A National Acid Rain Science Plan

Overview

The Acid Rain Task Group (ARTG) has developed a **National Acid Rain Science Plan** (Science Plan) as an accompaniment and in support of the ARTG *Long-term Strategic Plan* to Implement *The Strategy*.

Background

The ARTG reports to the Canadian Council of Ministers of the Environment on the progress made in implementing the commitments laid out in the *Canada-Wide Acid Rain Strategy for Post-2000* (*The Strategy*). Signed in 1998 by all 26 federal / provincial / territorial Energy and Environment Ministers, *The Strategy* is Canada's current policy instrument for addressing the acid rain problem in eastern Canada and preventing one in western and northern Canada. *The Strategy's* main goal is to ensure that critical loads are met across the country.

As a follow up to a recent 5-year review[1] of *The Strategy*, the ARTG has prepared a *Long-Term Strategic Plan*[2] to ensure Canada achieves the primary goal of *The Strategy,* which is 'to meet critical loads for acid deposition across Canada'. *The Strategy* calls for a specific set of actions most of which are dependent on two Key Features: 'Continuing science' and understanding 'The role of nitrogen'. In order to address these features and to provide the information necessary to implement the actions identified in the *Long-Term Strategic Plan*, the ARTG has prepared a Science Plan outlining research and monitoring activities that should be carried out over the next five years by federal/territorial/provincial governments in collaboration with industry, academia and non-government environmental organizations in order to monitor the health of the environment and the effectiveness of Canadian and U.S. emission control programs.

The Science Plan is the outcome of the clear guidance the ARTG has received in the last two years regarding research and monitoring activities needed to fill gaps in our understanding of the acid deposition problem. Such guidance has come from the *2004 Canadian Acid Deposition Assessment*[3]; two multi-stakeholder workshops hosted by the Acid Rain Task Group in 2004 and 2005: "Taking Stock and Next Steps on Acid Rain" and "Developing Critical Loads for Sulphur And Nitrogen"[4], and the completion of the report *Calculating Critical Loads of Acid Deposition for Forest Soils in Manitoba and Saskatchewan*"[5]. The ARTG was also able to identify gaps based on an inventory it collated of currently ongoing activities under existing programs across Canada.

Over the last several months the ARTG has compiled, prioritized, and reviewed all recommendations with the expert assistance of scientists from governments, academia and industry.

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[1] CCME, 2006. *Five Year Review of the Canada-wide Acid Rain Strategy for Post-2000.*

[2] *The ARTG Long-term Strategic Plan to Implement The Strategy* (draft).

[3] Environment Canada, 2005. *The 2004 Canadian Acid Deposition Science Assessment,* Ottawa.

[4] Acid Rain Task Group Workshops: Taking Stock and Next Steps, February 23-24, 2005, Gatineau, QC; Development of Critical Loads for Sulphur and Nitrogen, November 6-7, 2005, Calgary, AB.

[5] Aherne, J. & Watmough, S., 2006. *Calculating Critical Loads of Acid Deposition for Forest Soils in Manitoba and Saskatchewan - Final Report: Data Sources, Critical Load, Exceedance and Limitations.*

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The Science Plan

Goal

One of the specific actions set out at the time of the signing of *The Strategy* was for Environment Canada, in cooperation with provincial/territorial governments, to review the adequacy of existing science programs and provide recommendations. In the resulting report - *1999 Review of Acid Rain Science Programs in Canada*[6] - it was recommended that the goal of acid rain science programs should be **"to verify the effectiveness of emission control programs in reducing acid rain damage to lakes and forests by assessing the degree of environmental improvement achieved and detecting new problem areas"**; thus, the ARTG agreed such should be the goal of the enclosed Science Plan.

