S&E SCIENCE AND THE ENVIRONMENT BULLETIN S&E
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SANDPIPERS FEELING SQUEEZE IN STRAIT

Land along the southern shores of British Columbia's Strait of Georgia is at a premium — not only to developers eager to capitalize on access to ocean ports, fertile farmland and stunning views, but also to millions of migrating birds that pause to feed en route to and from their breeding grounds up North. With the human population of the area growing rapidly — and now topping three million — these birds are being caught in a potentially devastating squeeze play.

One of the area's smallest visitors is the Western Sandpiper, a sparrow-sized shorebird that nests in Alaska and migrates primarily along the Pacific flyway to extensive coastal wintering grounds between the southern United States and Peru. Biologists have long known that "peeps" — the generic term for small shorebirds — feed on bite-sized invertebrates in and on intertidal mudflats. One such mudflat is Roberts Bank, located on the Fraser River delta just north of the international border. The Bank teems with crustaceans, molluscs and other edibles, providing prey for a wide variety of birds, including millions of Western Sandpipers.

A Western Sandpiper

What was not known, until recently, is that there are other ways Western Sandpipers feed, and what they feed upon is more precisely tuned to particular conditions on the Bank than was originally thought. Scientists at Environment Canada's Canadian Wildlife Service and the Université de Nantes in France discovered, through the use of scanning electron microscopy, that the bird's bill and tongue contain structures that enable the bird to detect and slurp up "biofilm" — a micro-thin layer on surface mud that contains bacteria, algae, small crustaceans and their mucus excretions. This feeding method likely uses mucus on the bird's tongue to adhere to mucus in the mud, and the tip of its bill to sheer off gobs of the nutritious goo. Although other species of birds sift through mud to get food, it had never been appreciated that some might actually ingest this material itself. Other field observations and experiments involving researchers at the University of British Columbia and Simon Fraser University have shown that Western Sandpipers also find large worms in the mud by homing in on the pressure waves they produce.

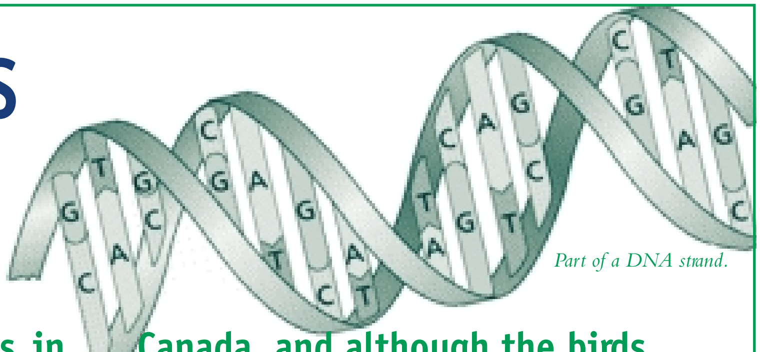
Like most of the shoreline along the Strait of Georgia, Roberts Bank has seen significant reduction, disruption and pollution from coastal development over the past four decades. Yet, despite the fact that it is an internationally important bird habitat, the Bank is currently under no legal protection as a wildlife area. It is home to giant ferry and port terminals that service thousands of ships per year — each vessel carrying fuel, oil and other products that could have devastating impacts if they were spilled. As a surface feeder, the Western Sandpiper is particularly susceptible to heavy metals and other pollutants from industrial sources.

The Bank has also been affected by the construction of two large human-made causeways that support the ferry and port terminals. These have blocked the natural flow of nutrients from the Fraser River onto the Bank, and thereby altered the invertebrate communities and disrupted the biofilm. Hence, mudflat feeders, such as the Western Sandpiper, seem to have been pushed into a much-reduced area. The future of the Bank is further threatened by the fact that 700 hectares of agricultural land along its shore are now the subject of development proposals that could have significant environmental impacts on the mudflats.

Teams of biologists from Environment Canada and local universities are continuing to study the Western Sandpiper and its habits in an effort to learn more about conserving the species in the Fraser Delta, and to ensure that steps are taken to protect its vital habitat — before human development squeezes it out. S&E

INSIDE

GENETIC TECHNIQUES AND WILDLIFE MANAGEMENT



Part of a DNA strand.

