Long-Range Transport of Air Pollution (LRTAP)

Air pollution knows no borders

Definition: Long-range transport of air pollutants (LRTAP) refers to the atmospheric transport of air pollutants within a moving air mass for a distance greater than 100 kilometres.

Outline of the lecture

1. **History of LRTAP problem**
2. **Environmenmental impact**
   a. Stratospheric ozone depletion
   b. Tropospheric ozone formation - Photochemical Smog
   c. Land acidification
   d. Mercury
   e. Persistent Organic Pollutants (POP)
   f. Anthropogenic radionuclides
   g. Lead
3. **LRTAP impact on a human health**
   a. Inhaled
   b. Ingested
   c. Indirect impact

Outline of the lecture

4. **Investigation of LRTAP**
    a. Monitoring LRTAP levels vs local background
    b. Modeling LRTAP
    c. Reduction action
5. **International Regulation and Monitoring Agreements**
6. **Summary**

Introduction to LRTAP

Long-range transport (LRT) of chemicals is a key issue being addressed by politicians at international level due to the far-reaching consequences of the phenomenon. As a result of the mobile nature of the Earth's atmosphere, every region of the globe is affected by air pollutants. Often, they travel thousands of miles from where they originate. As well as air, water and migratory animals also aid this process.

The time it takes for a substance to move from one area of the world to another depends on the substance and atmospheric conditions. Intercontinental atmospheric transport generally occurs over three to 30 days. Pollutants that occur in the troposphere will typically travel further and faster than those that are advected horizontally in the atmospheric boundary layer.

Introduction to LRTAP

Volatile pollutants with atmospheric lifetimes of years or longer experience no impediment to LRT once they are emitted to air. Their concentrations become practically uniform throughout the atmosphere, so the emission of a given amount anywhere on Earth makes the same contribution to global pollution. For air pollutants with lifetimes of several months, concentrations become uniform within the hemisphere of emission, but not in the opposite hemisphere. Crossing the equator takes about a year.

Trans-boundary movement applies to man-made substances such as pesticides and lead, as well as part man-made - part natural substances such as carbon monoxide and nitric oxide. Similarly, purely natural substances, including desert sand and sea salt, are subject to such environmental displacement.

Concerns for trans-boundary pollutant movement are persistence, bioaccumulation, toxicity and the capacity to affect the atmosphere.

Introduction to LRTAP

Long-Range Transport through media other than the atmosphere:

- Transport by Rivers, Oceans and Drifting Ice. Some substances may not be prone to atmospheric LRT, but may nevertheless be transported over long distances, by rivers and the oceans. This is the case, in particular, for compounds that, on account of their high affinity for aqueous phases:

  - are emitted to water and remain there;

  - are emitted initially to air, but subsequently partition to a greater or lesser degree to water

- Transport by migrating animals (POP)

- Anthropogenic transport (the shipment of goods or hazardous wastes (including ocean dumping)

Major historic LRTAP events

Kuwait oil fires:

500-600 oil wells were set alight by the retreating Iraqi army during Gulf War in February 1991. This provided the atmosphere with the largest loading of anthropogenically-produced aerosols in a single event. The Iraqi strategy of mining Kuwait's oil wells was announced beforehand, and the effects of the fires were predicted, some alarmist, some not.

The effects : The downward flux of shortwave radiation was reduced from 800 W m-2 to zero below centres of plumes. Daytime temperatures were reduced by up to 10°C. Mean monthly temps in region (March- September) were reduced by 0.8-2.4°C, and record lows occurred in July and August. Temperature reductions of 1-2°C were observed up to 2000 km from Kuwait. Black snow fell in the mountains of Pakistan, and Kashmir, 2600 km distant. Soot from the oil fires was detected over Japan, North America, and Hawaii several months later. Unburnt oil fell in drops from the sky within tens of km of the burning wells, leaving a sticky coating on buildings, crops, water reservoirs, livestock, and people, and particulates caused acute and chronic health problems, especially bronchitis and breathing problems among children and the elderly.

Major historic LRTAP events

Kuwait oil fires:

Major historic LRTAP events

Indonesian Forest Fires

During September - November 1997, the usual annual burning of vegetation in Kalimantan (Borneo), Sumatra and Irian Jaya (New Guinea) combined with severe drought associated with a strong El Nino event resulted in extensive fires. The fires caused vast smoke plumes and associated photochemical smogs, that covered much of the region, including parts of the neighbouring countries of Malaysia and Singapore, and affecting up to 70 million people. By late September, 15,000 Malaysians and 45,000 Indonesians (mostly elderly and children) had been treated for smog-related illnesses. An Indonesian airliner crashed, partly due to poor visibility, killing 234 people.

