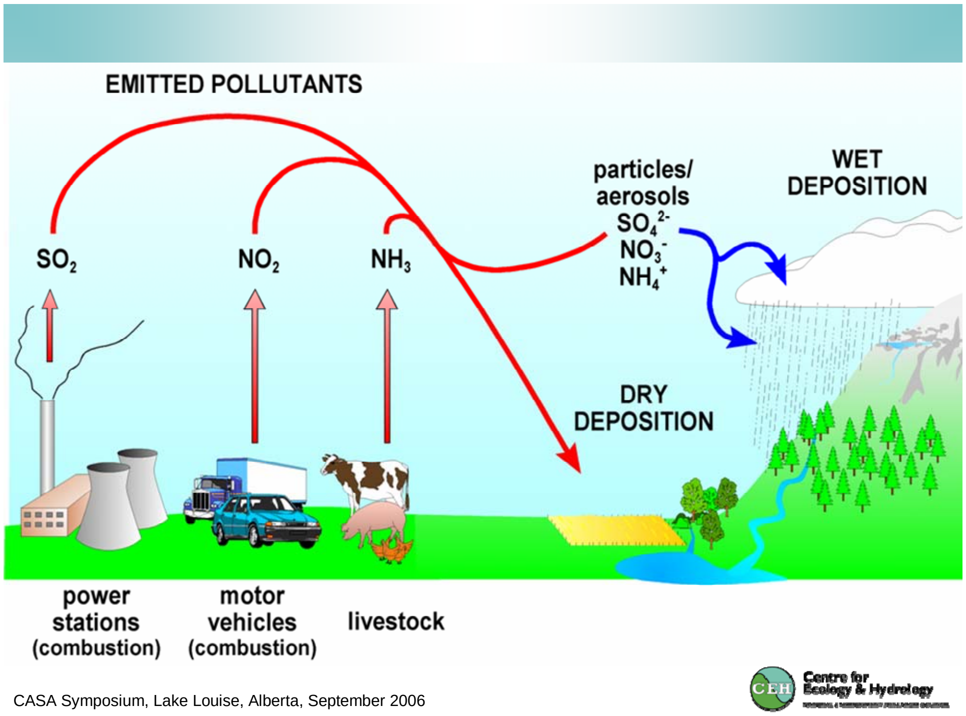
  Particulate matter, ground level ozone

- Certain forms of nitrogen play a part in both climate change and stratospheric ozone depletion.

  Effects of different forms of nitrogen

- Because nitrogen can have so many effects, and because emissions are increasing, it is important to understand and manage potential impacts in the Wood Buffalo region. CEMA has developed, or is working to develop, acidification, ozone and eutrophication management frameworks. Nevertheless, many regional nitrogen issues require further study and understanding and the conference provided information on what these are and how they might be addressed.

  Significance in the Wood Buffalo region



Emissions of nitrogen and other pollutants come out of the atmosphere in both wet and dry forms.
Source: Dr. Neil Cape

3 Nitrogen Chemistry

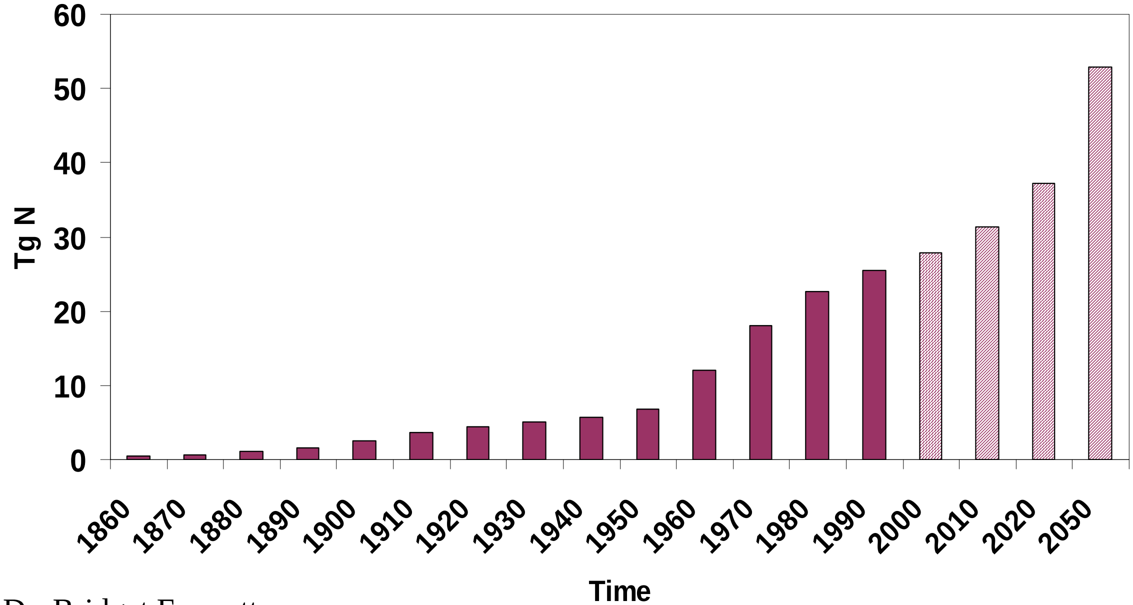
- The complex chemical behaviour of nitrogen depends on the form it is in and on air, water and soil conditions into which the nitrogen is released or deposited. Factors affecting how nitrogen compounds behave in air include what other chemicals are present, sunlight, relative humidity, temperature and mixing of the atmosphere. — Complex chemical behaviour
- In the part of the atmosphere that is closest to the earth (the troposphere), nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in the presence of sunlight to form ground level ozone and other compounds that are often referred to as "photochemical smog." — Contributor to smog
- Vehicles are a major source of VOCs. In the OSR, tailings ponds and mines are also a large source of VOCs. Ground level ozone can damage vegetation and produce a range of adverse health effects in humans, particularly in people with respiratory problems. — Impacts of ground level ozone
- NOx can also combine with water vapour and other chemicals to form tiny airborne particles, referred to as fine particulate matter, or aerosols, which play a role in smog formation. — Formation of fine particles
- High up in the atmosphere (in the stratosphere), another form of nitrogen – nitrous oxide, or N_2O – plays two very important roles. — Impacts of nitrous oxide (N_2O)
    - o N_2O is a very powerful, long-lasting greenhouse gas that contributes to climate change.
    - o N_2O in the stratosphere also reacts with oxygen to produce NOx. This starts a chain of reactions that result in the destruction of stratospheric ozone. Stratospheric ozone protects us from harmful ultraviolet radiation from the sun. Loss of this ozone allows more of the sun's rays to reach the earth's surface. Increased exposure to ultraviolet radiation has been linked to increases in skin cancer, eye damage and other health impacts in humans.
- In soils and water, different forms of nitrogen undergo a number of chemical and biological reactions that can affect acidity (pH), rates of biological decomposition, and plant health and growth. — Reactions affect other chemical and biological processes

See the sections on eutrophication and acidification for more information on nitrogen chemistry.

4 Where does nitrogen come from?

- Nitrogen occurs naturally in air, water and soil in many different chemical forms. Human activities also add nitrogen to the environment, the most important of which are agriculture, transportation, power generation and industrial activity. — Sources of nitrogen
- Globally, nitrogen emissions due to human activity were four to five times higher in 2000 than they were in 1950. Projections are that by 2050, emissions will be about ten times greater than 1950 levels. — Emissions due to human activity
- In Canada and Alberta, the main sources of nitrogen oxide (NOx) emissions are from transportation and various parts of the energy sector. — Sources of NOx emissions
- Nitrogen emission sources and amounts are tracked in Canada and many other countries. Environment Canada works with provincial and regional agencies to compile emissions inventories on a regular basis. These inventories account for nitrogen emissions from point sources (such as the stacks associated with industrial facilities), area sources, mobile sources, open sources, and natural sources (such as crops, forests and soils). — Emissions inventories
- Alberta is one of the largest emitters of nitrogen in Canada. Although NOx emissions from many sectors are stable or decreasing, growth in the energy sector (upstream oil and gas, oil sands, and electricity generation) led to a 51% increase in emissions between 1990 and 2002; an increase of 73% is expected by 2015. — Alberta's nitrogen emissions
- Modelling and emissions inventories suggest that some parts of Alberta, specifically the Edmonton-Calgary corridor and the Fort McMurray area, are growing hotspots for nitrogen. — Nitrogen hotspots
- Mine fleet vehicles, boilers, and co-generation units (units that produce both electricity and steam) are the main sources of nitrogen emissions in the OSR. One of the challenges in the OSR is calculating emissions from the substantial amount of equipment that operates at the mine sites. — Sources of NOx in the oil sands region
- The current and expected growth of industrial activity in the oil sands may result in an increase in nitrogen emissions from the approximately 140 tonnes/day in 2000 to anywhere from 400 to 600 tonnes/day at full development. — Emissions increases in the OSR

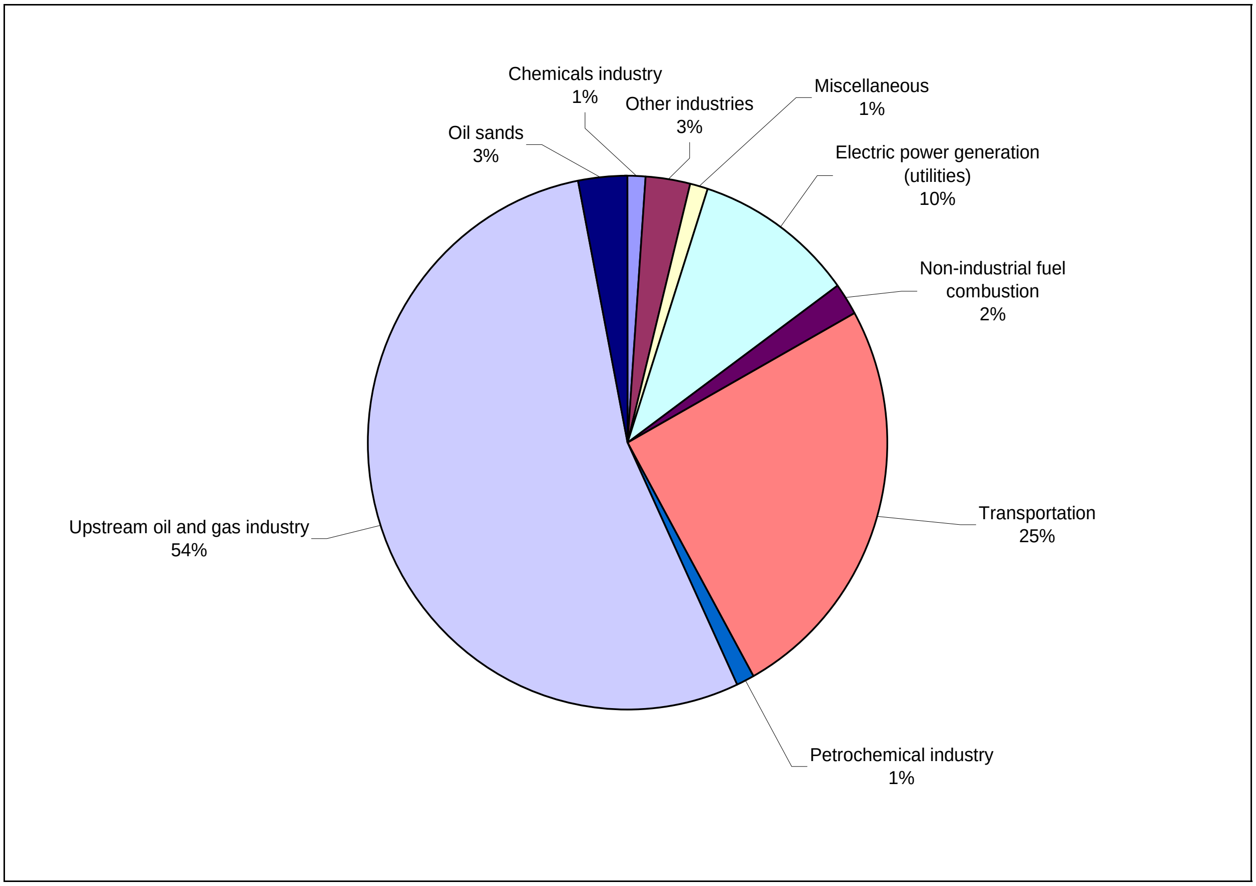
Global Emissions of Nitrogen



Source: Dr. Bridget Emmett

2003 NOx Emissions for Alberta

In 2003, total NOx emissions for Alberta were 878,808 tonnes; sources of these emissions are shown in this pie chart.