A shipment of juvenile parrots arrives in Canada, and although the birds are too young to be identified by sight, genetic material from a feather reveals that they are endangered Amazons that have been smuggled in. Blood from Eastern Massasauga Rattlesnakes shows that the genetic make-up of populations in close proximity is more highly differentiated than was ever imagined — posing serious implications for recovery plans to relocate members of the threatened species to new slithering grounds.

Analyzing and comparing the genetic make-up of plants and animals not only improves assessments made using traditional methods, but also yields information that is otherwise inaccessible. Once too labour-intensive and expensive for regular use, molecular techniques have been made more widely available in recent years due to refinements in laboratory techniques, improvements in computer power, and lower equipment costs. Environment Canada is working closely with university labs and other partners to apply genetic techniques to wildlife conservation — in such areas as population monitoring and conservation, studies of the impact of toxic contaminants, and the investigation and prosecution of wildlife crimes.

Deoxyribonucleic acid (DNA) is the principal constituent of genes, and is found in the cells of living organisms — including components of blood, skin, hair, nails, feathers and eggshells. DNA molecules are made up of a linear sequence of compounds called nucleotides, and form a long, continuous strand inside a structure called a chromosome. The unique sequence of the nucleotides in a chromosome determines the hereditary characteristics of an individual — from its species and sex, to traits such as eye colour. Each gene occupies a particular location on the DNA strand, making it possible to compare the same gene in a number of different samples.

Different areas of DNA accumulate mutations at different rates. Some genes are so basic to the functioning of the individual that most changes or mutations will affect survival and will not be passed on to the next generation. Other genes for more superficial traits can accumulate mutations more quickly, and some areas of DNA are "non-coding" and can have very rapid rates of change. Differences in mutation rate are like the hands of a clock — each is useful for different time scales. Differences in mutation rate can allow comparisons of very ancient divisions, all the way up to the very recent divisions between parents and offspring.

Many genetic techniques involve a process in which short segments of a DNA strand are replicated to produce a sufficient quantity of material for analysis. These segments can then be examined for differences in size between individuals or for differences in the actual nucleotide sequence of the segments. In contrast, other techniques cut DNA into segments using enzymes, and certain of these segments are radioactively tagged to create a visual pattern on X-ray film. DNA fingerprinting is the most popularly known of these techniques. The fingerprint of one individual can be compared to other fingerprints to determine if two or more samples originated from the same individual, or to identify close relatives, such as parents and siblings.

In the area of population monitoring and conservation, genetic techniques are used to link individuals found in separate areas, determine migration patterns, establish the geographic bounds of populations, estimate gene flow among populations, profile the genetic diversity and sexual make-up of populations, and manage captive breeding programs and translocation and reintroduction efforts. Genetic information can also be used to determine if small populations carry a unique component of overall biological diversity.

Analyzing DNA is particularly useful in studying organisms that are rarely encountered by humans, including snakes, frogs, and some species of birds. A recent genetic survey of Spotted Frog populations in the Pacific northwest revealed the existence of two distinct species where one had originally been supposed. The name Oregon Spotted Frog now refers to three isolated populations in the Fraser River lowlands of British Columbia and 10 in the United States. About 79 per cent of this species has been lost across its range, and Canadian populations number fewer than 300 individuals.

Genetics are equally useful in discerning species and subspecies with similar external characteristics.

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For example, there are as many as 100 subspecies of Canada Geese — many of which cannot be reliably distinguished by sight. Although the Atlantic population recently underwent a 75-per-cent decline, the trend was initially camouflaged by an exponential increase in the number of birds on common wintering grounds. Environment Canada is currently collaborating with Michigan State University to obtain genetic profiles of all the subspecies in Ontario, a project that will take up to four years to complete. This will enable biologists to use wings and tailfeathers provided by hunters to monitor individual populations more closely, and adjust bag limits as required.

Recent genetic studies of the endangered Eastern Harlequin Duck showed that birds formerly thought to be members of a single population are actually from two distinct populations that breed and winter at different sites, and do not naturally mix. DNA was also used to determine that the Dolly Varden and the Bull Trout are distinct biological species — information that was instrumental in identifying the watersheds used by each and in planning the restoration of fish habitat in northern British Columbia. Genetic techniques also recently proved that the small population of wolves in central Ontario's Algonquin Provincial Park are not related to the Grey Wolf — as has long been thought — but are actually closely related, if not identical, to the highly endangered Red Wolf. All of these findings have serious implications for the conservation of biological diversity.