The burning is due to 3 factors:

- traditional land use;
- logging activities;
- cash cropping.

Major historic LRTAP events

Indonesian Forest Fires:

Major historic LRTAP events

The nuclear mishap at Chernobyl, USSR (April 26, 1986)

The Chernobyl accident in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel.

The resulting steam explosion and fires released at least 5% of the radioactive reactor core into the atmosphere and downwind – some 5200 Becquerels. Majority of radioactive PM were released into the environment, with the greatest emissions occurring during the first ten days of the event.

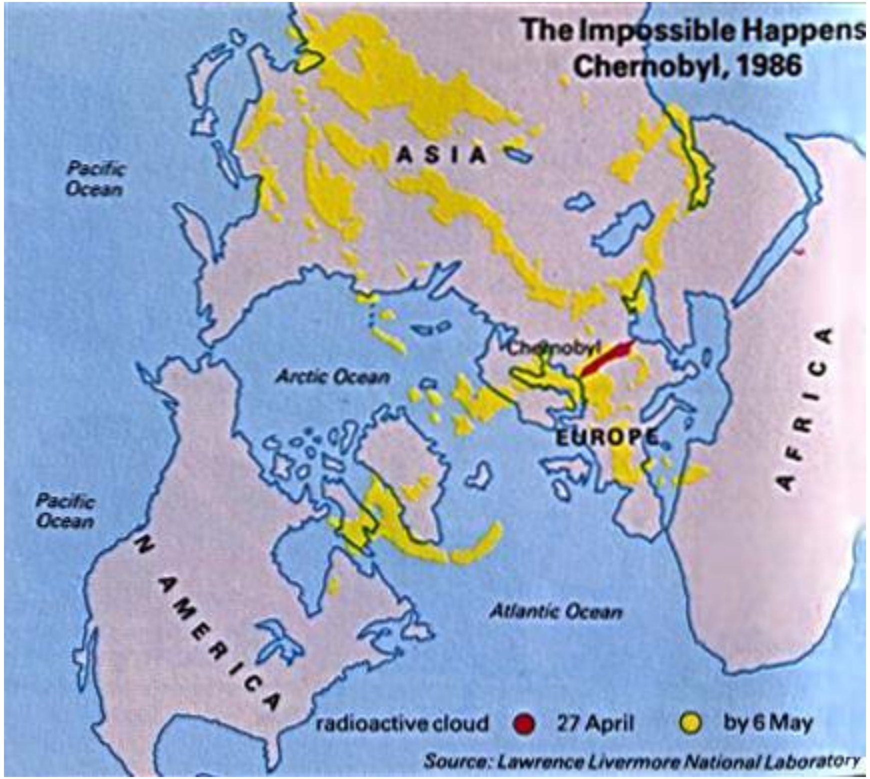
The accident caused the largest uncontrolled radioactive release into the environment ever recorded for any civilian operation, and large quantities of radioactive substances were released into the air for about 10 days. This caused serious social and economic disruption for large populations in Belarus, Russia and Ukraine. Two radionuclides, the short-lived iodine-131 and the long-lived caesium-137, were particularly significant for the radiation dose they delivered to members of the public.

Major historic LRTAP events

The accident left a major fall-out trail in Belarus, Ukraine and Russia

Major historic LRTAP events

Ten days after the accident, radioactive material from the plant was detectable at low levels over much the entire Northern Hemisphere



Stratospheric ozone depletion

Ozone depletion describes two distinct but related phenomena observed since the late 1970s: a steady decline of about four percent in the total amount of ozone in Earth's stratosphere (the ozone layer), and a much larger springtime decrease in stratospheric ozone around Earth's polar regions. The latter phenomenon is referred to as the ozone hole. In addition to these well-known stratospheric phenomena, there are also springtime polar tropospheric ozone depletion events.

The details of polar ozone hole formation differ from that of mid-latitude thinning but the most important process in both is catalytic destruction of ozone by atomic halogens. The main source of these halogen atoms in the stratosphere is photodissociation of man-made halocarbon refrigerants, solvents, propellants, and foam-blowing agents (chlorofluorocarbon (CFCs), HCFCs, freons, halons). These compounds are transported into the stratosphere by winds after being emitted at the surface sources.

