Muskoka WATERSHED COUNCIL

ATMOSPHERIC DEPOSITION

INTRODUCTION

Atmospheric deposition is a process whereby pollutants are transported from a ground-based source and through atmospheric processes are deposited on distant land or water.[1] In Muskoka the primary toxins of interest are sulphur and nitrogen as they result in acid deposition, and mercury. In large part, the source of these pollutants is from outside Canada and requires international cooperation before further reductions can be realized. For example, between 1990 and 1995 Canadian emissions of mercury dropped from 30 to 11 tonnes and by 2003 had dropped again to 7 tonnes. This represents a reduction in mercury emission of about 90% between 1970 and 2003. Emissions from international sources, especially from emerging markets have not decreased and now play a significant role in local mercury deposition.[2] Other pollutants that are important globally but may not have as direct an impact locally include:

- ozone and fine particulate matter (PM)
- Hazardous Air Pollutants (HAPs) including persistent organic pollutants (POPs) such as pesticides, heavy metals, and dioxins
- Increased UV due to the depletion in the ozone layer

Critical Load and Target Load

The levels of pollution as a result of atmospheric deposition are evaluated in terms of 'target load' and 'critical load'.

Critical load[3] is the amount of pollution that an ecosystem can tolerate without significant damage. Critical loads vary according to the ability of the ecosystem to neutralize the given pollutant.

Target load[4] is the amount of pollution that is deemed achievable and politically acceptable generally in relation to social values and the economy. This value is determined politically and may result in some loss of ecological function.

SULPHUR AND NITROGEN

Sulphur and to a lesser extent nitrogen are the main components of acid deposition. Acid deposition is any form of precipitation that is unusually acidic and can include wet and dry deposition. Wet deposition includes rain, fog, and snow amongst others. Dry deposition refers to wind-borne particles such as fly ash.

Sulphur and nitrogen are byproducts of both natural processes, such as volcanoes, and man-made processes such as emissions from industrial activity, ore smelting, coal-fired power generators and natural gas processing. Most nitrogen oxide emissions result from fuel combustion in motor vehicles, furnaces and industrial boilers. Further oxidation of Sulphur Dioxide (SO_2), usually in the presence of a catalyst such as Nitrogen Dioxide (NO_2), forms Sulphuric Acid (H_2SO_4), and thus acid deposition.[5]

Once acidic particles and vapours have been created they can be transported in the atmosphere over large distances and once deposited, they are absorbed into surfaces on both land and water and can cause significant ecological damage.

[1] www.dnr.state.md.us/criticalarea/glossary.html
[2] Environment Canada Mercury and the Environment Sources of Mercury http://www.ec.gc.ca/MERCURY/SM/EN/sm-cr.cfm?SELECT=SM
[3] United States Department of Agriculture, Forest Service, http://www.nrs.fs.fed.us/clean_air_water/clean_water/critical_loads/glossary
[4] ibid
[5] Holleman, A. F.; Wiberg, E. (2001), *Inorganic Chemistry*, San Diego: Academic Press, ISBN 0-12-352651-5

Acids are measured on a pH scale from pH1 to pH14; the lower the number the higher the acidic level. For comparison, battery acid has a value of pH1, a value of pH7 is considered neutral and pH14 is a very low acid level or high alkalinity. The pH scale is logarithmic which means that a change from a neutral reading of pH7 to a value of pH6 represents a tenfold increase in acidity.

According to the National Pollutant Release Inventory[6], the area within 300 km of the US/Canada border has elevated levels of acidic deposition. In areas such as Muskoka which lack natural alkalinity, such as a limestone base, acid cannot be neutralized naturally and lakes and soils resting on granite bedrock in these areas cannot neutralize the acid deposition.

The 'critical load' for acid deposition in Muskoka is 'low' and the area still experiences deposition rates that exceed this value. According to Environment Canada, the average pH of rain in Muskoka/Haliburton in 1984 was about 4.5, approximately 40 times more acidic than 'clean rain' which has a pH of 5.6. By 2000 it was projected to increase to about 4.6. [7]

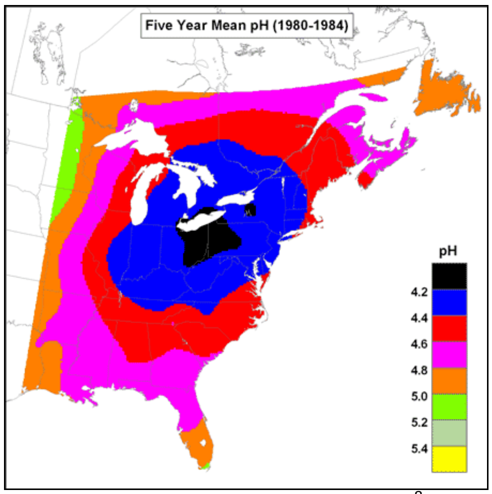

Table 1: The Average pH of Rain[8]