Genetic techniques are also used to test for genetic damage or the altered regulation of genes caused by contaminants such as pesticides — effects that might otherwise be invisible. Some contaminants, called endocrine disrupters, induce the expression of genes in the inappropriate sex. Environment Canada's National Wildlife Research Centre has devised a way to identify such substances by measuring their ability to artificially induce the expression of a gene linked to a particular sex — in this case, the egg protein vitellagonin, normally found only in female birds. Another study is using DNA analysis to determine the roles of polycyclic aromatic hydrocarbons, polychlorinated biphenyls and heavy metals in the creation of heritable mutations in Herring Gulls nesting near steel industries.

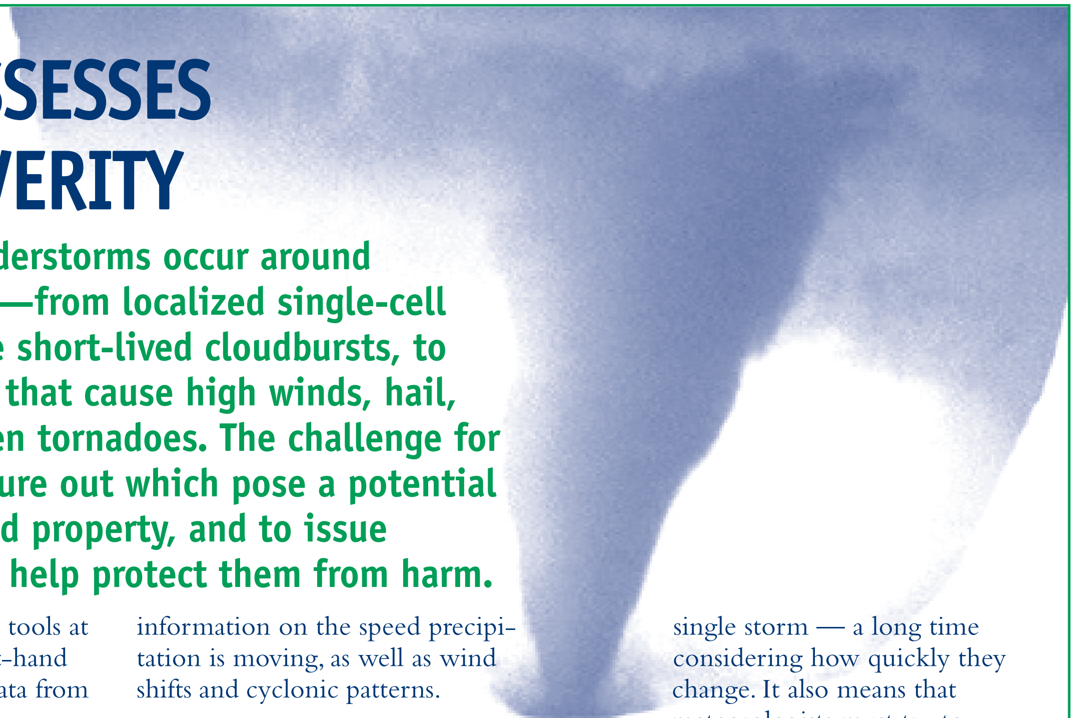
Wildlife enforcement officials in Environment Canada also use genetic markers to identify species from forensic material, link individuals to a geographic area, and determine parentage and sex. A major impediment to identifying species of origin, however, is the lack of a reliable DNA database to provide baseline references. To help build up such data, biologists are working with scientists at Trent University in Peterborough, Ontario, to develop DNA markers for species of ducks and other waterfowl. The markers have been used to detect illegal game in restaurant food — even in cases where quantities of the game are less than one per cent of a meat mixture. DNA analysis is also used to investigate cases where illegal hunting practices are suspected, but the bird carcasses have been plucked and decapitated, making identification otherwise impossible.

DNA analysis is also used to ensure that foods, such as caviar, do not contain products derived from plants or animals that are protected under the Convention on International Trade in Endangered Species.