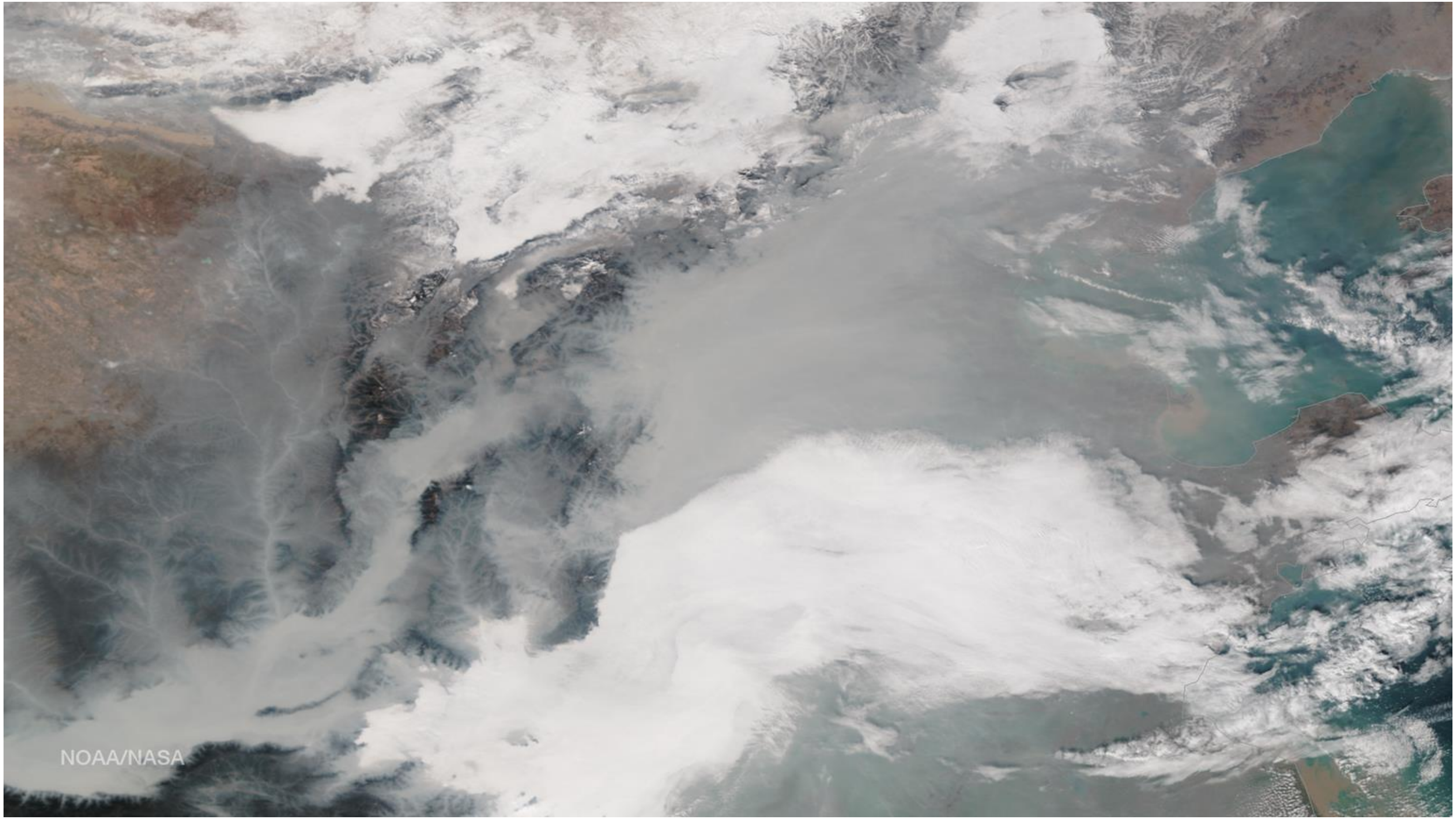
Since the ozone layer prevents most harmful UVB wavelengths (280–315 nm) of ultraviolet light (UV light) from passing through the Earth's atmosphere, observed and projected decreases in ozone generated worldwide concern, leading to adoption of the Montreal Protocol that bans the production of CFCs, halons, and other ozone-depleting chemicals such as carbon tetrachloride and trichloroethane.