Source: Dr. Ahmed Idriss

5 Measuring and Modelling Nitrogen

To develop appropriate management strategies for nitrogen, we need to know how much nitrogen is present in the air at a given time and at given locations. We also need to know the form the nitrogen is in, how much is being deposited on land and water now, and how much might be deposited in the future.

Monitoring is a tool to measure how much nitrogen is present or is being deposited. Monitoring nitrogen deposition can be very difficult.

Modelling is another tool that can help predict nitrogen deposition both now and in the future. Models are widely used to estimate the possible effects of proposed projects.

5.1 Monitoring Nitrogen Deposition

- Monitoring is done to find out how much nitrogen is present or being deposited in a particular area. The results can be used with other information and observations to see if nitrogen emissions are having or could have an impact. Monitoring results can also be used in models, as described below.

  Reasons for monitoring

- Monitoring involves collecting samples or directly analyzing air to measure nitrogen content. When measuring nitrogen deposition it is important to monitor both wet and dry deposition; that is, to measure the amount of nitrogen that comes down in rain and snow (wet), as well as the amount that is deposited as gases or particles (dry).

  Monitoring nitrogen deposition

- In Alberta, the annual dry deposition of nitrogen compounds is likely to be at least as important as wet deposition in transferring nitrogen from the atmosphere to land. In the oil sands region, models predict that most nitrogen deposition is now and will continue to be in a dry form.

  Relative importance of wet and dry deposition

- With wet deposition monitoring, samples of rain or snow are collected and analyzed in a laboratory to determine the amount of nitrogen (and other chemicals) in the sample.

  Wet deposition monitoring

- To measure gases or particles in the air, three types of monitoring are commonly used in Alberta: continuous, intermittent, and passive. All three types are used in the oil sands region, although only continuous and passive monitors are normally used for nitrogen oxides.

  Types of air monitoring

- Continuous monitoring involves drawing air through a special piece of equipment called an analyzer; it provides almost instant results. Oxides of nitrogen (the main nitrogen compounds emitted by industry in the oil sands region) are typically measured using continuous monitors. This type of monitoring shows short-term changes in air quality and can help identify sources of pollution.

  Continuous monitoring

- With passive samplers, a special surface that reacts with certain chemicals is exposed to the air, where gases and particles are absorbed onto the surface. The samplers are typically exposed for a one-month period and are then analyzed in a laboratory.

  Passive monitoring

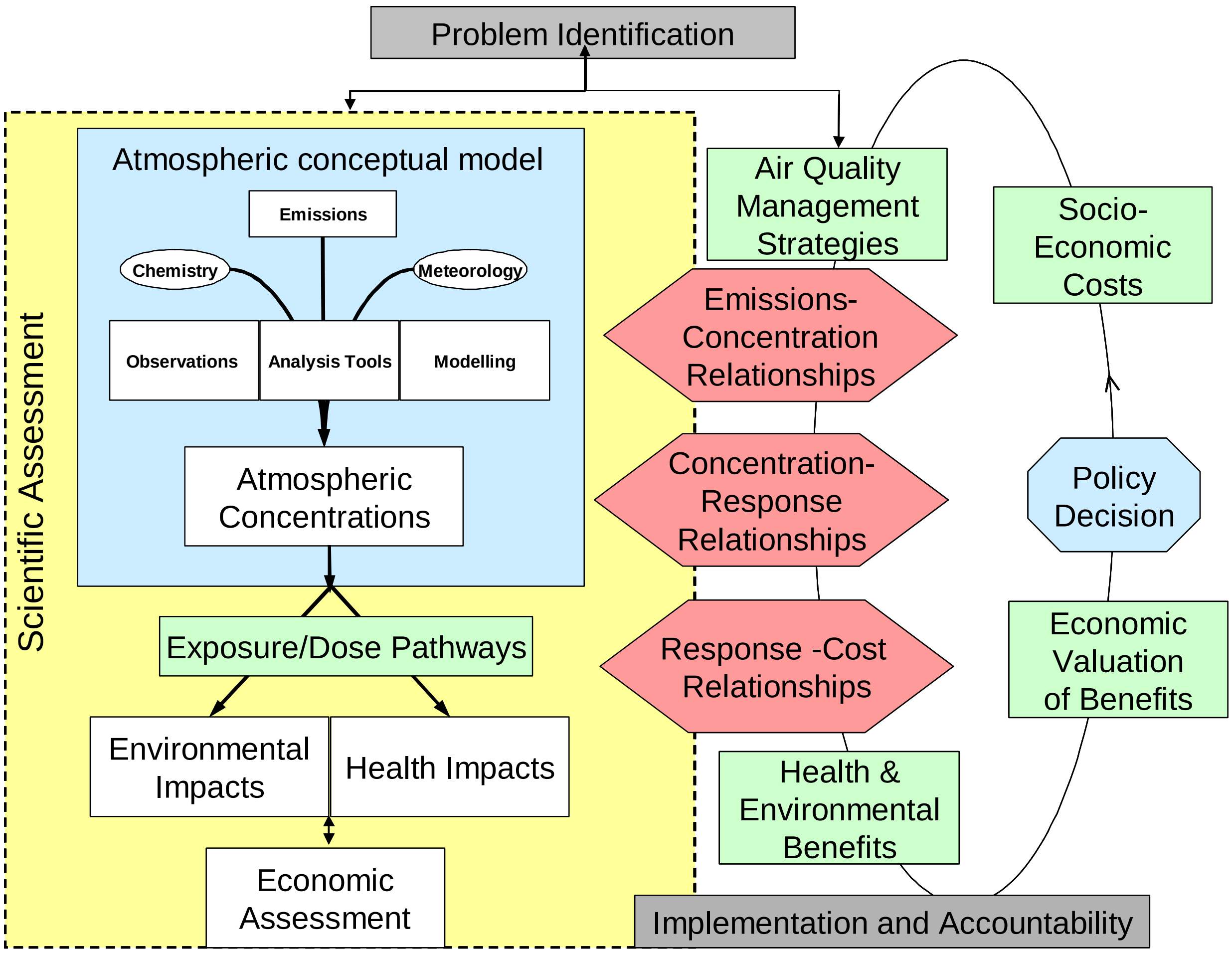
- In the OSR, the Wood Buffalo Environmental Association (WBEA) monitors air quality at 14 continuous and 13 passive stations. Current and past air quality at any of the continuous stations can viewed at WBEA's website (**http://www.wbea.org**).

  WBEA monitoring network

5.2 Modelling Atmospheric Nitrogen

- A model is a way of describing how things work using mathematical terms. Once the model is developed and put on a computer, scientists can insert different numbers to see how things behave and change in different situations. — What is a model?
- Models help us understand how things interact and affect one another. An air quality model describes mathematically the chemical and physical condition of the atmosphere and how it changes with time. Models can be used to predict how clean or dirty the air will be tomorrow or they can be used to predict air quality 20 or more years in the future if current trends continue. — Air quality models
- Some models can show how emissions from an industrial facility will be carried and dispersed by the wind. In these models, we can change the height of the stack and the temperature of the gas being emitted to see what effect those changes have on where the emissions go and on the concentrations that might occur in a nearby community. — What a model can show
- Models have advanced over the years as scientific information has improved. With modern computers, we can run models that represent what is happening in the environment. But a great deal of information is needed to develop any given model. Scientists regularly compare observations for the locations where the model is being used to what the model predicts for that location to confirm that the model is making good predictions. — Model accuracy
- There are many different air quality models and each has strengths and weaknesses. The model used in any given situation depends on many factors. In the oil sands region an air quality model called CALPUFF is generally used to predict the impact of emissions on air quality and deposition. This model is widely used in North America. — Different kinds of models
- Modelling of nitrogen is difficult because of the different ways nitrogen reacts in the atmosphere. Nevertheless, modelling is very important because of the impact nitrogen can have on human health and the environment. For example, under the right conditions, NOx emissions can contribute to smog and other forms of air pollution. If a model predicts that conditions are right for smog formation, health agencies may decide to issue a warning so that people with asthma or other respiratory problems can take precautions. — Modelling nitrogen
- Air quality models help us better understand what happens to air emissions. This area of research is called atmospheric science. Models also play an important role in helping governments make decisions on projects and what they can emit to the air. Models can also help governments decide if new regulations or standards might be needed for particular pollutants. — Role and value of modelling