Another major project is a collaboration with the United States Fish and Wildlife Service Forensic Laboratory in Ashland, Oregon, to identify sturgeon species from caviar samples. The Ashland lab has already established species-specific DNA sequences for most of the 23 species of sturgeon, to identify cases where eggs from Short-Nosed Sturgeon and European Sturgeon — both protected under the Convention on International Trade in Endangered Species — have been illegally imported, and to ensure that the necessary permits have been obtained for caviar from other species. In a recent case, a DNA analysis revealed that a shipment of "sturgeon" caviar was actually a mixture of herring and other fish eggs, which had been coloured and reshaped.

To prevent illegal trade in Gyrfalcons and Peregrine Falcons, Environment Canada is collaborating with Canadian breeders to establish a DNA bank of genetic profiles of specimens in captivity. This will enable enforcement officers to tell if chicks in trade are actually the offspring of registered breeding pairs, or if they have been taken illegally from the wild.

Although most of Environment Canada's genetic projects are still at the pilot stage, the successful use of DNA analysis for a wide range of purposes related to wildlife management prompted the Department's Canadian Wildlife Service to conduct a complete review of current and potential applications. The review recommends that, while genetic techniques are still fairly expensive and labour-intensive compared to traditional methods of obtaining species information, there are many instances in which their use would greatly improve wildlife management efforts. It also encourages the pursuit of more partnerships with university labs and other facilities to build up the baseline genetic data that wildlife enforcement officers need to identify and prosecute people involved in the illegal hunting or trade of species at risk. S&E

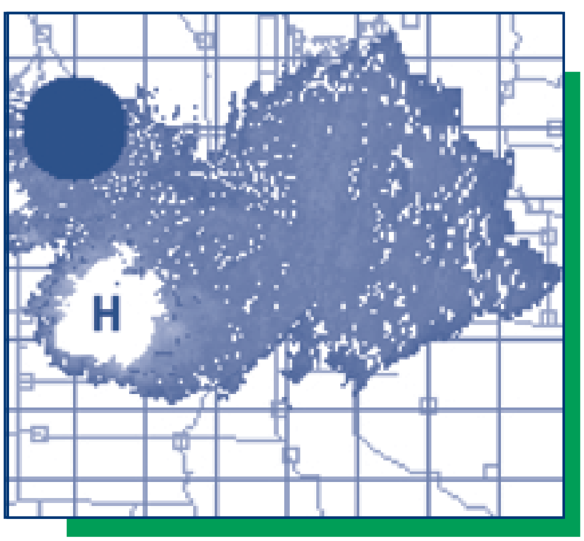


SYSTEM ASSESSES STORM SEVERITY

About 44 000 thunderstorms occur around the world each day —from localized single-cell storms that produce short-lived cloudbursts, to powerful supercells that cause high winds, hail, flash floods and even tornadoes. The challenge for forecasters is to figure out which pose a potential hazard to people and property, and to issue warnings in time to help protect them from harm.

Until fairly recently, the only tools at forecasters' disposal were first-hand reports from observers and data from weather radars. Unfortunately, because observations are usually reported when storms are almost overhead, they provide less lead time for warnings. Conventional radars, on the other hand, can send microwave signals up to 325 kilometres and measure the time it takes for them to bounce back off rain, snow or ice — thereby enabling meteorologists to determine the type, amount and rate of precipitation in a storm. New Doppler radars provide additional information on the speed precipitation is moving, as well as wind shifts and cyclonic patterns.

Although the curve of the earth's surface makes it impossible for radars to detect low-altitude storms at their furthest points of reach, their data reveal much about the internal structure of storms less than 150 kilometres away. The unique air circulation and precipitation patterns in a storm indicate whether or not it is a supercell — an immensely powerful kind of storm that is responsible for most of our severe weather, including tornadoes.



RDSS output on a tornadic supercell that occurred southwest of Winnipeg on July 24, 2000. The circle in the upper left-hand corner marks the location of the radar, and the shaded area indicates the extent of the storm — with the white area around the "H" identified as the most dangerous, and the "H" as an area where large hail is occurring.