Tropospheric ozone formation - Photochemical smog

Smog is one of most well known pollutants among the general public. It occurs mainly in urban or built-up areas and causes reduced visibility and can make breathing difficult, even for healthy people, and can also increase susceptibility to cardiorespiratory diseases. Smog is a complex mix of pollutants including nitrogen oxides (NOx), sulfur dioxide (SO_2), volatile organic compounds(VOCs), particulate matter (PM) and ozone (O_3), but can also contain many other compounds.

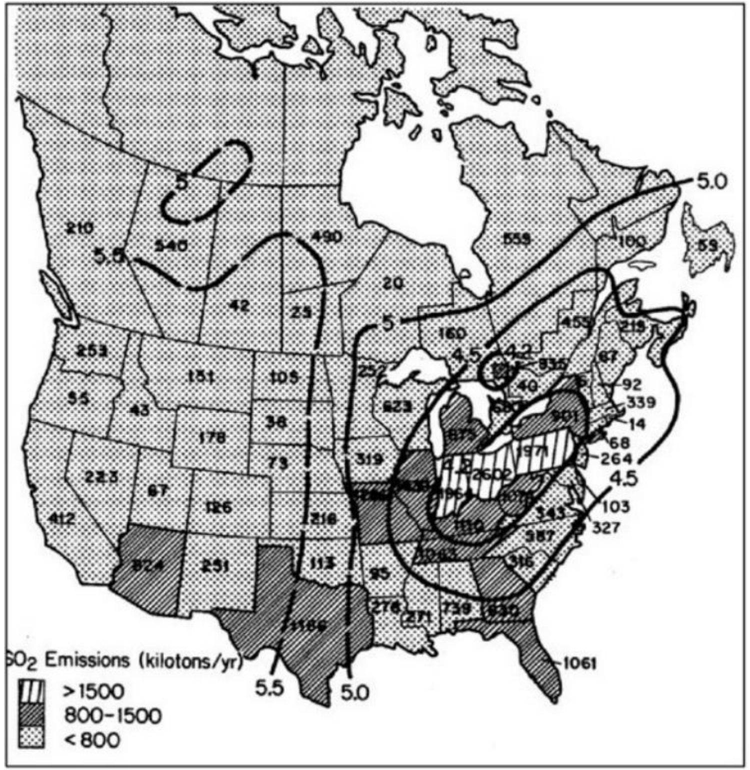
Ground-level (as opposed to Stratospheric) ozone is a colorless and highly irritating gas that forms just above the earth's surface. It is called a "secondary" pollutant because it is produced when primary pollutants undergo reactions due to photochemically induced production of free radicals. Two primary pollutants that strongly affect ground-level ozone are NOx and VOCs. NOx includes the gases nitric oxide (NO) and nitrogen dioxide (NO_2), and are produced mostly by burning fossil fuels.

Smog tends to be a regional pollutant, as opposed to a global problem. An example of a transboundary smog problem occurs in southern Ontario, Canada. About half of the nitrogen oxides and VOCs that form smog in southern Ontario originate in the United States Midwest and are carried by prevailing winds through the Ohio Valley to the north-east. But as with other transboundary pollutants, local sources are also important. In most of places of Canada, the largest single domestic source of smog is vehicle emissions; about 40 per cent of ozone-forming nitrogen oxides come from this source.