The Canada-Wide Acid Deposition Strategy for Post-2000 established new sulphur reduction targets and timelines. In it, Ontario undertook to reduce its previous target for SO_2 under the former Eastern Canada Acid Deposition Program by 50% to 442.5 kilotonnes (kT) per year by 2015. The Province is now considering advancing this timeline to 2010.[9] By 2000, Ontario had reduced its SO_2 emissions by 33% from the baseline.[10]

The result of these programs has been a reduction in acid deposition in Muskoka over the last few decades. Figure 7 shows that Sulphate (SO_4) deposition rates in Muskoka have decreased from 20 - 25 kg/ha/yr in 1990-1994, to 15 - 20 kg/ha/yr from 1996-2000. Scientists indicate, however, that a further reduction to as low as 8 kg/ha/yr is required to ensure that critical load levels are achieved in this area.[11]

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[6] Environment Canada, National Pollutant Release Inventory, http://www.ec.gc.ca/inrp-npri
[7] Environment Canada, *Acid Rain and Water* http://www.ec.gc.ca/acidrain/acidwater.html
[8] Ibid
[9] Canadian Council of Ministers of the Environment, *Five-year Review of The Canada-Wide Acid deposition Strategy for Post-2000*, December 2005. ISBN-10 1-896997 – 47 -3
[10] Ibid
[11] Ontario Ministry of the Environment, Transboundary Air Pollution in Ontario, June 2005.

Impact on forests

Acid deposition can impact both forest soils and vegetation. Acid deposition depletes the supply of important nutrients and base cations such as calcium, potassium and magnesium, from soils. In turn this will impact the health, ability to withstand stresses such as drought, insects and disease and the growth of trees causing them to grow more slowly or stop all together. Acid deposition also increases the concentration of aluminum in the soil interfering with the uptake of nutrients. When calcium is leached from the needles of spruce, these trees become less cold tolerant and exhibit winter injury and even death[12]. In the long-term, acid stressed forests leads to loss of habitat and food sources which has impact throughout the ecosystem.[13]

Given that the bedrock of Muskoka is primarily granite with little capacity for neutralizing acid, Muskoka's forests continue to be impacted by acid deposition even though sulphur emissions have been reduced. This impact is compounded by the fact that the recovery rate of soils from acidification (replacement of base cations) is extremely slow with the most important process in the replacement of these nutrients being the 'weathering of bedrock'.

These added stresses on the forests in Muskoka will not only impact the local forestry industry, which is already struggling, but also the tourism and recreation industry that relies on forested areas and scenic views.

Impact on water

Acidic deposition can result in both lower pH (higher acidity) and higher aluminum concentrations in surface water and can cause damage to fish and other aquatic animals.

As lakes and rivers become more acidic, biodiversity is reduced. In some areas, acid deposition has impacted insect life and some fish species. Chart 1, below, shows that not all fish, shellfish, or the insects that they eat can tolerate the same amount of acid; for example, frogs can tolerate water that is more acidic (lower pH) than trout.[14] Acid stresses on fish result in the failure of females to spawn as well as deformities and weaknesses in the young. Muskoka species, such as smallmouth bass, walleye, brook trout and salmon are particularly susceptible to acidity. In addition, mosses and plankton may overrun the near-shore areas. Terrestrial animals and waterfowl will disappear as their food sources are depleted. As a result, acid deposition reduces the biodiversity of aquatic systems.

Acid deposition can either fall directly onto the waterbody or it can flow to the waterbody overland as stormwater runoff. The extent to which runoff from the watershed to a lake or river contributes directly or indirectly to the impact of acid deposition on aquatic environments is variable depending on the number of wetlands, soil type, vegetation, and rock formations in the watershed. As noted previously, the soils and rock formations in Muskoka do not have a high ability to neutralize acids as the land is granite based.

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[12] Hawley, Gary, Schaberg, Paul, Eagar, Christopher, Borer, Cathy, Calcium addition to watershed at Hubbard Brook LTER reduces red spruce winter injury. ESA 2004 Annual Meeting, Portland Oregon. http://abstracts.co.allenpress.com/pweb/esa2004/document/37536

[13] Phinney, L., Waugh, D., Tordon, R., Air Quality Services Meteorological Services of Canada, *Environmental Impacts of Air Pollution.* http://www.gov.ns.ca/nse/air/docs/Phinney-EnvironmentalImpacts.pdf

[14] U.S. Environmental Protection Agency *Effects of Acid Rain – Surface Water and Animals*. http://en.wikipedia.org/wiki/Acid_rain#cite_note-EPA-16