To assess the strength of the storm's updraft — and therefore its supercell potential — radar operators have traditionally used the Lemon Technique, sending beams into the storm to take readings of the rainy downdraft from a variety of angles. With these readings, and some complex calculations, they can visualize the downdraft in three dimensions and infer the strength of the updraft. The problem with this technique is that it takes about 15 minutes to assess a single storm — a long time considering how quickly they change. It also means that meteorologists must try to guess which storms, out of a possible choice of dozens, to focus their efforts on.

To speed the process, Environment Canada meteorologists in Winnipeg and experts from Infomagnetics Technologies devised a computer software package, called the Radar Decision Support System (RDSS). Using conventional weather radar data, the state-of-the-art system analyzes the internal structure of every storm in the area and flags those with supercell characteristics as green, yellow or red (most severe) — all in less than five minutes. In addition to tracking the storms and indicating if they're getting stronger or weaker, it allows forecasters to click on them to see their characteristics in more detail — a feature that has also proven invaluable for post-storm studies.

Since the RDSS was first instituted in Manitoba in 1994, it has undergone numerous improvements, including the addition of step-by-step computational procedures, or algorithms, for identifying the formation of hail and strong winds.

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The Prairie Storm Prediction Centre now uses the system to monitor all the weather radars in Manitoba, Saskatchewan and Alberta simultaneously, and has seen a significant improvement in the lead time for issuing warnings. One of the many situations in which the RDSS has proven useful was in 1996, when hail as big as baseballs rained down on Winnipeg from a supercell storm that materialized out of clear air in about half an hour. At the first sign of the storm, the RDSS flagged it red, prompting the forecaster to issue a hail warning before any observational reports of severe weather were made.

A presentation on the system attracted great interest from countries participating in an international meteorology workshop held in Sydney, Australia, after the 2000 Olympics. As part of Canada's National Radar Project, Environment Canada is currently developing a new Unified Radar Processor that will combine RDSS and Doppler data to create an even more effective severe weather assessment system. The new processor may be operational as early as 2002. Over the long term, Environment Canada's scientists also plan to develop and implement new algorithms to detect severe winter weather, such as heavy snowstorms, blizzards and freezing rain. S&E

Anatomy of a Storm

The churning cauldron of dark clouds we see during a thunderstorm is actually a complex and continously evolving three-dimensional structure. This structure is made up of one or more self-contained systems or "cells" — each with an organized pattern of rising and sinking air that moves moisture between the upper and lower atmosphere, and affects the wind flow around it.

In Canada, most thunderstorms occur during the spring and summer, usually on hot, muggy days, when the air higher up in the atmosphere is cold and dry. In this unstable atmosphere, all it takes is a lifting mechanism — such as heat from the sun and ground, a cold air mass, or a hill, mountain or other obstacle — to cause the warm, moist air near the earth's surface to rise rapidly. As this warm updraft rises into the atmosphere, it creates a cumulus cloud.

As a thunderstorm develops, these updraft cells grow and reach ever higher. Although the air in the updrafts cools slightly as it reaches greater heights, it still remains warmer than the surrounding environment. As it cools, the moisture inside the updraft condenses, forming rain droplets and ice crystals. Eventually, the abundance of condensation in the cloud becomes too much for the air to hold, and it begins falling as precipitation — marking the transition from a cumulus cloud to a mature cumulonimbus or "thunder" cloud.

The drag of the precipitation as it falls to the earth is one of the factors that causes a downdraft. At first, the downdraft is found only in the middle and lower levels of the cells, but after 15 to 30 minutes, it gradually expands upward and outward to occupy the entire cloud, except for its very summit — smothering the warm updrafts and causing the storm system to collapse. During this dissipation stage, the rainfall gradually stops, and the cold air from the downdraft spreads across the surface of the earth. This is what causes the cold air that is felt after a storm passes.

About 90 per cent of storms fit into this pattern, lasting half an hour to an hour before they decay. Some are single-cell thunderstorms that have a single updraft that forms, grows to maturity, produces a heavy downpour, and then dissipates. More common are multicell storms that consist of successive, separate updraft pulses that maintain a more or less steady state. Multicell storms can have severe effects, and occasionally produce short-lived tornadoes.