Smog over China as seen from NOAA/NASA

Land acidification



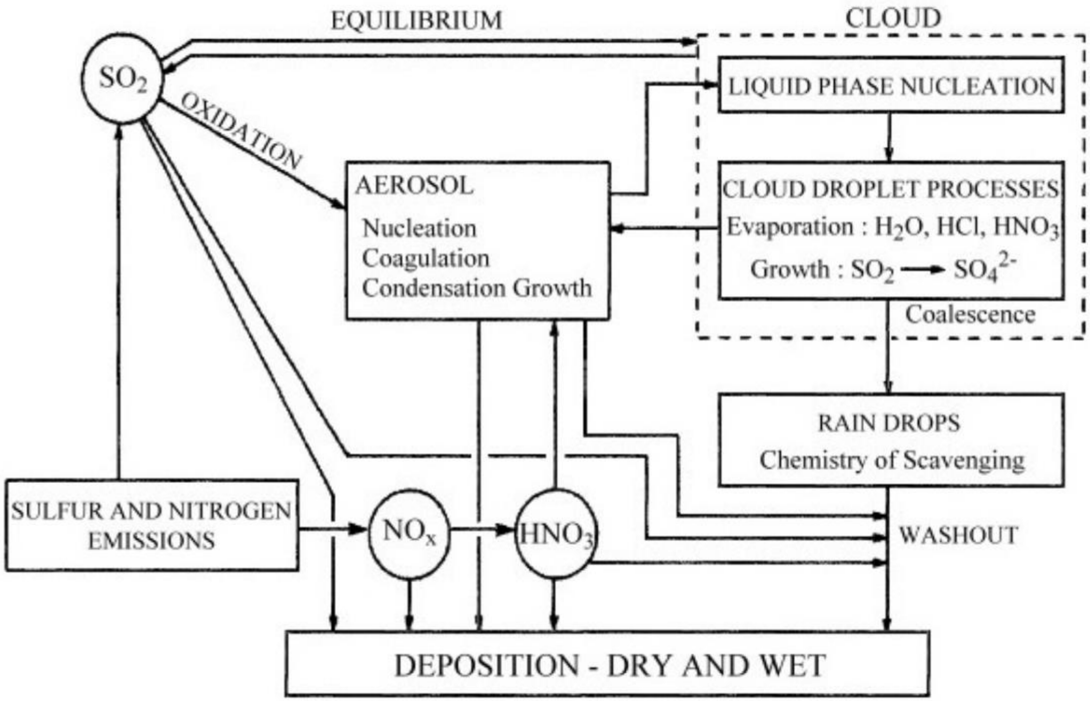
When SO_2 and NO_x are released into the atmosphere (from combustion sources or numerous industrial sources) these compounds are oxidized to the produce acidic compounds sulfuric and nitric acid respectively:

$$SO_2 + NO_x + H_2O + O_2 + \text{oxidants} \rightarrow \text{acidic compounds}$$

In North America, predominant sources of SO2 are in the USA, in states to the south of Lake Erie (Mid-East Coast part of USA) with effects felt in north-eastern USA and in south-eastern Canada. In 1995, the estimated transboundary flow of SO2 from the USA to Canada was between 3.5 – 4.2 millions of tonnes per year (Meteorological Service of Canada). Studies by the Canadian Meteorological Service indicate that some regions in eastern Canada received deposition amounts in excess of the target loading of 20 kg ha^{-1} yr^{-1} for SO_4.

← Emissions (for SO2) and acid precipitation effects across North America

Land acidification



Despite the popular term “rain,” a significant portion of the acidic species that are adsorbed by the earth’s surface may be deposited via dry deposition and also by fog, especially at higher elevations (Environment Canada). Dry deposition has been found to be especially important for nitrate deposition (Environment Canada). Because of a number of factors (location and height of release of the precursor chemicals, rate of chemical reaction, etc.) acid deposition effects can be measured many thousands of kilometers from the source region, making this pollutant a transboundary issue both in Europe and in North America.

←Atmospheric paths leading to acid deposition

Mercury

Mercury is a naturally occurring element that is present throughout the environment and in plants and animals. Human activities have increased the amount of mercury that is currently cycling in the atmosphere, in soils, and in lakes, streams and the oceans. Mercury concentrations in air are usually low and of little direct concern, but when mercury enters water, biological processes transform it to a very toxic and bioaccumulative form, known as methylmercury that builds up in fish and animals that eat fish.

In the atmosphere, mercury is transported by wind either as a vapor or as particles. Mercury reaches waters either through direct deposition or as run-off from soil after rain. Mercury deposition can occur very close to the source or, depending on the chemical form in which it is emitted, it can be transported great distances across international borders.

In Canada, airborne mercury is emitted mainly from base metal smelting plants and incinerators. In the USA, based on EPA's National Toxics Inventory, the highest emitters of mercury to the air include coal-burning power plants, municipal waste combustors, medical waste incinerators and hazardous waste combustors (www.epa.gov/mercury/information.htm)

Persistent organic pollutants (POPs)

Persistent organic pollutants (POPs) are highly toxic chemicals that are not easily broken down or converted in the environment. Outside of the Arctic, sources exist for a number of POPs; the main contaminants of concern include eight pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene), two industrial chemicals (PCBs and hexachlorobenzene, which is also a pesticide), and two unwanted by-products of combustion and industrial processes (dioxins and furans). Once deposited and incorporated into living tissues, these pollutants bioaccumulate, having long-term toxic effects.