Priorities

Acid deposition continues to affect ecosystems in eastern Canada, where despite Canada's progress in reducing SO_2 emissions in the last few decades, ecosystems are still exposed to deposition levels in exceedance of their natural buffering capacity. While improvements have been observed in the chemical status of some lakes, a return to sustainable acidity levels and the recovery of biological species to a healthy status have not yet been observed. In addition, more evidence suggests long-term acidification of soils has severely depleted nutrients essential for trees in turn threatening the health and growth of Canada's forests and delaying the recovery of watershed surface waters. Under current deposition scenarios it will take several decades for these nutrients to become replenished, not accounting for the potential impact of nitrogen acidification should current nitrogen deposition levels continue into the future.

Meanwhile, large areas of Canada characterized by bedrock with low buffering capacity (~1/3 of the West and 2/3 of the North) are not being adequately studied and monitored. In light of rising acidifying emissions in western Canada, these areas may be at risk of damage; however, without adequate information it is very difficult to assess the current and long-term level of risk. Based on the above current knowledge, the recommendations in the Science Plan focus on addressing the following high priority needs:

- Improve the spatial coverage and representativeness of deposition, aquatic and terrestrial chemical and biological information across Canada, with an emphasis on sensitive terrain by expanding science efforts to the west and at minimum maintaining current efforts in the east.
- Continue and enhance a focus on the mechanisms and rates of ecosystem impacts and ecosystem recovery concerning acidification and related stressors.

The activities listed in the plan will greatly contribute to more accurate determinations of critical loads across Canada, which will provide the means to assess the risk of ecosystems to acid deposition damage and evaluate the effectiveness of current and future emission reductions. The activities are organized into different areas: wet and dry deposition, aquatic chemistry and biota, terrestrial ecosystems, critical loads, and human health.

Implementation

Scientific Steering Committee

It is important to note strong dependencies exist among the various areas and activities on the Science Plan; therefore, the work will be conducted more effectively in a systematic and integrated manner. The ARTG recommends establishing a Scientific Steering Committee to develop a more detailed work plan including an identification of who is best suited to conduct the work, and to coordinate the implementation of these activities.

[6] Environment Canada, 2000. *The 1999 Review of Acid Rain Science Programs in Canada.*

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NATIONAL ACID RAIN SCIENCE PLAN

NEEDS & RECOMMENDATIONS

WET AND DRY DEPOSITION

Measured total deposition data as well as models are needed to describe the composition, spatial distribution and changes over time of deposition in order to determine how, where and to what extent acid levels have responded to changing emissions; as well as to support critical load and exceedance determination.

SCIENTIFIC CASE STUDIES	MONITORING	MODELLING APPLICATIONS
• Continously improve methods to map S, N, base cation and chloride total deposition. • Evaluate model predictions of dry deposition with supplemental S and N dry deposition data. • Develop an inventory for emissions of base cations and chloride to add to existing deposition models. • Investigate fog deposition at high elevation and coastal sites. • Measure organonitrates in wet and dry deposition to assess their contribution to N total deposition. • Investigate the influence of changes in climate on acid deposition levels.	• **Maintain current deposition monitoring sites.** • **Establish new appropriate monitoring sites in northern Manitoba (2), northern Saskatchewan (2), in BC (1), in southern AB (1), the Territories (3), northern QC (1), Cape Breton (1), and NL to measure S, N and base cation wet and dry deposition as needed (order of priority needs to be determined) and collocate with the ecosystem effects research sites as possible.** • Establish passive monitoring sites to scope out current monitoring needs. • Supplement existing dry deposition monitoring network by adding 3 new filter pack sites and passive samplers, and by augmenting monitoring of SO_2 and N species (NH_3, NO_2) at existing sites across Canada as needed. • Increase the number of wet deposition monitoring sites in ON and NL in light of the shutting down of provincial networks. • Develop and apply a method for improving the estimation of deposition across Canada by integrating measurement data and modelling results.	• **Develop critical load exceedance maps based on current/future projections of acid deposition across Canada for most up to date critical loads.** • **Run modelling scenarios (developed by the ARTG) for current and proposed /future emission controls, for use across all ecosystems; include the evaluation of American measures, e.g., U.S. EPA Clean Air (Act) Program (Title IV Acid Deposition Control, CAIR, and the new Canadian controls on base-metal smelters)** • **Compare and evaluate wet and dry deposition outputs from ADOM, RELAD, CMAQ and AURAMS.** • **Calculate and compare critical load exceedances using deposition output from various models.** • **Expand atmospheric modelling abilities to western and northern Canada in order to determine spatial gaps in deposition data and identify hot spots and potential locations for new deposition monitoring sites (use at least 1 degree by 1 degree of resolution).** • Improve accuracy of model predictions of S and N deposition (i.e. more accurate emissions data, source apportionment at a finer resolution, fine resolution meteorological data). • Add base cation deposition into existing models.