Hail can occur during the mature stage of a cell when an updraft of higher than usual intensity carries raindrops into extremely cold areas of the atmosphere, where they freeze and merge into lumps of ice. When the lumps become too heavy to be supported by the updraft, they fall to the ground at high speeds.

In about 10 per cent of cases, an overabundance of moisture in the lower atmosphere feeds an updraft with such vigour that it becomes greatly magnified and begins to rotate — a phenomenon known as a mesocyclone. These supercell storms can maintain an intense, steady state for many hours, and actually exert control over the surrounding environment, rather than being affected by it. Supercells account for most of the extreme weather events we experience, including very large hail and long-lived, damaging tornadoes.

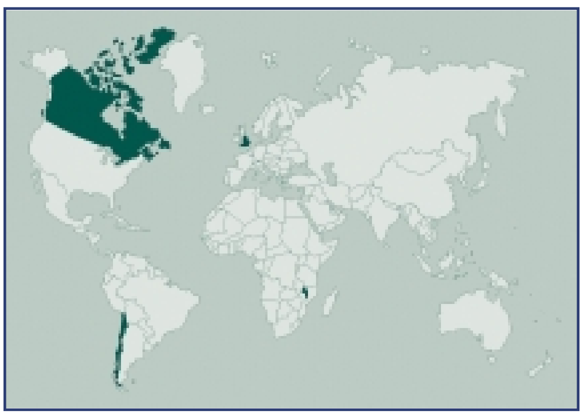
HALOACETIC ACIDS IN THE ENVIRONMENT

Haloacetic acids (HAAs) have been found in lakes, groundwater, drinking water, glacial ice, precipitation, air and soil. At high enough concentrations, they are poisonous to plants, and some are suspected carcinogens. Although HAAs have been studied extensively in Europe, little was known about their extent and concentration in Canada until recently, when Environment Canada's National Water Research Institute (NWRI) devised a unique *in situ* method of measuring these substances in freshwater and marine systems.

Haloacetic acids include many different compounds, such as monochloroacetic, dichloroacetic, trichloroacetic and trifluoroacetic acids. Some HAAs are believed to occur naturally, while others are found in the environment as a consequence of human activities. For example, trichloroacetic acid is thought to form in the atmosphere from degradation of the industrial chemicals tetrachloroethene and 1,1,1-trichloroethane.

NWRI used its new technique, which is based on traditional analytical methods, to conduct the first Canada-wide testing for HAAs in freshwater systems. The research team chose lakes from diverse locations across the country — Ontario's Great Lakes, Loon Lake in British Columbia, Great Slave Lake in the Northwest Territories, Lake Winnipeg in Manitoba, and Lake Kejimkujik in Nova Scotia — and also tested precipitation samples at seven departmental sites across Canada.

Results of the precipitation tests showed concentrations of haloacetic acids ranging from below detectable limits to 2400 nanograms per litre, with higher concentrations in rainfall from air masses that had passed near or over highly populated, industrialized areas. The lake studies revealed a similar pattern, with those associated with industrial activities found to contain higher HAA levels. Lake Superior, which has some industry and a low population, had trifluoroacetic acid concentrations of about 18 nanograms per litre. This figure increased through the Great Lakes system, with Lake Ontario having concentrations of approximately 150 nanograms per litre. Chloroacetic acid concentration levels were relatively constant throughout the Great Lakes at approximately 450 nanograms per litre. Lake Winnipeg, situated downstream from urban sources, contained high concentrations, while the lakes in more isolated regions contained the lowest.



Global map showing countries sampled in comparisons of haloacetic acid concentrations in soil and precipitation (Canada and the United Kingdom in the northern hemisphere, and Chile and Malawi in the southern hemisphere).

To build on this first effort to establish concrete information on the presence of these contaminants in Canadian freshwaters, NWRI scientists next conducted a study with international partners comparing HAA levels in the northern and southern hemispheres. Their efforts involved collecting and analyzing samples of precipitation and soil from Canada, Malawi and Chile, and soil samples from the United Kingdom.