Generally, POPs are emitted from sources outside of the Arctic region and follow the same pathways into Arctic as for Arctic haze. However, their travels are interrupted by a number of step-wise occurrences of deposition, followed by re-entrainment into the atmosphere. Deposition can occur by condensation, adsorption or adherence into or on various substances. This multi-hop pathway, the so-called “Grasshopper” effect, together with their relative chemical inertness, causes these substances to be distributed globally. At some point in their journey, the winds are likely to carry them into the Arctic, where the cold climate and low evaporation rates trap POPs within the Arctic region.

Anthropogenic radionuclides

For the general public, one of the most vivid, albeit tragic, demonstrations of the reality of atmospheric LRT was experienced after the explosion occurring in the nuclear reactor at Chernobyl, Ukraine, in April 1986. Following this largest reported accidental release of radioactive material, the initial pollution plume dispersed to the northwest and reached Finland and Sweden. However, broad areas of Europe were soon blanketed by a radioactive cloud.

Another case of accidental atmospheric release of ^{137}Cs occurred at a steel mill in Algeciras, Spain, in May 1998. This radio-isotope was subsequently detected in air across broad areas of Europe.

Radionuclides, in particular ^{90}Sr(Strontium), were also widely dispersed on a global scale by the atmospheric nuclear weapons testing in the 1950s and 1960s

Lead

Anthropogenic sources of lead include its use as a petrol/gasoline additive (now phased out in the more developed countries), non-ferrous metal production and fossil fuel combustion.

Although lead does have minor natural sources (namely soil dust, volcanoes, forest fires, biogenic emissions and sea-salt spray) it has been shown that between 3700 and 5900 years ago, the atmospheric deposition rate was orders of magnitude lower than in the recent decades. It is therefore obvious that atmospheric Pb is today primarily anthropogenic in its origin.

Interestingly, lead is one of the most ancient anthropogenic pollutants contributing to remote pollution through atmospheric LRT. Analysis of “varved” (annually layered) sediments in Sweden shows pollution beginning approximately 3000-4000 years ago (corresponding to the birth of metallurgy), with a peak in Roman times (about 2000 years ago) and a large and permanent Medieval increase (1000 years ago), arising from the development of metal production. Subsequently, there was a rapid increase after 1945, with a peak in the 1970s followed by the large decline, due to the use and subsequent phaseout of leaded petrol

LRTAP impact on a human health - Inhaled

Certain air pollutants – namely those that are inhaled – can lead to human health effects even without being deposited to the biosphere. The World Health Organization lists four “classical” air pollutants: nitrogen dioxide, ozone, suspended particulate matter and sulphur dioxide. All these substances may undergo atmospheric LRT. Furthermore, all can contribute to or aggravate respiratory ailments, particularly in sensitive subjects such as asthmatics, children or the elderly (WHO, 2000; NARSTO, 2000; IAQAB, 2002; USEPA, 2004; EEA, 2004).

While the concentrations of the pollutants are not necessarily high enough to cause significant harm to human health following LRT over distances of hundreds or thousands of kilometres, there are nevertheless instances when this may occur, especially for ozone and particles..

LRTAP impact on a human health - Ingested

Humans may also be adversely affected by pollutants arising from distant sources and ingested with drinking water or foodstuffs, for example as a result of LRT through the atmosphere and deposition onto soil, pastures, crops or water bodies, followed – in some cases – by biomagnification up the food chain, ultimately leading to high levels in fish, meat or dairy products.

Examples of particular concern include:

Toxic metals: After deposition from the atmosphere, inorganic mercury can be converted by environmental microorganisms to the highly potent neurotoxin monomethylmercury, the concentration of which is biomagnified with increasing trophic
level up the food chain. Other toxic metals of special concern are lead and cadmium;

Radionuclides

POPs: Most of the semi-volatile organic compounds discussed above are lipophilic in nature, especially the PCDDs, PCDFs, PCBs and chlorinated pesticides, including DDT and HCH. They tend to concentrate in the fatty tissues of living organisms and biomagnify from one species to the next up the food chain. POPs/PBTs are associated with a wide range of adverse effects, including endocrine disruption, immune dysfunction, neurological deficits, reproductive and developmental anomalies, behavioural abnormalities and carcinogenesis.