Air-Quality Models and Government Policy - Overall Framework and Decision Making



Source: Dr. Paul Makar

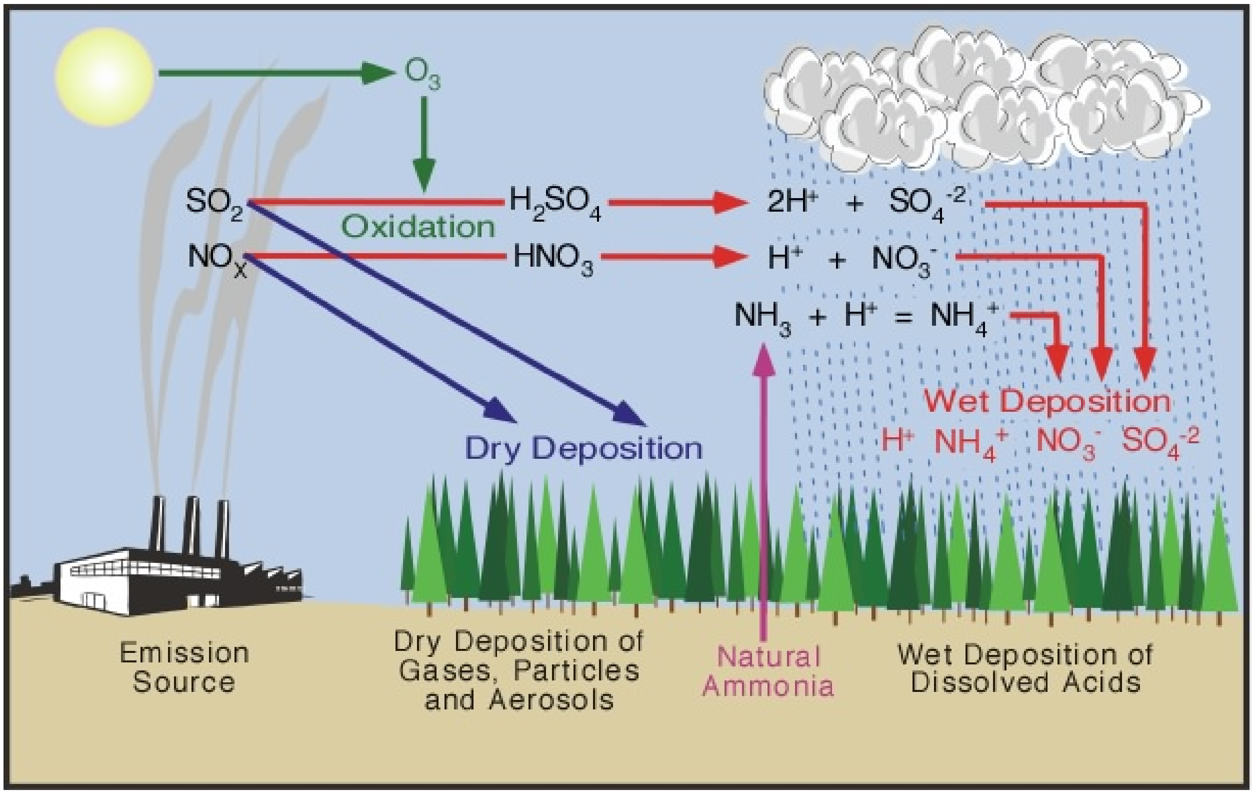
This figure shows the role that models can play as part of a larger process to assess air quality science and provide scientific advice to policy makers. Many other factors in addition to modeling contribute to policy decisions.

6 Nitrogen Acidification

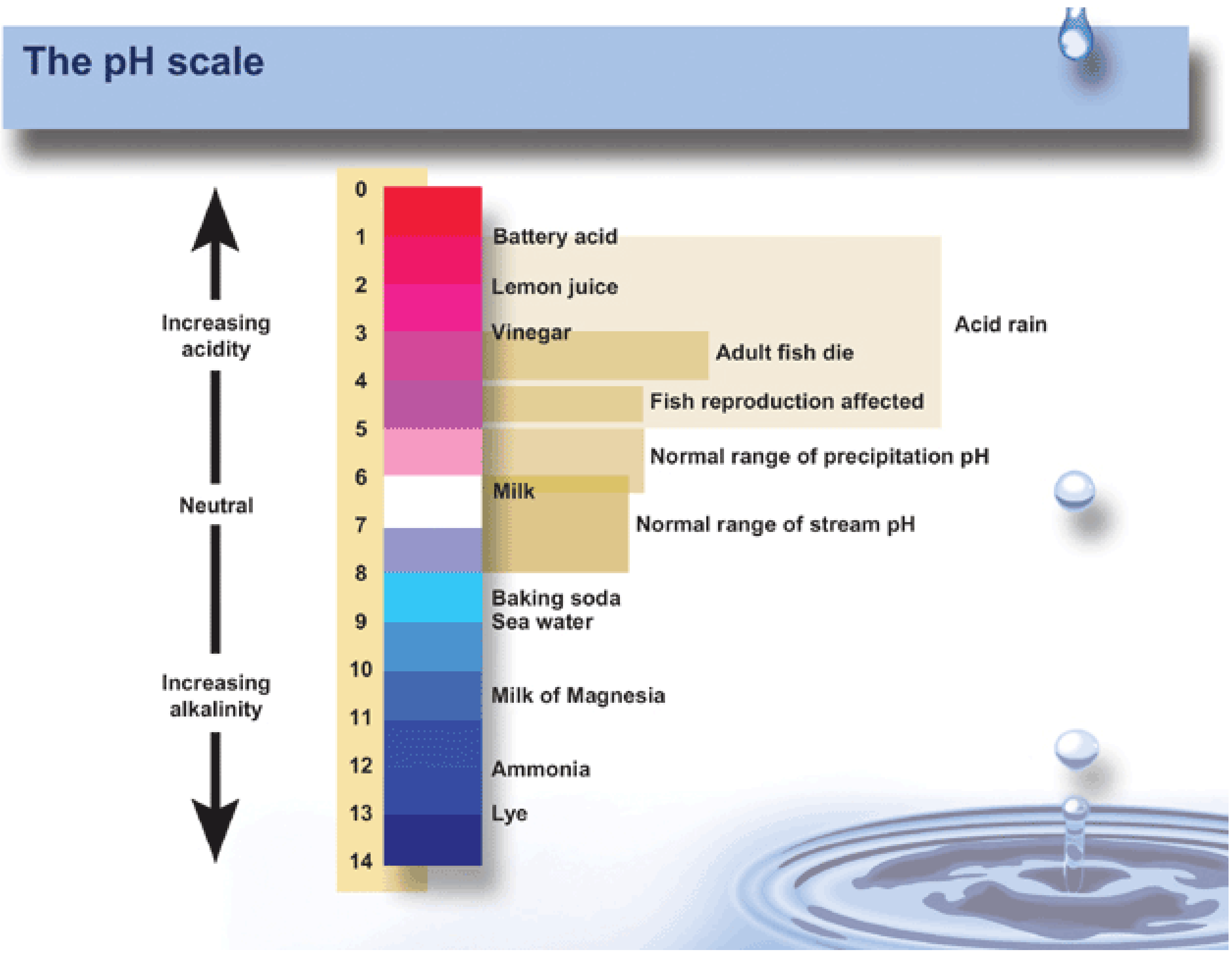
- In chemistry, an acid is a type of substance that contains hydrogen. When the acid is dissolved in water, it literally comes apart and the hydrogen part of the substance is changed into hydrogen ions. The hydrogen ions are what cause acidification. — What is an acid?
- The quantity of hydrogen ions is measured on a special logarithmic scale called "pH." The pH scale ranges from 0 to 14. A pH of 7 is considered neutral, and a pH below 7 is acidic. The logarithmic nature of the pH scale means that a change of 1 is actually a difference of ten times. This means that lemon juice, with a pH of 2 is ten times more acidic than vinegar (pH 3) and 100 times more acidic than a soft drink (pH 4). Unpolluted rainwater typically has a pH of about 5.6, which is slightly acidic due to the presence of dissolved carbon dioxide. See the pH scale illustration below. — pH
- Solutions at the other end of the scale, with a pH above 7, are referred to as alkaline. Baking soda dissolved in water, for example, has a pH of about 8, while ammonia dissolved in water has a pH between 11 and 12. — Alkaline solutions
- Acidification occurs when the pH of soil or water decreases, usually due to external influences. The drawing below uses both sulphur dioxide and oxides of nitrogen as examples of how emissions can affect pH. — Acidification process
- Substances that cause acidification can be deposited in wet or dry forms. Wet deposition includes rain, snow, sleet and fog. When it hits the ground or a river or lake, it is already acidic. Dry deposition means that gases or particles in the air get into the water or soil in a dry form. The chemical reaction to create the acid occurs when the particles come into contact with plants, water or soil. — Wet and dry deposition
- The impact of acid deposition depends on the pH of the soil or water where it falls. If the receiving ecosystem is naturally alkaline, it can tolerate a certain amount of acid deposition without any negative impact. This ability is called buffering capacity. Soils that are high in calcium or contain a lot of organic material such as peat usually have a high buffering capacity (that is, they are well-buffered). Well-buffered soils and water are less sensitive to acid deposition. In the OSR some soils and waters are well-buffered and others are not. The map below shows the sensitivity of areas in Alberta to acid deposition. — Sensitivity to acid deposition
- Some of the nitrogen that is deposited on soils and vegetation is used by plants and by soil and water organisms as a nutrient source (fertilizer). This nitrogen is not considered acidifying, but it can have eutrophication effects. — Fertilizing effect of nitrogen
- Nitrogen in the form of nitrate is an important contributor to acid precipitation. Acidification of soils and surface water occurs when the soil cannot absorb any more nitrogen and it starts to move from the place where it was deposited, through groundwater, into surface waters. This is referred to as "leaching" and the amount of leaching varies from place to place. — Leaching of nitrogen
- When nitrogen is deposited on snow and the snow melts, there can be a short burst, or pulse, of acidification. Some kinds of vegetation are sensitive to this acid pulse. — Acid pulse
- Soils naturally contain essential plant nutrients along with many other substances, including heavy metals and other toxic elements (e.g., aluminum, mercury). Different chemicals and nutrients dissolve at different pHs. Although toxic elements may be present, they are normally locked into the soil structure because they do not dissolve at the pH levels usually found in the soil. — Role of soil pH
- For plants to take up the nutrients they need from soil, the nutrients must be dissolved in water. When soil or water becomes acidic and the pH changes, two things can happen. First, some nutrients that plants require may no longer — Soil acidification

be available, and second, some of the toxic elements such as heavy metals dissolve and have adverse effects on the plants.

Emissions can be deposited in wet or dry form.