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NATIONAL ACID RAIN SCIENCE PLAN

NEEDS & RECOMMENDATIONS

AQUATIC CHEMISTRY

Aquatic chemistry data is needed to determine how, where and to what extent aquatic ecosystems are being acidified and/or recovering from acidification over time, as well as to support critical load determination for surface waters.

SCIENTIFIC CASE STUDIES	MONITORING	MODELLING APPLICATIONS
• **Design and conduct a statistically-based regional lake water chemistry survey in order to ascertain acid sensitivity levels at selected sites across Canada where critical loads are assessed to be low or exceeded, and to identify spatial gaps in the existing monitoring network.** • Investigate the interaction of lake acidification with other stressors (e.g. climate change, UV, mercury and other contaminants, base cation depletion, food web and population dynamics disruptions, land use change and management practices, invasive species, etc.) and its influence on the rate and mechanisms of aquatic ecosystem acidification and recovery.	• **Maintain current level of freshwater regional surveys and monitoring networks in areas where CLs are, have been, or may be exceeded.** • **Expand regional networks based on where survey results indicate a chemical sensitivity or acidification changes, and/or where modelling output indicates that critical loads are being exceeded or have the potential to be exceeded.** • Enhance the collection of catchment parameters at regional monitoring sites required for the application of dynamic models (e.g. MAGIC).	• See CRITICAL LOADS section

NATIONAL ACID RAIN SCIENCE PLAN

NEEDS & RECOMMENDATIONS

AQUATIC BIOTA

Information on aquatic biota is needed to evaluate how, where and to what extent changes in surface water and watershed soil chemistry resulting from deposition changes are affecting biodiversity, habitat utilization, and ecosystem function and productivity. Also, information is needed to understand and track ecosystem recovery, evaluate the effectiveness of control measures in protecting fish and wildlife, and assessing economic risk.

SCIENTIFIC CASE STUDIES	MONITORING	MODELLING APPLICATIONS
• **Review existing bio-monitoring programs using the hierarchical monitoring framework as a guide and determine what kind of improvements are required.** • Based upon review, conduct biotic surveys at the same locations where aquatic chemistry and soil sampling are occurring in order to estimate regional status, with emphasis in areas where critical loads are or may be exceeded. • Evaluate the differences in ecosystem responses during lake acidification compared to those occurring during recovery (pathways and endpoints may, and in some cases will, differ). • Investigate the interaction of acidification effects on biota with other ecosystem stressors (e.g. climate change, UV, mercury and other contaminants, base cation depletion, food web and population dynamics disruptions, land use change and management practices, invasive species, etc.) and its influence on the rate and mechanisms of acidification and biological recovery. . • Identify key biological recovery indicator species.	• Review and realign regional biomonitoring networks to provide representative and consistent coverage of areas in Canada where CLs are or may be exceeded.	• Maintain and improve integrated assessment models (e.g. IAM) and their application to predict chemical and biological responses to various emission reduction scenarios. • Link dynamic MAGIC model to biological recovery models. • Account for interactions of acidification with other stressors in existing models.

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NATIONAL ACID RAIN SCIENCE PLAN

NEEDS & RECOMMENDATIONS

TERRESTRIAL ECOSYSTEM

Information on soil chemistry and terrestrial biota is needed to determine how, where and to what extent changes in soil chemistry resulting from deposition changes are affecting forest soil fertility and forest health and productivity and to determine cumulative impacts (for this need to determine baseline sensitivity), to evaluate the socio-economic costs of impacts to Canadian forests, to assess the role of nitrogen in acidification, and to support critical load determination.