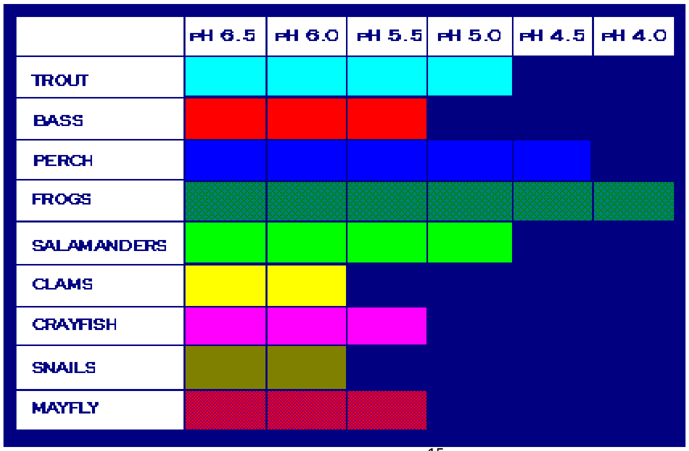

Chart 1: Species Tolerance to pH Levels[15]

MERCURY

Mercury is a liquid heavy metal that can easily volatilize into the atmosphere. Although, in Canada, we have seen dramatic reductions in mercury emission since 1990, we are still impacted by airborne mercury that comes primarily from coal-fired power plants in the United States and from Canadian metal smelting operations and incinerators.[16] Mercury also has natural sources such as the weathering of bedrock and gaseous emissions from soils. Mercury is found in the atmosphere as mercury vapour and attaches itself to airborne particles allowing it to be transported over long distances.[17] When it combines with carbon, its organic form methylmercury is created. Methylmercury is highly toxic and bioaccumulates (inflicts increasing harm in higher order species through biomagnification through the food chain) in the body fat of animals.

In Muskoka, sources of mercury are both local and global. Naturally, local granite may contain up to 0.2 ppm of mercury (parts per million) versus other forms of rock which have mercury levels closer to 0.1 ppm. However, mercury can also come from volcanic eruptions and undersea vents. Anthropogenic (human) sources of atmospheric emissions are primarily the result of:

- Industrial sources - electricity generation, non ferrous mining and incineration;
- Improper disposal of mercury containing products - thermometers, fluorescent lights, batteries, electrical relays/switches, dental amalgam and medical devices etc into landfill sites;
- Direct disposal into sewage systems; and
- Direct mercury pollution and emissions from landfill gasses or leeching into the ecosystem.

Mercury is a neurotoxin and high levels of exposure can cause illness or death in humans and animals. When atmospheric mercury falls to earth, it may be altered by bacterial or chemical action into an organic form known as methylmercury. This may be particularly the case in wetlands and waterways. Methylmercury is much more toxic than the original metal molecules that drifted in the air, and has the ability to "bioaccumulate" in living tissue. Methylmercury is absorbed easily by organisms and is capable of migrating through cells which normally provide barriers to toxins. For example, if the concentration of methylmercury in lake water is considered to have an absolute value of 1, then approximate bioaccumulation factors for microorganisms like phytoplankton are 10^5; for macroorganisms like zooplankton and planktivores (an animal feeding primarily on plankton) are 10^6; and for piscivores (a fish eater) like fish, birds and humans are 10^7.

[15] Ibid
[16] Environment Canada Mercury and the Environment Sources of Mercury http://www.ec.gc.ca/MERCURY/SM/EN/sm-cr.cfm?SELECT=SM
[17] Hrabik T. R. and C. J. Watras Recent declines in mercury concentration in a freshwater fishery: isolating the effects of de-acidification and decreased atmospheric mercury deposition in Little Rock Lake The Science of The Total Environment Volume 297, Issues 1-3, 7 October 2002, Pages 229-237

The combined impacts of mercury contamination in Canada are difficult to quantify. The exact proportion of the impact which can be ascribed to natural mercury and to past and present anthropogenic releases cannot presently be quantified. Because it is a natural and persistent bioaccumulative element which can be transported many miles in the atmosphere, mercury can have impacts many years and many miles removed from its original source.

Impact of forests

More research on the impact of mercury in the environment is required to fully understand this heavy metal. In one study, mercury reduced the photosynthesis and transpiration, water uptake, and chlorophyll synthesis as well as inhibiting root growth in Norwegian spruce.[18] Studies indicated that root damage induced by mercury causes a decrease in water and nutrient uptake by the root and subsequent lower supply to the needles which results in lower rates of gas exchange. Mercury is taken up from the air by leaves/needles and airborne mercury can create phytotoxins.[19]

The impact of mercury on soil microorganisms and invertebrates, important to root health, also requires further research but high mercury levels may reduce microbial respiration.