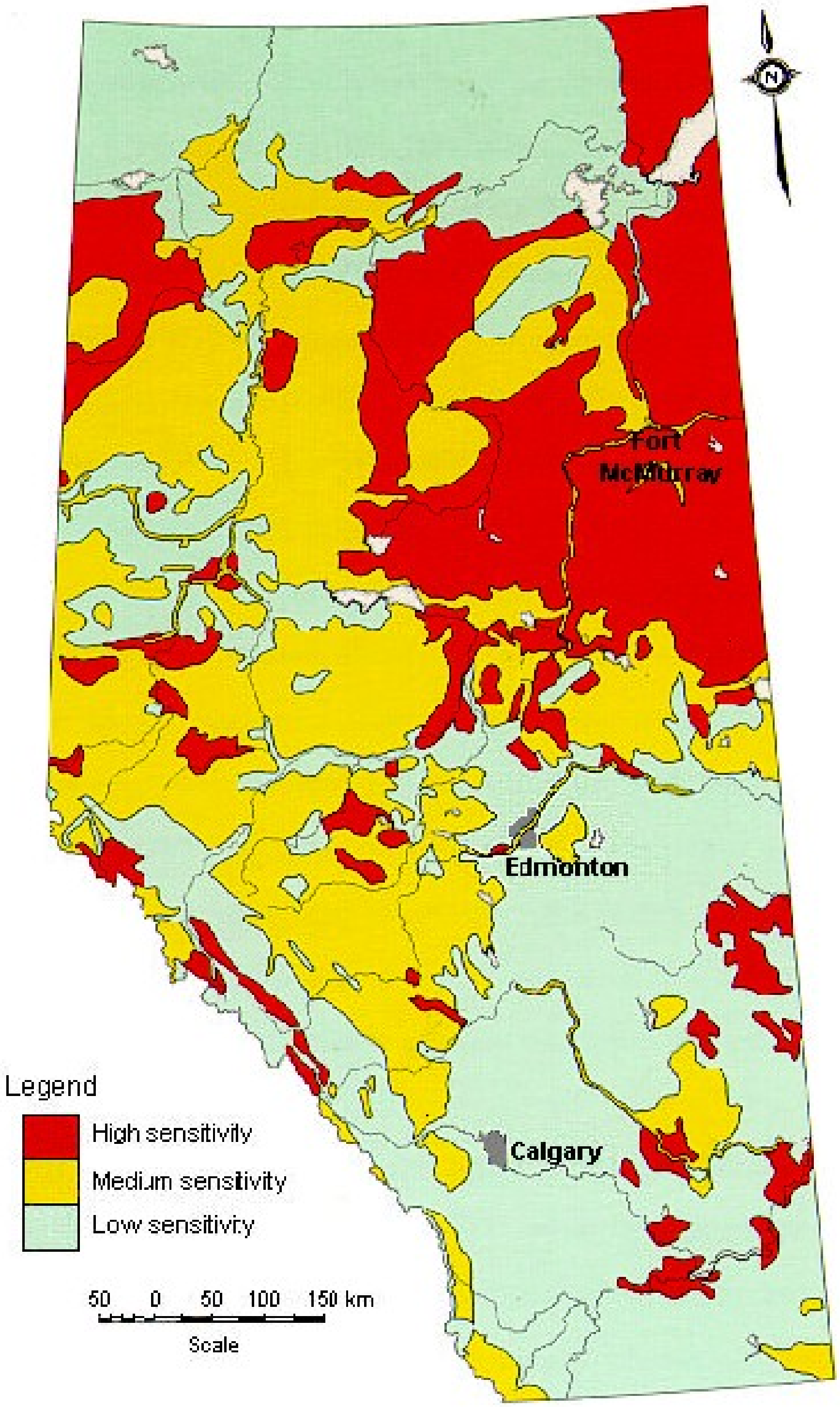


Source: **www.physicalgeography.net**



Source: **http://www.ec.gc.ca/water/en/manage/qual/e_ph.htm**

Sensitivity to Acid Deposition in Alberta



Source: Holowaychuk and Fessenden, 1987

7 Nitrogen Eutrophication

- Because plants need nitrogen to grow, nitrogen is called an essential plant nutrient. It is often deliberately added to agricultural land, managed forests, and gardens to encourage higher crop production. (The impact of nitrogen that is deliberately added to land was not discussed in detail at the symposium.)

  Nitrogen as an essential plant nutrient

- When plants die or drop their leaves, the nitrogen they contain is recycled by micro-organisms in the soil and the nitrogen stays in the ecosystem. However when plants (trees and crops) are harvested, or when there is a fire, nitrogen is removed from the nitrogen cycle.

  Cycling of nitrogen

- Natural nitrogen levels influence the type of plants that will grow in an area. Many ecosystems have slow-growing species that are adapted to conditions of low nitrogen. Up to a certain point, especially in poor soils, adding nitrogen can increase plant growth. However, if more nitrogen is added than the plants can absorb and use, or if it is applied improperly, it can damage the plants, the land and the water. For example, nitrogen can run off a field during a heavy rain and flow into a pond or creek, where it will also have a fertilizing effect. This **unintended** enrichment of land and water systems is called eutrophication.[1]

  Nitrogen eutrophication

- Nitrogen emissions can also be deposited on plants, soil and water and can have the same impacts as nitrogen that was added deliberately. The form of nitrogen and type of deposition (for example, wet or dry) influence the impact on plants.

  Nitrogen emissions as fertilizer

- Eutrophication can significantly affect the types and the health of plants, and can also change the chemistry and other conditions of soil and water.

  Impacts of eutrophication

- In water, nitrogen's fertilizing effect promotes the rapid growth of vegetation, including algae. In the short term, more plants add more oxygen to the water and they also can be a food source for certain animals. However, when the plants die, they rot. This process, called decomposition, takes oxygen out of the water, which can kill fish and other animals.

  Nitrogen enrichment of water

- On land, both plants and soils are affected by nitrogen enrichment. The nutrient balance in the soil can change as a result of too much fertilizing nitrogen, and this affects plant growth and reproduction. Plants that prefer low-nitrogen conditions, such as mosses and lichens, disappear and are often replaced by plants that like nitrogen, such as grasses. Plants may also become more vulnerable to disease and pests. These impacts can affect animals that depend on certain plants for food or for habitat. Soil animals and micro-organisms that help keep the soil healthy can also be affected.

  Nitrogen enrichment on land

- Many factors can influence the impact of nitrogen deposited to an ecosystem, and some systems are more sensitive to the fertilizing effects of nitrogen than others. Systems that are the most vulnerable tend to be cold and dry with a long period of frost or snow, and with soils that are covered by mosses, lichens or scrub vegetation.

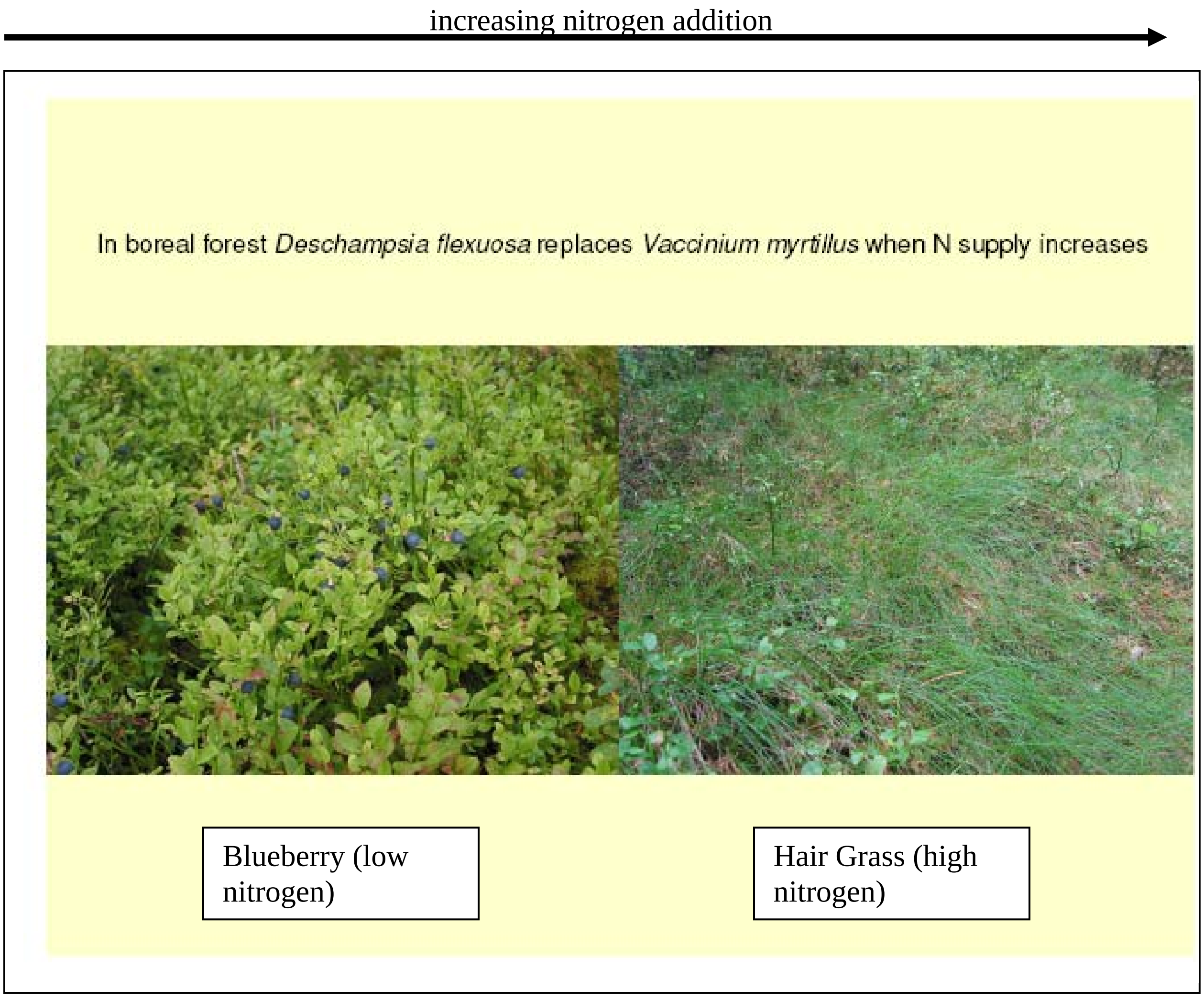
  Ecosystem sensitivity

- It can be difficult to link changes on land to the fertilizing impact of deposited nitrogen because so many factors affect plant health, and changes can occur very slowly. Work is now underway to determine the amounts of nitrogen that could be added to the environment in the oil sands region without causing significant eutrophication effects.

  Assessing impacts

[1] Phosphorus is another essential plant nutrient found in many fertilizers, and excess phosphorus can also lead to eutrophication.

The photograph below shows the difference in vegetation when more nitrogen is added.



Source: David Spink

8 Impacts of Nitrogen

In addition to acidification and eutrophication, nitrogen can have a wide range of direct and indirect effects on humans, animals, plants and the environment. In general, direct effects are those impacts that occur due to direct contact with the emissions themselves. Indirect effects occur due to exposure to a substance that is the result of a physical or chemical transformation of the original nitrogen emissions.