The lowest trichloroacetic acid concentrations in the precipitation samples were found in Malawi and the highest in Canada. Malawi had low monochloroacetic acid concentrations as well, but they were slightly higher than those taken in Canada or Chile. In soil samples, HAA concentrations were highest in the United Kingdom and lowest in Malawi, with Chilean samples having higher levels than Canadian ones. Malawi soil and precipitation samples also contained small amounts of monobromoacetic acid, but this particular HAA was found in only one of 11 Chilean sites. In general, dichloroacetic acid was the most prevalent HAA found in all samples.

Overall, results showed that concentrations of HAAs were greatest in the industrialized northern hemisphere — supporting the NWRI's earlier Canadian research, and the theory that levels of these substances are higher in industrialized areas. Although substantial quantities of some HAAs were also found in the southern hemisphere, the pattern there was by no means uniform.

Haloacetic acids are an emerging environmental issue, and much work remains to be done to determine their sources, how they are transported in the atmosphere, and the exact nature of the threats they may pose to the Canadian and global environment. Environment Canada researchers continue to work with national and international partners to find the answers to these questions and to lay the scientific groundwork for actions to control these substances. S&E

BURNING TAKES BITE OUT OF LANDFILL GAS

A specially equipped truck from Environment Canada's Environmental Technology Centre tests emissions from a reciprocating engine that burns landfill gas to generate electrical energy.

Although planes, trains and automobiles are responsible for the lion's share of global greenhouse gas emissions, sources such as industrial plants and landfill sites are also major contributors. Understanding more about emissions from these stationary sources — and the effectiveness of technologies being used to control them — assists in designing preventative and control measures to reduce their impacts on air quality and climate change.

Environment Canada's Environmental Technology Centre (ETC) is determining how these sources stack up by collecting, analyzing and monitoring emissions at sites across Canada. Among the assessments currently under way is one on the combustion of landfill gas — a mixture of gases produced by the decomposition of degradable organic material in landfill sites. The ETC's efforts have determined that several of these methods are effective ways of destroying many harmful components of landfill gas, and reducing its impact on climate change.

Landfill gas is composed primarily of methane and carbon dioxide, but can contain trace amounts of hundreds of other compounds, with the exact composition varying from site to site. Carbon dioxide is the greenhouse gas most commonly associated with climate change, and the most prevalent of those emitted as a result of human activity. However, methane is a much more powerful greenhouse gas — with a warming effect 21 times that of carbon dioxide. Since one quarter of all the methane produced by human activity is from landfill, limiting emissions from this source is one of the strategies encouraged by the Kyoto Protocol on Climate Change.

Burning landfill gas converts methane into carbon dioxide, and therefore dramatically reduces its impact on climate change. If even half of all the landfill gas produced in Canada were combusted, it would mean a reduction equivalent to some six million tonnes of carbon dioxide annually. There are a number of landfill sites across the country where landfill gas is collected and burned in flares — either in the open air or in more efficient enclosed stacks. At a growing number, however, landfill gas is burned in boilers or industrial-scale internal combustion engines to produce energy. These methods have the added benefit of offsetting the consumption of other pollution-producing fossil fuels.

Although traditional methods of burning landfill gas destroy many of its harmful components, some compounds may still be released into the air — including volatile organic compounds (VOCs), which are precursors of smog, ozone-depleting substances such as freons, and toxic substances such as vinyl chloride and 1,3-butadiene. Others may be created through the combustion process or as the result of incomplete combustion, including carbon monoxide, sulphur and nitrogen oxides, dioxins and furans, and polycyclic aromatic hydrocarbons.

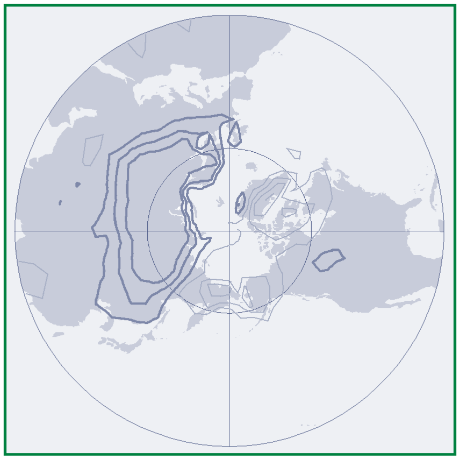
In order to reduce the potential impacts of these emissions on human and environmental health, Environment Canada is evaluating the effectiveness of several technologies used to burn landfill gas. Emissions studies have been carried out at the Meloche landfill in Montréal and in Waterloo, Ontario, on reciprocating engines that burn landfill gas to generate electrical energy that is then fed into electricity distribution grids. Additional studies have looked at emissions from a boiler in suburban Toronto, and an enclosed flare in Ottawa.