Impact on water

Mercury can convert to methylmercury more readily in water and as a result has significant negative impacts on water animals. Fish eating waterfowl, such as loons, are impacted primarily by the disruption of their reproductive systems resulting in declining populations and weaker offspring. As mercury levels in loons increase, they become lethargic and there is a reduction in interactive behavior. Back-riding may stop and preening may increase. Mortality increases.[20,21]

Mammals, such as mink and otter that eat large quantities of fish, tend to suffer more neurological impacts affecting behaviour. Carnivorous fish such as bass, walleye, and pike can bioaccumulate up to 1 million times the level of methylmercury as the level in the surrounding water. The bioaccumulation of methylmercury in fish is the reason for the limits on eating fish detailed in the provincial Guide to Eating Ontario Sport Fish. Limits to eating larger fish are provided in this publication to warn people about mercury levels.

Emission standards

Between 1990 and 1995, Canadian anthropogenic mercury emissions dropped from approximately 35 to 11 tonnes primarily as a result of process improvements in the base metal mining and smelting industry. In 1995, this industry was the largest source of mercury into the atmosphere, contributing approximately 40% of total emissions. From 1995 to 2003, Canadian anthropogenic mercury emissions dropped to a total of just under 7 tonnes. Three sectors, electricity generation, non-ferrous mining & smelting and incineration were responsible for 71% of mercury emissions into the atmosphere, accounting for 35%, 19% and 17% of Canadian emissions respectively.[22]

The Canada-wide Standards development process reviewed the nature of the mercury issue in Canada, and concluded that two distinctive source categories were amenable to further actions, namely life-cycle management of products containing mercury to minimize releases, and reduction or minimization actions for major point source emissions of incidental mercury. The Federal Government has developed specific emission standards on an

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[18] Godbold, Douglas *Mercury in Forest Ecosystems; Risk and Research Needs,* in Mercury Pollution: Integration and Synthesis by by Carl J. Watras, John W. Huckabee - Science - 1994 – pg. 295.

[19] Mishra Anita and Choudhuri M. A. *Monitoring of Phytotoxicity of Lead and Mercury from Germination and Early Seedling Growth Indices in Two Rice Cultivars* Water, Air, & Soil Pollution Volume 114, Numbers 3-4 / September, 1999. http://www.springerlink.com/content/w22p72u125v5p4r1

[20] Phinney, L., Waugh, D., Tordon, R., Air Quality Services Meteorological Services of Canada, *Environmental Impacts of Air Pollution.* http://www.gov.ns.ca/nse/air/docs/Phinney-EnvironmentalImpacts.pdf

[21] A. M. Scheuhammer, Environment Canada, Canadian Wildlife Service, 100 Gamelin Blvd.,Hull, Quebec K1A 0H3 http://www.eman-rese.ca/eman/reports/publications/mercury95/part1.html

[22] Environment Canada, Green Lane, *Mercury and the Environment* http://www.ec.gc.ca/MERCURY/SM/EN/sm-cr.cfm?SELECT=SM

industry basis. These emission standards are based on the belief that reduced deposition will contribute, in time, to reduced impacts.[23]

What you can do[24]

1. Use less energy - Coal-fired electricity generation represents one of the largest sources of mercury emissions to the Canadian environment. By decreasing the amount of electricity we use, we can reduce mercury emissions from this sector. Hydro-electric dams also increase mercury levels in the water reservoirs that result from their construction. Less demand for energy means fewer dams built.
2. Reduce your use of mercury-containing products - Some commonly used consumer products contain mercury. Although the mercury content has been reduced for some products, such as fluorescent light bulbs, consumers often have the choice to avoid purchasing mercury-containing products in favour of mercury-free alternatives. Although incandescent bulbs are a mercury-free alternative for lighting, they are far less energy efficient than fluorescent lamps. Using fluorescent lamps, which contain small amounts of mercury, can reduce energy consumption and can decrease overall mercury emissions as long as they are recycled properly.

OTHER POLLUTANTS

Hazardous Air Pollutants – HAPs such as pesticides, dioxins, and heavy metals bioaccumulate and are persistent in nature. They are often the bi-product of industrial or manufacturing operations with a point source outside Muskoka. Their impact both on people and animals can be as a carcinogen, mutagen, teratogen (an agent that can disturb the development of an embryo), or endocrine disruptor. Often time they are transported over large distances attached to fine particulate matter. The result of many of these pollutants is loss of ecosystem health and biodiversity.

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[23] Canadian Council of Ministers of the Environment, *Canada-wide Standards for Mercury.* June 2000. http://www.ccme.ca/assets/pdf/mercury_emis_std_e1.pdf
[24] Environment Canada, *Mercury and the Environment,* http://www.ec.gc.ca/MERCURY/EN/do.cfm