8.1 Direct Impacts on Vegetation

- Nitrogen is an important plant nutrient and plants need a certain amount of nitrogen for healthy growth. All plants have a natural range of nitrogen requirements and if they get too much or too little, they suffer adverse effects. Among other things, nitrogen is an important component of chlorophyll, the substance that gives plants their green colour. Plants that lack nitrogen often appear pale green or yellow. *Importance of nitrogen to plants*
- Many things influence the way plants respond to changes in air quality; these include the specific pollutants involved, plus all the other factors that affect plant growth (temperature, precipitation, soil moisture, nutrients, and pests or diseases). *Plant response to air quality changes*
- Direct effects can occur when plants are exposed to a high concentration of pollution for a short time (called acute exposure), or from exposure to a lower concentration over a longer period of time (chronic exposure). *Exposure to pollution*
- Acute exposure often leaves a noticeable injury on the leaves of sensitive plants, but may or may not affect plant growth in the longer term. Chronic exposure may or may not noticeably affect the leaves, but can reduce plant growth or yield and may affect its ability to reproduce. *Effects of acute and chronic exposure*
- Plant damage can occur because of exposure to one air pollutant, but effects are most often due to a mixture of air pollutants. Each pollutant alone might not be harmful, but the combined (or synergistic) effect of several pollutants can damage sensitive vegetation. Chronic effects tend to occur when plants are exposed to several pollutants at the same time or to several pollutants one after the other. *Effects of pollutant mixtures*
- Air quality standards and objectives are designed to protect both human and vegetation health. These standards or objectives are often based on acute effects and on single pollutants rather than a combination of chemicals that can interact with each other. This is because it is very difficult to study all of the possible mixtures of pollutants that plants may be exposed to and so develop “safe” levels for each mixture. *Air quality standards*
- Direct effects of nitrogen occur when nitrogen gases in the atmosphere (such as ammonia and nitrogen oxides) are absorbed through the leaves. Near the emissions source, coarse particles containing nitrogen can also be deposited on the leaves, blocking sunlight and interfering with leaf function. *Exposure mechanisms*
- The direct impacts of nitrogen on plants have not been as well studied as the impacts of sulphur. Ammonia (NH_3) is known to have acute effects on plants that are close to the source of the ammonia emissions. Effects include leaf damage, as well as impacts on plant growth, flowering, yield and response to other stresses. Ammonia is not considered an issue in the Wood Buffalo area as there are no major ammonia emission sources. *Impacts of nitrogen on plants*
- At concentrations normally found in the atmosphere, nitrogen oxides do not directly damage plants, but nitrogen oxides can produce ozone, which can be very toxic to plants. The effects of ozone and the acidifying and fertilizing impacts of nitrogen are discussed in other sections of this document. *Ozone formation*

8.2 Indirect Impacts of Nitrogen

Nitrogen can have positive as well as negative indirect impacts. Indirect impacts occur in three main ways:

1. Nitrogen emissions react in the atmosphere with other chemicals and under certain conditions to form new substances. These new substances, such as ozone and fine particulate matter, have their own, mainly negative, impacts on people and the environment.
2. Nitrogen is deposited as particles or in rainwater on the soil or in water. It is then transformed into substances that affect the soil or water conditions. In this way, nitrogen can have a fertilizing effect on soils (in water, this effect is called eutrophication), and it can also act to acidify soils and water. These impacts are described in more detail elsewhere in this report. These effects can be positive in some situations and negative in others.
3. One particular form of nitrogen is a greenhouse gas, which contributes to climate change.

8.2.1 Effects of Particulate Matter (PM) and Ozone on Vegetation

- The wet and dry deposition of PM on soils and its indirect effects on plants are of major concern. PM can acidify soil, create soil nutrient imbalances, and alter ecosystem health. It can also affect how plants respond to other stresses, such as frost, disease or pests.

  Indirect effects of PM on plants

- Ozone is the most important toxic air pollutant to plants and its effects have been shown in some 40 countries. Ozone does not accumulate in plants. After entering a leaf, it is almost immediately converted to other compounds, and it is these new substances that cause the damage.

  Behaviour of ozone

- Plants respond rapidly to ozone pollution. The effect of ozone on plants can be made worse by ozone's interaction with other air pollutants and other stress factors the plant may be experiencing. Ozone affects the ability of plants to absorb nutrients needed for growth, as well as the ability of plants to reproduce.

  Plant response to ozone

- On plants such as beans, the impact of acute exposure to ozone is typically seen on the upper surface of the leaf. Symptoms include bleaching, bronzing, spotting and potentially death of the leaf tissue. In conifers such as pine trees, symptoms such as loss of the green colour in the needles and needle drop occur on second year or older needles.

  Effects of acute exposure to ozone

- Chronic effects of ozone include changes in growth, yield, nutrient quality (which affects animals that browse on the plant), ability of the plant to compete with other plants, and impacts on the structure of the plant community. Chronic exposure can also affect how plants respond to other stresses.

  Effects of chronic exposure to ozone

- It is a challenge to study the impacts of ozone on vegetation because different conditions in the atmosphere affect how much ozone plants are exposed to. This means there is a lot of randomness in plant responses and longer term studies are needed to ensure that effects are what they seem.

  Challenges in studying ozone impacts

8.2.2 Health Effects of PM and Ozone

- Air pollution has become a priority health issue in many countries, and the health effects of fine particulate matter ($PM_{2.5}$) and ozone are well known. *Air pollution and health*
- Fine particles can contain solid or liquid material or both. They are suspended in the air and often contain a complex mixture of substances such as nitrates, sulphates, ammonium, carbon, soil, and other matter. Fine particles are the most damaging to human health as they can get deep into the lungs. They can contribute to heart disease and asthma as well as many other respiratory problems. *Health impacts of fine particles*
- Ground level ozone can also contribute to respiratory and heart problems. In the worst cases, death can result. People who have existing heart or respiratory conditions are particularly at risk. New research suggests that people with diabetes may also be more vulnerable. Impacts tend to be more severe in cities where the high numbers of vehicles produce emissions that cause smog. *Health impacts of ground level ozone*
- Like many other countries, Canada has set standards for levels of exposure to these substances in the interest of protecting human health. The present 24-hour standard for $PM_{2.5}$ is 30 micrograms/m^3. For ozone, the 8-hour standard is 65 parts per billion. *Canadian standards*
- Ozone levels in the OSR are currently well below the Canadian standard. There is a concern that increasing emissions of the substances that form ozone may cause ozone levels to increase. An Ozone Management Framework for the OSR has been developed to address this concern. *Ozone levels in the OSR*
- $PM_{2.5}$ levels are predicted to increase in the OSR. A provincial $PM_{2.5}$ management framework has been developed and would be triggered if $PM_{2.5}$ levels exceed 20 micrograms/m^3. At present, $PM_{2.5}$ concentrations in the OSR meet the Canadian standard of 30 micrograms/m^3. *Fine particulate levels in the OSR*

8.2.3 Health Effects of NO_2

- Most of the nitrogen that is emitted when fuels are burned is in the form of nitric oxide (NO). Nitric oxide is very quickly transformed in the atmosphere to nitrogen dioxide (NO_2), which makes the health impacts of NO_2 of interest. *NO and NO_2*
- NO_2 is one of many air pollutants that can cause respiratory problems. At certain concentrations, it can irritate the airways, causing wheezing, coughing, chest tightness and shortness of breath. It is often associated with other pollutants, which makes the study of its effects more challenging. *Respiratory problems*
- As well as outdoor sources of nitrogen, NO_2 also is emitted indoors from sources that include gas appliances, space heaters and tobacco smoke. *Indoor sources*
- Studies of health impacts of NO_2 need to be interpreted cautiously because: *Interpreting health impact studies*
  - NO_2 occurs in complex chemical mixtures,
  - Measurements taken at a particular site may not be the same as the level to which a person is exposed,
  - Indoor and outdoor sources of NO_2 are rarely looked at together, and
  - There may be other risk factors associated with an individual's overall health and economic well-being.

8.2.4 Nitrogen and Climate Change

- Because nitrogen emissions and nitrogen fertilizers get into virtually every part of the environment, nitrogen's contribution to climate change is complex. The most obvious negative impact is due to nitrous oxide (N_2O) which is a major greenhouse gas. Nitrous oxide lasts a long time in the atmosphere and is a much more powerful greenhouse gas than CO_2. Direct emissions of N_2O are fairly small, but indirect emissions are significant, due to the use of nitrogen as a fertilizer.

Nitrous oxide as a greenhouse gas

- Other chemical reactions involving nitrogen compounds can contribute to the formation of other greenhouse gases, such as ground level ozone. These reactions are complex and their eventual impact can be positive, negative or zero, depending on the location and time frame. At certain times and in certain regions (e.g., the Arctic in winter), these effects could be important.

Climate change and other nitrogen compounds

- On the positive side, nitrogen deposited to the soil can have a fertilizing effect, which encourages plant growth. Through the process of photosynthesis, plants remove carbon from the atmosphere and this can slow down the rate of climate change.

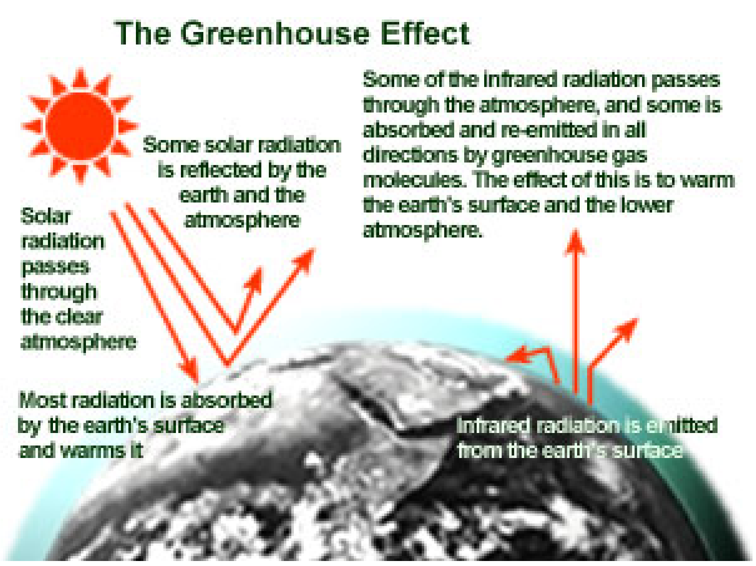
Nitrogen and photosynthesis

- Many uncertainties exist regarding additions of nitrogen and climate change.
  - If a region lacks nitrogen, adding nitrogen through wet or dry deposition may encourage enough new plant growth to offset any negative impacts on climate change.
  - Nitrogen additions may increase or decrease soil carbon levels depending on the nutrient status of soil organic material.
  - Increased nitrogen deposition can create local hotspots that change soil conditions and thus alter the species of plants that will grow there. This can lead to important changes in a region's plant diversity.

Uncertain relationship between added nitrogen and climate change

- In the OSR, additional nitrogen due to industrial emissions has not been assessed in detail from the standpoint of climate change. A recent review of nitrogen in boreal forest ecosystems suggests that at current nitrogen deposition rates, the boreal ecosystem would be a sink for carbon and thus help reduce greenhouse gas levels. Some research now underway in the OSR related to nitrogen cycling should provide more information on this issue.

Research in the OSR on nitrogen and climate change



Source: **http://epa.gov/climatechange/kids/greenhouse.html**

9 Managing Nitrogen: Issues and Opportunities

Many industrialized countries and regions have recognized the importance of managing both nitrogen emissions and the effects of these emissions. Different nitrogen management approaches have been successful but more work and understanding are needed. Challenges include:

- Lack of knowledge in many areas about how nitrogen behaves in the atmosphere, on land and in water.
- Developing better controls to reduce nitrogen emissions.
- Conflicting interests and priorities (for example, between economic development and stringent emissions control).
- Reducing the costs of controlling emissions.
- Addressing environmental impacts.
- The possible need for management strategies that consider the type of environment and the time of year. The effects of nitrogen depend on the type of ecosystem and on weather conditions and season because nitrogen chemistry changes with factors like light and temperature.

As our understanding of how nitrogen behaves in air, water and soil continues to improve so will our knowledge of the impacts and the best approaches to prevent and/or manage these impacts.

9.1 Managing Industrial Emissions in Alberta

- Industrial emissions are the main source of nitrogen in the oil sands region – from vehicles associated with the open pit oil sands mines, boilers, heaters and gas turbines. They emit nitrogen in the form of nitrogen oxides (NOx). Nitrogen emissions in the Wood Buffalo Region are expected to more than double in the next 10 years.