SCIENTIFIC CASE STUDIES	MONITORING[7]	MODELLING APPL.
• **Design and conduct a statistically-based regional soil chemistry survey, guided by aquatic chemistry data, to ascertain acid sensitivity levels at selected sites across Canada where critical loads are determined to be low or exceeded, and to identify spatial gaps in the existing monitoring efforts. Include sampling of 'pristine' (no registered exceedances) upland forest sites to serve as controls (benchmarking).** Conduct the following work to better understand the relationship between acid deposition and forest health: • Obtain further data on the functioning of forest ecosystems (i.e. nitrogen pathways and dynamics, N saturation, forest stability, specific impacts on trees, and nutrient cycling within forest vegetation species and species variability), and use existing data to develop models to evaluate ecosystem function. • Study processes governing transformation and export of S and N and depletion and replenishment of base cations (determine soil pool size) from terrestrial catchments (uplands to wet areas to wetlands) into surface waters in context of decreasing S and N emissions. • Evaluate methodologies and improve/validate estimates of weathering rates considering spatially variable conditions (priority is to obtain omore accurate soil depth measurements). • Conduct catchment based studies to understand the linkage between ambient N concentrations, subsequent deposition, nitrification and impacts, and links to eutrophication. • Conduct field studies to develop and verify indicators of acid deposition stress on forest health in areas where the CLs are exceeded. Can then develop dose-response functions for economic impact assessment. • Conduct field studies to relate CL exceedances to potential impacts on biota due to altered terrestrial habitat and food quality and quantity.	• **Examine information available from current vegetation and soil chemistry monitoring efforts and investigate the possibility of setting up a national network of sites. This may include setting up a soil parameter database.** • **Based on existing and new observations (survey) expand soil chemistry and forest health monitoring efforts to sensitive or potentially sensitive areas.** • **Develop a standardized methodology for monitoring the adverse effects of acid rain (and other pollutants) on forest ecosystems across Canada.** • **Continue to monitor N dynamics in soil solution at two of the whole ecosystem sites (at least) to assess/detect potential N saturation.** • Collect information on organic soils at locations where past efforts have been focused. • Monitor aluminum mobilization from forest soils.	• See CRITICAL LOADS section

[7] Monitoring networks needed to collect data on parameters required to calculate critical loads and exceedances for terrestrial ecosystems in Canada (weathering rates, base cation deposition, soil base cation content, Ca and Al soil solution concentrations, soil depth and rooting zone, nutrient uptake and pools., etc).

Note: Bold text identifies activities of highest priority.

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NATIONAL ACID RAIN SCIENCE PLAN

NEEDS & RECOMMENDATIONS

CRITICAL LOADS

Critical load and exceedance maps indicate areas that are sensitive to acid deposition and where damage may be occurring or will potentially occur, and also provide the scientific basis for evaluating and determining emission reductions necessary to protect sensitive ecosystems. CL and exceedance estimates evolve over time as new spatially-representative environmental monitoring data (i.e. deposition, aquatic and soil chemistry) is obtained and methodologies are improved; thus, the work in the above section will contribute toward more accurate CL and exceedance estimates.