Investigation of LRTAP - GAPS

Canada recognizes the importance of air quality and is actively involved into international, national and regional air quality monitoring. Canada maintains following air quality monitoring networks:

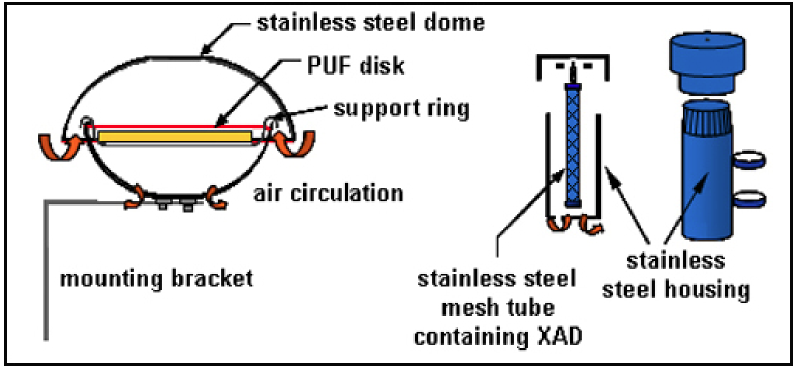
Global Atmospheric Passive Sampling (GAPS) is a Canadian monitoring network. Twelve sites are located in the country. The GAPS Network conducts measurements of POPs and priority chemicals in air with the following objectives:

Demonstrate the feasibility of passive air samplers (PAS);

Determine spatial and temporal trends in air;

Screen for and identify new chemicals in air;

Contribute useful data for assessing regional and global long-range atmospheric transport.



Two types of passive air samplers(Polyurethane Foam Disk and XAD-resin)

Passive air sampling sensors

Investigation of LRTAP - IADN

The Integrated Atmospheric Deposition Network (IADN) has been in operation since 1990 under the guidance of an implementation plan signed that year and it has regional focus. The first implementation plan committed the United States and Canada to work cooperatively towards the initiation of the IADN. Currently, the program is comprised of Environment Canada and the U.S. Environmental Protection Agency (U.S. EPA). The goals of IADN are to:

Determine the atmospheric loadings and trends (both spatial and temporal) of priority toxic chemicals to the Great Lakes and its basin on, at least, a biennial basis.

Acquire quality-assured air and precipitation concentration measurements, with attention to continuity and consistency of those measurements, so that trend data are not biased by changes in network operations or personnel.

Investigation of LRTAP -CAPMoN

The Canadian Air and Precipitation Monitoring Network (CAPMoN), operated by Environment Canada, is designed to study the regional patterns and trends of atmospheric pollutants such as acid rain, smog, particulate matter and mercury, in both air and precipitation. The network began operating in 1983.

The Network was originally designed to make integrated measurements to help Canadians understand the sources and impacts of acid rain. This included integrated measurements of wet deposition (through rain or snow) and (inferential) dry deposition, as well as the ambient concentrations of acid-forming gases and particles. The regionally representative sites required to understand the sources and how long range transport impacts the Canadian environment have proven invaluable for a wide range of atmospheric issues.

As of 2010 there are 33 CAPMoN sites across Canada. The sites are predominantly located in central and eastern Canada but new sites are being developed in the west. CAPMoN is the core of the World Meteorological Organization Global Atmospheric Watch program's measurements in Canada.

Investigation of LRTAP -CAPMoN

CAPMoN was designed as an atmospheric research network and its data must be of the highest possible quality. Quality control protocols are extensive and quality assurance is vigorous. Most data are publicly available but some are sequestered until peer reviewed papers are published or until data quality issues are resolved.

CAPMoN objectives:

To determine spatial patterns and establish temporal trends of pollutants;

To provide information for atmospheric model evaluations and effects research (aquatic, terrestrial, building materials and health);

To ensure the compatibility of federal, provincial, U.S. and global measurements;

To study atmospheric processes;