  Emissions sources in the OSR

- Alberta Environment is responsible for managing air emissions and air quality in Alberta. Alberta Environment's air quality management system for the province uses approaches that range from regulation to stewardship.

  Role of Alberta Environment

- Alberta regulates NOx emissions using the Industrial Air Quality Management System. This system includes everything from objectives for ambient air quality to emissions standards and monitoring, approvals, enforcement and research. The management system was designed to ensure that:
  - industry minimizes its emissions by using the best available technology that is economically achievable (BATEA), and
  - ambient air quality in the area of the emissions source meets Alberta's objectives.

  Alberta's Industrial Air Quality Management System

- Many agencies and organizations have worked through the Clean Air Strategic Alliance (CASA) to develop other frameworks that involve nitrogen emissions, including the Acid Deposition Management Framework and the Particulate Matter and Ozone Framework. These CASA provincial frameworks have been used to develop specific Acid Deposition and Ozone Management Frameworks for the Wood Buffalo Region.

  Nitrogen management frameworks

9.2 Controlling Industrial and Mobile NOx Emissions

- Managing nitrogen begins with reducing emissions. This is normally done by selecting processes that have lower emissions and then further reducing emissions through the use of control technologies.

Reducing emissions

- Nitrogen oxides (NOx) form when fuel is burned (combustion). Their formation is largely a function of temperature and the mix of fuel and air that is used. Controls can be applied in two places:
    - during combustion to reduce the NOx emissions that form when fuel is burned (this is called a primary or combustion control technology), or
    - after combustion but before the emissions are released into the outside air (this is called a secondary or post combustion control technology).

Controlling the formation of NOx emissions

- Primary control technologies control the amounts and ways the fuel and air are mixed during burning so that less NOx is produced. In the OSR, primary control technologies are the principal method used to manage NOx emissions.

Primary control technologies in the OSR

- Secondary control technologies involve the use of equipment (such as scrubbers or reactors) to remove NOx that formed during combustion and thereby reduce NOx emissions. A common technology involves adding ammonia (sometimes a catalyst is also used to improve the reactions) which changes the form of nitrogen from NOx to N_2, which has no environmental effects. Primary and secondary control technologies are often used in combination to achieve low total NOx emissions.

Secondary control technologies

- In the OSR, Alberta Environment is reviewing the best available technology economically achievable for natural gas-fired turbines, boilers and heaters and these may be finalized by June 2007.

New technology

- The US Environmental Protection Agency has developed off-road diesel equipment emission limits that are being applied to fleets in the OSR. These emission limits apply in steps from 2006 to 2015.

Controlling mobile emissions

9.3 Tools for Managing Nitrogen

Modelling and Monitoring Programs

- To manage nitrogen, it is important to know how much nitrogen is being deposited in a given area. This requires good modelling and monitoring programs. These programs provide the information needed to understand effects and are a base for negotiating agreements to reduce emissions. Once in place, such programs need to be maintained and updated as new emission sources are approved and as new information becomes available.

Emissions Trading Programs

Some parts of the world have put limits on the amount of nitrogen that can be emitted to the atmosphere by giving allowances to industrial sources in a region. This is called an emissions trading program. If facilities reduce emissions below their allowance, they generate credits which can be sold to other emitters in the region who cannot easily reduce emissions below their allowance. This emission management approach encourages companies to keep looking for ways to reduce emissions. In the US where total emission limits have been set, and then reduced in a scheduled way, trading has resulted in cost-effective emission reductions below requirements. The federal government recently announced plans for such a program in Canada.

Critical Loads

- Critical loads are a tool that was developed specifically to deal with air pollution and atmospheric deposition. They are a measure of how much pollution can be added to an ecosystem before long-term damage is likely to occur.

  What is a critical load?

- The critical load for an ecosystem depends on its sensitivity to the particular pollutant. It takes less nitrogen to damage a system that is very sensitive to nitrogen than it does to damage a system that is not sensitive to nitrogen. Thus the system that is more sensitive to nitrogen would have a lower critical nitrogen load.

  Sensitivity to pollution

- Nitrogen sensitivity is affected by many factors, and experiments and soil-vegetation condition surveys are needed to find out which local species are most sensitive to nitrogen deposition. Critical nitrogen loads can then be set according to which species you want to protect. Good background information on the plants normally present in an area is essential, especially when large increases in emissions have occurred or are likely to occur. This information helps determine whether a particular plant was once there and disappeared because of emissions, or was never there.

  Vegetation sensitivity to nitrogen

- Critical loads can be set for nitrogen in both of its major roles: as a contributor to acid deposition and as an added nutrient (eutrophication). However, it is very difficult to determine how much nitrogen is having an acidifying effect and how much is having a fertilizing effect, which makes it harder to calculate critical loads. Once the critical load is known, the goal is to ensure that deposition to the soil, water or vegetation never exceeds that level.

  Critical loads for nitrogen

- The critical load for acid deposition is expressed as the amount of hydrogen ions deposited on an area of land (usually a hectare) in a year. This number typically takes into account nitrogen as well as sulphur emissions, both of which can have an acidifying effect.

  Critical load for acid deposition

- The critical load for nitrogen as a nutrient is expressed as kilograms of nitrogen per hectare per year. Critical loads for nitrogen for eutrophication effects will likely be different than those for acidification effects. In general, critical loads for eutrophication will be less than those for acidification.

  Critical load for nitrogen as a nutrient

- The critical loads concept differs from earlier strategies to reduce pollution because it focuses on regional impacts of specific pollutants. Previous strategies concentrated on reducing overall emissions at all sources without much regard for the actual damages of specific emissions in certain regions. The critical loads approach allows emission reduction efforts to be focused on

  Regional approach to managing pollution

sources that are having the most impact.

- Critical loads have been used in many places to manage acid deposition, including Alberta, Europe and other parts of North America. The concept was a significant factor in reducing emissions that cause acid rain in eastern Canada and the US.

Use of critical loads

- The critical loads approach has been an important tool in achieving emissions reductions in Europe and North America, but it does have limitations. Among other things, critical loads:
    - Simplify complex ecosystem processes into one or two numbers.
    - Assume a threshold of damage that might be uncertain or not really exist.

  It is therefore important to understand the limitations and possible risks when setting critical loads.

Value and limitations of critical loads approach

- The Acid Deposition Management Framework for the OSR currently assumes that all deposited nitrogen has an acidifying effect, but this is not realistic and work is underway to determine more accurate and reasonable numbers.

Application of critical loads in the OSR

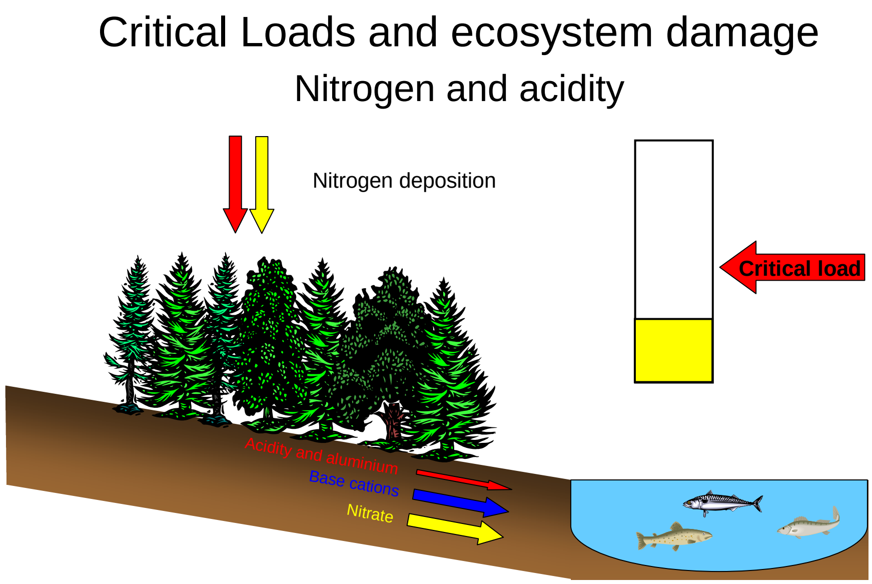
- In Alberta, critical loads for acidification have not been exceeded anywhere so the emphasis is on preventing damage from occurring in the future.

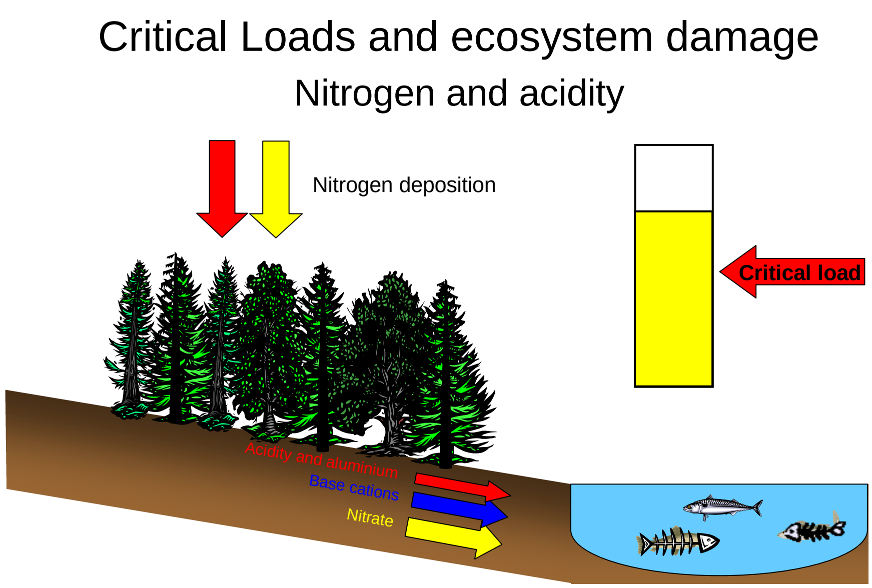
Acidification levels in Alberta

- Critical loads for nitrogen as a nutrient have not yet been applied in Alberta. A eutrophication management framework is being developed for the OSR, but it may be some time before definitive critical loads for this region can be set.

Critical nitrogen loads in Alberta and the OSR

The drawings below show what happens when the critical load is exceeded. In the first picture, the nitrogen being added to the lake is below the critical load and the fish are not being affected. In the second picture, nitrogen deposition has gone up significantly and runoff to the lake has risen. The critical load is exceeded, damaging the lake and the fish and other animals and plants that live in it.





Source: Dr. Chris Evans

10 Glossary

Acidification

The process that results from the emission of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ammonia (NH_3), and the ultimate deposition of sulphur and nitrogen compounds that cause soil and water to become more acidic, which means a lowering of pH (see “pH”).

Acute exposure

Single high level exposure to a toxic substance which may result in severe biological harm or death. Acute exposures are usually characterized by short-term immediate impacts leading to more subtle impacts, as compared to longer, or chronic, exposure over a period of time.