SCIENTIFIC CASE STUDIES	MONITORING	MODELLING APPLICATIONS
• **Extend CL analysis and mapping for aquatic and terrestrial ecosystems to remaining provinces /territories in western and northern Canada using available data.** • **Refine and update critical load maps across Canada as additional lake, soil and deposition chemistry information becomes available.** • **Validate and improve regional critical load mapping using available site-specific (plot) soil or lake data.** • **Develop more comprehensive and higher resolution soils and surface waters maps (this requires detailed soil and water data and a tremendous mapping effort).** • Develop criteria to aid in the selection of appropriate end-point indicators for specific regions across Canada. • Obtain better runoff estimates • Determine spatially variable chemical thresholds for all parameters. • Develop a better understanding of critical chemical limits for aquatic CL determinations (Acid Neutralizing Capacity (ANC)) and for upland forest soils (BC:Al) as well as nitrogen parameters. • Reassess nitrogen parameter values and critical limits for future Canada-wide critical load determinations • Check to determine if the chemical thresholds for setting the CLs for upland forest soils are protective/ applicable to that province (SK). • Investigate the utility of a soil point approach as an alternative to soil maps (difficult to produce) to estimate CLs and exceedance for upland forest soils. • Produce nutrient uptake maps for western and eastern Canada. • Improve models to consider nitrogen, forestry activities and dynamic effects. • Determine the confidence interval or uncertainty level for different critical load estimates. • Revise methodologies used to combine and map terrestrial and aquatic critical loads.	• See above sections on WET & DRY DEPOSITION, AQUATIC CHEMISTRY, and TERRESTRIAL ECOSYSTEMS. • Improve documentation around chemical limits.	• Review existing forest soil chemistry models (steady-state and dynamic) to ensure relevant components are included such as spatially variable thresholds and changes in soil from forest harvesting and fire. • Include spatially variable parameter/threshold values in aquatic mass-balance models, including base cations and DOC. • Handle N more comprehensively /realistically in calculations • Conduct scenario analyses for forest harvesting and fire to better quantify their impact on forest ecosystems for input into CL models • Develop a framework that specifies nationally consistent approaches and parameters for developing critical loads across Canada. • Expand analysis of time-dependent CLs (dynamic modelling) to include a prediction of when the critical loads will be reached under various acid and base emission scenarios. • Develop protocols and guidelines for estimating critical loads for terrestrial ecosystems other than upland forest soils e.g., organic soils and lowlands. CLs restricted to semi natural ecosystems. • Examine difficulties associated with developing critical loads for high altitude areas.

Note: Bold text identifies activities of highest priority.

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NATIONAL ACID RAIN SCIENCE AND MONITORING PLAN		
NEEDS & RECOMMENDATIONS		
HUMAN HEALTH		
Information on the impact of acid aerosols on human health are being investigated and assessed under other national air quality (particulate matter and ground-level ozone) science programs. Activities in this section are aimed to explore other aspects of acid deposition that may impact human health and that do not overlap with other existing programs.		
SCIENTIFIC CASE STUDIES	MONITORING	MODELLING APPLICATIONS
• Investigate and develop the linkages between acidification effects (e.g. aluminum mobilisation, cadmium, mercury and fish consumption, copper in lead pipes) and human health particularly on First Nation communities. • Upon completion of the 2008 Canadian Smog Science Assessment (co-led by Environment Canada and Health Canada), review the gaps and recommendations for future research as they relate to the impacts of PM and aerosol acidity on human health.		• Link reductions in acidifying emissions to a quantifiable measure of human health impacts

COMMON ACTIVITIES ACROSS CATEGORIES

- **Integrate research and monitoring among the topic areas of emissions, atmospheric deposition, aquatic chemistry and biology, terrestrial chemical and biology, socio-economics and human health.**
- **Define and implement a hierarchical framework and program of integrated research and monitoring that enables effective ecosystem assessment, reporting and related policy development.**
- **Set up a trans-Canada network of whole ecosystem research and monitoring sites/regions with sites currently operated by governments or universities (e.g. five federally operated sites in eastern Canada; ELA, Turkey Lakes Watershed, Lac Laflamme, Kejimkujik, and Dorset located in eastern Canada) and expand to cover sensitive areas.**
- Establish impacts and generate dose-response functions of acidification on aquatic systems, forest growth (rates of tree growth, changes in canopy density) and productivity (quality of timber), recreational fishing, bird watching, wildlife consumption, and biodiversity (survival, health and frequency of species) to facilitate socio-economic assessments.
- Refine estimates of functional relationships between acidification and ecosystem functions and services.
- Set up a data focal centre to hold and coordinate the development and update of critical loads and exceedances.