More studies are already being considered, but results to date show that boilers and enclosed flares can destroy over 99 per cent of the amount of the compounds present in the landfill gas, while reciprocating engines can destroy about 95 per cent. Engineers have found that these processes also produce relatively low levels of other gases such as carbon monoxide, hydrogen sulphide and halogenated hydrocarbons.

These results present a compelling argument for capturing landfill gas and turning it into "green power". The further development of this kind of power generation will require commitments from municipalities and private landfill operators to invest in existing and new technologies, while incentives will also be required to promote the recovery and use of landfill gas across Canada. S&E

CLUES TO CLIMATE MYSTERIES

New ideas about climate variability in the Northern Hemisphere are attracting international attention to the Arctic Oscillation — the phenomenon that describes how changes in atmospheric surface pressure in the Northern Hemisphere affect mid-latitude weather patterns. The ideas, which stem from research conducted at Environment Canada's Canadian Centre for Climate Modelling and Analysis (CCCma) in Victoria, British Columbia, may alter the way climate variability and change are studied in the future.



Simulation of the surface temperature pattern in the positive phase of the Arctic Oscillation by the CCCma's global climate model. Low pressure dominates the Arctic during this phase, causing warmer than usual temperatures (indicated by dark lines) over Europe and Asia, and colder than usual readings (indicated as light lines) over northern Canada.

Once described in *Science* magazine as the "master switch" for climate, the Arctic Oscillation has an even greater reach than the El Niño Southern Oscillation, which is associated with the warming and cooling of the tropical Pacific Ocean. When the Arctic Oscillation is in what is called its positive phase, low pressure dominates the Arctic and high pressure prevails in the mid-latitudes of the planet. This causes warmer than usual temperatures over Europe and Asia, and cooler than usual readings over northern Canada. It usually takes somewhere between a few days and several months for the Oscillation to flip to its negative phase, which brings high pressure over the Arctic, low pressure over the mid-latitudes, and a resultant reversal in temperatures.

Of great interest to scientists is the fact that the Oscillation has been stuck in its positive phase over recent decades — something many point to as yet another symptom of human-induced changes in the climate system. In 1999, the CCCma demonstrated that increased levels of carbon dioxide may partly account for the more frequent appearance of the positive phase of the Arctic Oscillation. Since then, scientists around the world have undertaken a large amount of research on the Oscillation, and the phenomenon was the subject of a special session at a recent meeting of the 10 000-member American Geophysical Union.

In the meantime, Environment Canada scientists have taken their research a step further. Based on analyses using a new, more powerful statistical technique, they now suggest that climate variability in the Northern Hemisphere is best interpreted in terms of a small set of climate regimes, or states. The atmosphere resides for extended periods of time in a given regime and then moves relatively quickly to another. From this perspective, global warming is seen as an increased tendency toward one regime (a relatively warm one, for instance) over another.

Using the CCCma's sophisticated computer model of the earth's atmosphere and oceans, scientists have identified two dominant climate regimes. The first, more persistent regime is characterized by large-scale changes in surface pressure centred over Eurasia. The second, more episodic regime is centred over the north Atlantic and associated with dramatically altered storm tracks, with storms being deflected into the Arctic instead of northern Europe, as is usually the case.

When the model is run with significantly increased carbon dioxide levels, as are expected in the coming decades, the second regime mysteriously vanishes, while the first, relatively warm regime continues on even more powerfully than before. Recent studies published by Environment Canada indicate that the real atmosphere may already be behaving in much the same way. These findings shed new light on the climatic conditions Canada and other countries may face in the future, and reinforce the need to take firm steps to control greenhouse gas emissions on a global scale. S&E

ALL ABOUT S&E Bulletin

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Media representatives and others interested in conducting further research may obtain contact information from the *Bulletin*'s editor, Paul Hempel, at Paul.Hempel@ec.gc.ca, or (819) 994-7796. Readers' comments and suggestions are also welcome.

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