Adverse health effects

The range of health effects that have been linked, to varying degrees, to air pollution. These effects include heart disease, allergies, effects on the nervous system, cancer and various respiratory diseases such as asthma. Not all air pollutants have all these effects and effects are related to the level of exposure and to difference between individuals.

Aerosols

Very fine solid or liquid particles emitted to or formed in the atmosphere. Gases dissolved in small water droplets in the air are a major source of aerosols and may be an important form of acid deposition.

Algae

Simple plants that grow in sunlit waters. Algae are a food source for fish and small aquatic animals.

Alkaline

Having a pH above 7 (see “pH”).

Ambient air quality

Refers to the quality of the outdoor air at a particular location or area, and is generally determined by measuring the concentration of certain substances in the air on a continuous or some other regular basis. An Air Quality Index is often used to report ambient air quality. The index categories typically range from very poor to good.

Ammonia

A chemical compound composed of nitrogen and hydrogen (NH_3). It is formed naturally when biological material rots or decomposes and is also produced commercially in large quantities for use as a fertilizer.

Area sources

Sources of emissions that are too numerous or too small to be accounted for individually. Examples include home furnaces, commercial establishments such as dry cleaners, and other small industrial activities. Car and truck emissions are not considered area sources but rather are categorized as “mobile” sources; similarly, sources such as farms and forest fires are categorized as “open” sources.

Atmosphere

The gases that surround the earth.

BATEA

Best Available Technology Economically Achievable. BATEA refers to technology that can achieve superior emissions performance, is proven or demonstrated, and is economically realistic. BATEA is used to establish air emission control expectations or limits.

Biological decomposition

The breakdown of biological material into basic or stable components by soil organisms such as bacteria and fungi.

Boreal forest

The most northerly and coldest forest zone of the northern hemisphere. It forms a belt across North America, Europe and Asia. In Canada, the boreal forest is dominated by evergreens and small-leaf deciduous trees. Much of the Fort McMurray region is boreal forest.

Buffering capacity

A measure of the ability of water or soil to resist change in pH when an acid or alkaline substance is added. In the context of acid deposition, soil or water that has a high buffering capacity is able to withstand more acid deposition before suffering damage than a system with low buffering capacity.

Calcium

Calcium (chemical symbol Ca) is an essential element for the normal growth and development of plants and animals. Calcium is commonly found in the earth's crust in substances such as limestone. Soils that were formed from limestone are usually alkaline and thus better able to absorb acid than other soils (that is, they have a high buffering capacity).

Carbon dioxide

A colourless, odourless gas (chemical symbol CO_2) that is absorbed by plants during photosynthesis and released by both plants and animals when they breathe. It is found naturally in the atmosphere and is also produced during the burning of fossil fuels. CO_2 is the major greenhouse gas that is contributing to climate change.

Catalyst

A substance that increases the rate of a chemical reaction without being permanently changed itself. For example, NOx and chlorine act as catalysts in the upper atmosphere and are largely responsible for depletion of the ozone layer.

Chlorophyll

The substance that gives plants their green colour. Chlorophyll enables plants to absorb light energy from the sun through photosynthesis.

Chronic exposure

Exposure to a substance over a long period of time.

Climate change

The change in climate systems that has occurred naturally in the past and is now at least in part occurring due to the build-up of greenhouse gases that trap heat and reflect it back to the earth's surface. Climate changes include changes in global temperature and more frequent severe weather.

Coarse particles

See "particulate matter."

Continuous monitoring

Continuous monitoring of air quality involves drawing air continuously or in short cycles through a piece of equipment called an analyzer, which indicates the ambient concentration of the substance being monitored. This method is often used to monitor sulphur dioxide, hydrogen sulphide, nitrogen oxides, ozone, and particulate matter.

Critical load

A measure of how much acid or nitrogen deposition can occur before the deposition affects an ecosystem. The critical load is often set as the threshold above which the additional pollution will harm the environment. Different regions and ecosystems have different critical loads. For example, ecosystems that can tolerate acidic pollution have higher critical loads, than ecosystems that are sensitive to acidic pollution.

Diversity

Diversity reflects the variety of species in an area and is a measure of the complexity of an ecosystem. It is generally considered desirable to retain a wide variety of plants and animals in natural systems.

Ecosystem

A biological community of organisms (plants, animals, microorganisms) that interact with each other and with the physical environment in which they are found.

Element

A substance that cannot chemically be broken down into simpler substances. Carbon, hydrogen, oxygen and nitrogen are examples of elements.

Emissions inventories

Data and other information on sources of air pollutants that are gathered and updated on a regular basis. Emissions inventories allow governments and others to track the progress of emissions reductions programs and see if adjustments are needed. Emissions inventories also help identify which air pollution sources may be having the greatest impact on air quality and therefore should be the focus of reduction programs. These inventories include a wide range of information about the sources and amounts of many different substances.

Essential nutrient

Elements such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and certain other elements are essential for plant growth. Soil is the major source of these elements for plants.

Eutrophication

The process by which nutrients (especially nitrogen and phosphorus) are added to water or soil and increase biological activity, often to levels that have adverse effects on the original ecosystem. These nutrients can be from natural sources but are more commonly due to human activity. The impacts of eutrophication can include reduced oxygen levels in the water, which can make it hard for fish and other animals to survive, and changes in the types of plants that grow in an area, e.g., grasses replace shrubs.

Fine particulate matter

See “particulate matter.”

Fossil fuels

Fossil fuels include coal, oil, refined petroleum products like gasoline, and natural gas. They are called fossil fuels because they consist of the remains of plants and animals that lived millions of years ago. These remains were buried in sediments, including the oil sands. They contain large amounts of carbon and when these fuels are burned, they produce large amounts of carbon dioxide, which is a greenhouse gas. Coal also often contains large amounts of sulphur, which produces sulphur dioxide when it burns.

Greenhouse gases

Gases that absorb and trap heat from the atmosphere and reradiate a portion of this heat back to the earth, causing a warming effect. Greenhouse gases such as carbon dioxide, ozone, nitrous oxide and methane occur naturally but are also all produced by human activities.

Ground level ozone

A colourless gas that irritates the respiratory system, is toxic to plants and is a major component of smog. It forms just above the earth's surface, when nitrogen oxides and volatile organic compounds react in the presence of sunlight.

Hectare

A metric unit of land measure equal to 10,000 square metres (just under 2.5 acres).

Hotspots

Areas that are experiencing or are likely to experience enough pollution to have a harmful effect on humans, animals, plants, soils or water.

Hydrogen ions

Hydrogen ions cause acidity and have a major influence on chemical balances and reactions. In chemistry, when a hydrogen atom loses one electron it takes on a positive charge and becomes an ion (H^+). The more hydrogen ions there are in a solution, the more acidic the solution is. (See "pH" and "acidification.")

Intermittent monitoring

Intermittent air quality monitoring refers to air pollutants that are monitored as a 24-hour integrated concentration; the National Air Pollution Surveillance monitoring schedule is one example. This usually requires sampling systems that collect pollutants using canisters, reactive tubes, absorbents or filters. The samples are analyzed at a laboratory to determine air pollutant levels. Volatile organic compounds and particulate matter are among the substances monitored in this way.

Kilogram

A metric unit of weight of 1000 grams (about 2.2 pounds).

Logarithmic (scale)

A scale of measurement in which an increase or decrease of one unit represents a ten-fold increase or decrease in the quantity measured. pH is measured on a logarithmic scale. For example, when pH goes from 7 to 6, it has become ten times more acidic – that is, ten times more concentrated in hydrogen ions (see "pH").

Micrograms/m³

Micrograms per cubic metre (m^3) is a measure of the concentration of a substance. A microgram is one-millionth of a gram. A gram is a metric unit of weight; there are about 28 grams in an ounce. A cubic metre is a metric unit of volume amounting to just over 35 cubic feet.

Micro-organism

A micro-organism is an organism too small to be seen with the unaided eye. Examples are bacteria, viruses and moulds.

Mobile sources

Emissions related to the transportation sector. Trucks, buses, trains, passenger vehicles, boats, and aircraft are mobile sources.

Modelling

The use of a mathematical description of a system (called a “model”), such as the behaviour of a pollutant in air, to predict what will happen to the pollutant. Models are generally very simplified descriptions of a physical system and their predictions have to be used with caution. They are a necessary tool for trying to estimate the effects of possible future changes in emission levels.

Molecule

A particle that consists of connected atoms of one or more chemical elements. Most air pollutants are molecules and not elements.

Nitrogen oxides (NOx)

Nitric oxide (NO) and nitrogen dioxide (NO_2) are often found together and are known collectively as nitrogen oxides (NOx). Nitric oxide is colourless, while nitrogen dioxide is reddish brown. Both of these gases are produced as a result of burning fossil fuels at high temperatures, as in boilers, and both play a role in the formation of photochemical smog. They can also have direct effects on plants and health and can contribute indirectly to eutrophication and acidification.

Nitrous oxide (N_2O)

Nitrous oxide is a greenhouse gas that is produced naturally and as a result of human activities. Major sources include natural organic matter breakdown by soil microorganisms, land clearing, application of soil fertilizers, fossil fuel combustion, and burning of biomass.

Open sources

Emissions that come from activities that occur over a wide area and are often hard to measure; examples are forest fires, road dust and agricultural tillage.

Organic material

Non-living matter that is derived from living organisms. For example, compost and manure are referred to as organic material.

Ozone (O_3)

A colourless and highly reactive gas. In the upper atmosphere (the “stratosphere”) ozone is formed when intensive ultra-violet radiation from the sun breaks down oxygen molecules (O_2) into two oxygen atoms. These oxygen atoms are highly reactive and can then react with more O_2 to form ozone (O_3). The stratospheric ozone layer acts to screen out and protect us from the sun’s ultraviolet radiation. Ozone is also a greenhouse gas. When ozone is formed close to the ground, it contributes to the formation of smog (see “ground level ozone”).

Particulate matter (PM)

Tiny particles of solid material or liquid aerosols in the air that, depending on the levels and make-up, may become an air pollution concern. These tiny particles range in size from 0.001 to 500 micrometres (a human hair is about 70 micrometres in diameter) and, depending on their size and other properties, may remain suspended in the air for a few seconds or indefinitely. The smallest particles, called "fine particulates," have been shown to be harmful to human health because they can enter deep into the lungs. Larger particles are referred to as "coarse particulate matter" and include things like road dust. Fine particulate matter is generally considered to be less than 2.5 micrometres in diameter ($PM_{2.5}$), while coarse particulate matter is generally considered to be between 2.5 and 10 micrometers in diameter.

PM may result from a variety of natural and human sources. These sources include vehicle exhaust emissions, industrial emission sources, soil, road dust, dust resulting from other human activities (e.g., agriculture), smoke from forest fires, and smoke from recreational sources (e.g., campfires and fireplaces).

Parts per billion (ppb)

The number of parts of a substance found in one billion parts of a gas, liquid or solid. For example, a concentration of 10 ppb of substance "x" in the air means that there are 10 atoms or molecules of this substance in every 1,000,000,000 atoms or molecules in the atmosphere.

Passive monitoring

Passive sampling involves exposing a reactive surface to the air, and the pollutant being monitored is absorbed by the sampler. Samplers are typically exposed for periods of one month, and analysis is done in a laboratory. Sulphur dioxide, nitrogen dioxide, ozone, hydrogen sulphide, volatile organic compounds and total hydrocarbons are common pollutants monitored using passive samplers.

Photochemical smog

Smog is a harmful mixture of gases (mainly ground level ozone) and tiny particles (fine particulate) that often appears as haze in the air. Smog develops when pollutants such as nitrogen oxides and volatile organic compounds combine in the presence of sunlight and undergo chemical changes to produce many new hazardous chemicals.

Photosynthesis

The process by which plants capture and convert the sun's energy and carbon dioxide into food (organic matter). This food is mostly carbohydrates, which include sugars and starches. They provide energy and are used as building blocks for other tissues. Photosynthesis is the chemical basis for life on earth, since virtually all other organisms depend on plants for food. Plants take carbon dioxide, a major greenhouse gas, out of the air during photosynthesis and release oxygen.

pH scale

The pH scale is the measure of how much hydrogen ion is present in a solution. Thus, the pH scale is used to measure the acidity or alkalinity of a solution. A pH of 7 is neutral – it is neither acidic nor alkaline. A substance such as lemon juice, that has a pH less than 7, is acidic. A substance such as baking soda, that has a pH greater than 7, is alkaline. Literally, pH means "potential of hydrogen."

Point source

A non-moving, identifiable source of air emissions such as the stack(s) at a power plant. Most large industrial facilities are considered point sources.

Reactive nitrogen

Nitrogen is an essential element for living things but it must be in what is called a "reactive" chemical form for organisms to be able to use it. However, almost all of the nitrogen that occurs naturally in the atmosphere is in a non-reactive form – as molecular nitrogen, or N_2. For this nitrogen to be available naturally in a reactive form, the normal chemical bonds between nitrogen atoms must be broken, and the nitrogen must re-attach itself to an element such as carbon, hydrogen or oxygen. This process occurs in nature thanks to bacteria in the soil. When fossil fuels are burned, the nitrogen in the combustion air is burned and NOx is produced. The natural nitrogen cycle is now being altered because most of the nitrogen that human activities are adding is in the reactive form (e.g., fertilizers, nitrogen oxides).

Respiratory problems

Health problems that affect a person's ability to breathe properly and efficiently. A common respiratory problem is asthma. Such problems can arise in response to, or be affected by, poor air quality as well as lifestyle choices such as smoking.

Sink (for carbon)

Any process, activity or mechanism that removes greenhouse gas emissions from the atmosphere such as chemical breakdown or absorption or uptake in oceans, forests and soils. Forests and agricultural soils are examples of sinks as they can remove and store carbon dioxide from the atmosphere.

Smog

See "photochemical smog."

Stratosphere

The atmospheric layer found at an average altitude of 11 to 50 kilometres above the earth's surface. The stratosphere contains the ozone layer, which shields the earth from harmful ultraviolet (UV) rays from the sun.

Stratospheric ozone depletion

Loss of, or damage to, the ozone layer. This allows more of the sun's ultraviolet rays to reach the earth's surface. This increased radiation is linked with human health impacts, such as increases in skin cancer and cataracts.

Sulphur dioxide (SO_2)

A colourless gas that is produced during the burning of coal, the smelting of sulphur-containing ores and other processes. SO_2 can be deposited on plants, soils and water in wet or dry form and, when combined with water, forms sulphuric acid. In the air it can have direct effects on plants and people, can contribute to the formation of fine particulate matter and is a major cause of acid rain.

Synergistic effects

Synergistic effects occur when a combination of two or more substances produces a greater effect than would be expected from adding the individual effects of each substance.

Tonne

A metric unit of weight equivalent to 1000 kilograms (about 2200 pounds).

Troposphere

The layer in the atmosphere found from the surface of the earth to a height of between 8 and 16 kilometres. This is where most of our weather occurs.

Ultraviolet radiation

A form of energy from the sun that is invisible. There are three types of ultraviolet (UV) radiation: UV-A, UV-B and UV-C. UV-A is the weakest form and can cause skin aging, wrinkles and damage to outdoor plastics and paint. UV-B is the most harmful to us and other life forms. UV-B causes skin cancer and cataracts. UV-C, which is even stronger than UV-B, never reaches the earth's surface because it is filtered out by the atmosphere.

Upstream oil and gas

Refers to the portion of the oil and gas industry involved in exploration, production and basic processing of crude oil and natural gas. It does not include oil refining or the oil sands.

Volatile organic compounds (VOCs)

Volatile organic compounds include a large group of chemicals that contain carbon and hydrogen atoms that can react quickly to form other chemicals in atmosphere. VOCs are important because they can: 1) react with oxides of nitrogen in the presence of sunlight to form ozone and photochemical smog; and 2) be toxic to humans, animals or vegetation.

The major sources of VOCs are vegetation, automobile emissions, gasoline marketing and storage tanks, petroleum and chemical industries, dry cleaning, fireplaces, natural gas combustion and aircraft. The main source of VOCs in most urban areas is vehicle exhaust emissions. The oil sands are a major emitter of VOCs.

Sources:

The following print and online sources were consulted in preparing this glossary. Definitions used above usually represent an adaptation or combination of published definitions, so specific references have not been given.

Alberta Environment Air Definitions, online at: **http://www3.gov.ab.ca/env/air/Info/definitions.html**

Barber, Katherine, ed. *Canadian Oxford Dictionary.* 1998. Oxford University Press, Toronto.

Canadian Pollution Prevention Clearinghouse Glossary, online at: **http://www.ec.gc.ca/cppic/En/glossary.cfm**

Clean Air Strategic Alliance (CASA) Data Warehouse, online at **http://www.casadata.org/index.asp**

Dunster, Julian and Katherine. 1996. *Dictionary of Natural Resources Management.* UBC Press, Vancouver.

Environment Canada glossaries and fact sheets, online at
http://www.ec.gc.ca/default.asp?Lang=En&n=7EBE5C5A-1
http://www.ec.gc.ca/cleanair-airpur/Ground_Level_Ozone-WS590611CA-1_En.htm
http://www.ec.gc.ca/acidrain/acidfact.html:

Green Facts Digest, online at **http://www.greenfacts.org/glossary/index.htm**

NPS Nature and Sciences, online at **http://www2.nature.nps.gov/air/AQBasics/glossary.cfm**

Oxford Dictionary of Science, fourth edition. 1999.

PhysicalGeography.net, online at **http://www.physicalgeography.net/glossary.html**

Life Science Dictionary, online at **http://biotech.icmb.utexas.edu/search/dict-search.html**

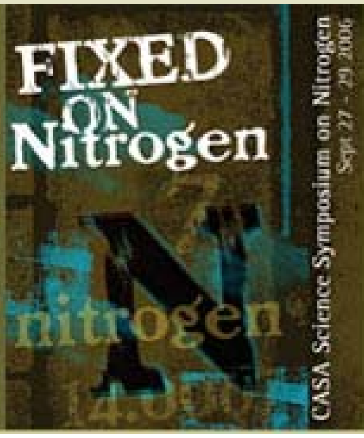
US Environmental Protection Agency, Terms of Environment, online at: **http://www.epa.gov/ocepaterms/**

Wikipedia: **http://en.wikipedia.org/wiki/Main_Page**

Appendix: *Fixed on Nitrogen* Program Overview

Clean Air Strategic Alliance

The Clean Air Strategic Alliance (CASA) presents:



FIXED ON NITROGEN

CASA Science Symposium on Nitrogen

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

Program Overview

Wednesday, September 27, 2006

Overview on Nitrogen

11:00	Registration	
13:00-13:15	Welcome	Peter Watson
13:15-13:30	Overview of CASA	Donna Tingley
13:30-14:15	Overview on nitrogen	Dr. Bridget Emmett
14:15-15:00	Sources of nitrogen in Alberta	David Niemi
15:00-15:20	**Break**	
15:20-16:05	Nitrogen concentrations and deposition in Alberta	Dr. Karen McDonald
16:05-16:50	Management approaches for nitrogen emissions	Dr. Julian Aherne
17:00-19:30	**Reception**	

Thursday, September 28, 2006

Nitrogen Chemistry

7:15-8:15	**Breakfast**	
8:15-9:05	Atmospheric chemistry of nitrogen	Dr. Mary Anne Carroll
9:05-10:00	Soil, groundwater and surface water chemistry of nitrogen	Dr. Shaun Watmough
10:00-10:30	**Break**	

Nitrogen Eutrophication

10:30-11:15	The general science of nitrogen eutrophication	Dr. Bridget Emmett
11:15-12:00	Specific nitrogen eutrophication issues	Dr. Per Gundersen

Direct Nitrogen Health and Environmental Impact

10:30-11:00	The direct health effects of various common nitrogen Species	Dr. Kathleen Belanger
11:00–11:30	The direct effects of various common nitrogen species on vegetation	Dr. Sagar Krupa
11:30–12:00	Odour and aesthetic issues associated with common nitrogen species	Dr. Ralf Both

12:00- 13:00 **Lunch**

The Clean Air Strategic Alliance (CASA) presents:

Thursday, September 28, 2006
Nitrogen Measurement and Modeling

13:00-13:45	Atmospheric and depositional nitrogen monitoring	Dr. J. Neil Cape
13:45-14:30	Modeling of nitrogen dispersion, ambient air concentrations and deposition	Dr. Paul Makar
14:30-15:00	**Break**	

Nitrogen Acidification

15:00-15:45	The general science of nitrogen acidification	Dr. Julian Aherne
15:45-16:30	Specific nitrogen acidification issues	Dr. Per Gundersen

Nitrogen in relation to Particulate Matter, Ozone and Climate Change

15:00-15:20	The role of nitrogen in PM and O_3 formation	Dr. Mary Anne Carroll
15:20-15:40	The environmental effects of PM and O_3	Dr. Sagar Krupa
15:40-16:00	The health effects of PM and O_3	Dr. Barry Jessiman
16:00-16:30	Nitrogen and climate change	Dr. Chris Evans

18:00 Gala Dinner: Guest speaker: Dr. Joe Schwarcz, McGill University, Montreal, Quebec

Friday, September 29, 2006
Nitrogen Impact Management

7:30-8:30	**Breakfast**	
8:30-9:15	Approaches to the management of industrial and agricultural nitrogen emissions and impacts in Alberta	Dr. Ahmed Idriss Len Kryzanowski
9:15-9:45	Agricultural nitrogen control practices and options	Dr. Brent Auvermann
9:45-10:15	**Break**	
10:15-10:45	Industrial and mobile NO_x control practices and options	Tim Smith
10:45-11:15	Critical loads for the management of nitrogen acidification and eutrophication	Dr. Chris Evans
11:15-12:30	Panel discussion and questions	
12:30-14:00	**Lunch: Guest speaker: Dr. Joe Schwarcz**	

14:00-16:00 **Meetings**

1. Approaches to odour measurement and management
2. Approaches to ambient air quality objectives for nitrogen compounds
3. CEMA/ADAG – meeting of group members