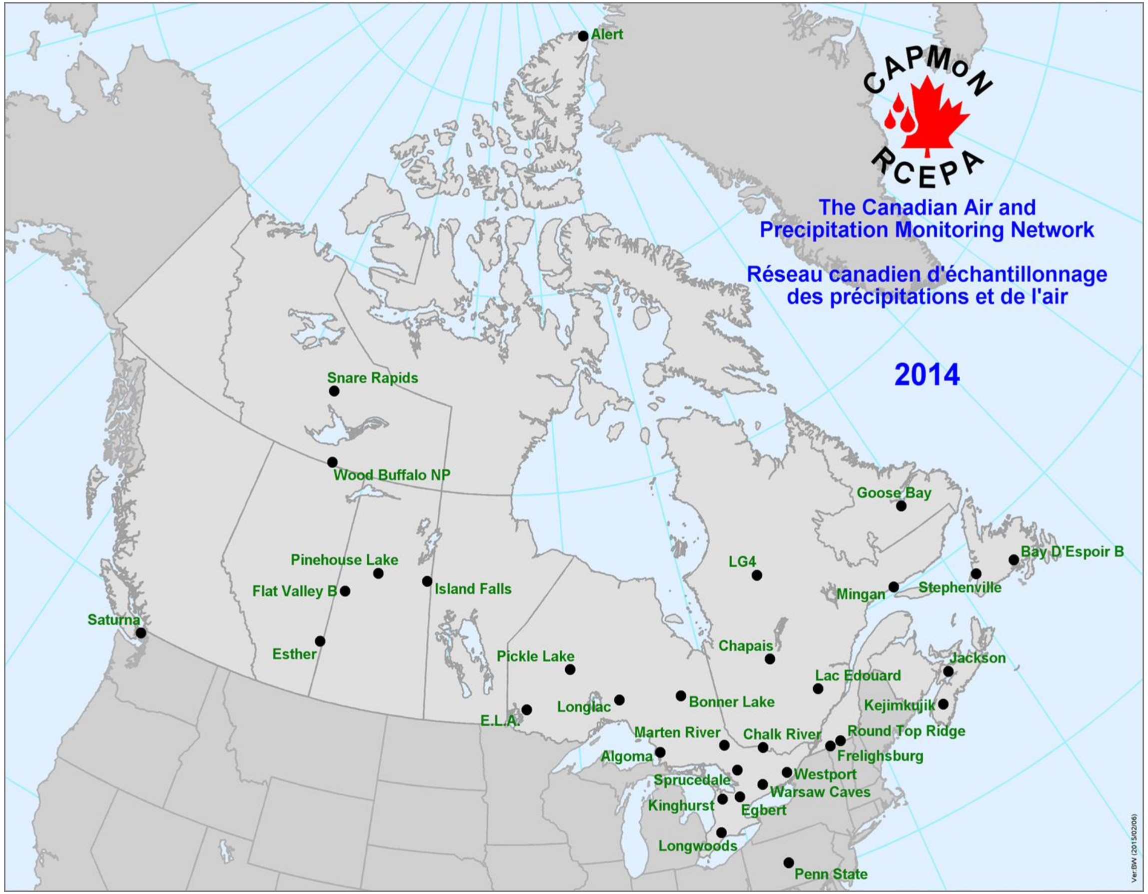
To provide real-time information for air quality forecasts.

Investigation of LRTAP -CAPMoN

CAPMoN Measurements Summary:

- Precipitation Chemistry , 24 hour integrated samples. Cl-, NO3-, SO4=, NH4+, Na+, K+, Ca++, Mg++, pH
- Particles and Related Trace Gases , 24 hour integrated filter samples. particulate Cl-, NO3-, SO4=, NH4+, Na+, K+, Ca++, Mg++, gaseous HNO_3 and SO_2
- Tropospheric (ground level) Ozone Measurements , hourly averages.
- Nitrogen Measurements , gaseous NO, NO_2, and NOy hourly averages.
- Size Selective Particulate Matter, 24 hour integrated samples PM2.5 , PM10 and coarse fraction mass;
- Total Gaseous Mercury , hourly averages;
- Hg in Precipitation, weekly integrated samples

Investigation of LRTAP -CAPMoN



Investigation of LRTAP -NAPS

The goal of the National Air Pollution Surveillance (NAPS) program is to provide accurate and long-term air quality data of a uniform standard across Canada. NAPS was established in 1969 to monitor and assess the quality of ambient air in the populated regions of Canada. NAPS is managed using a cooperative agreement among the provinces, territories and some municipal governments.

Air quality data gathered by the National Air Pollution Surveillance (NAPS) Network provide the basis for evaluating air pollution control strategies, identifying urban air quality trends and for warning of emerging air pollution issues. The recognition in recent years of the importance of long range transport of air pollution (both national and international) underlines the usefulness of a nationwide network of air monitoring stations.

Depending on the specific reasons and purpose for monitoring, some or all of the air quality criteria pollutants may be monitored. Some stations are used by jurisdictions for air quality index (AQI) reporting, other stations are used for CWS achievement determination or for trans-boundary transport monitoring or for special studies of local air pollution problems. Some of the stations are air pollution oriented but not source-specific oriented.

Investigation of LRTAP -NAPS

Investigation of LRTAP -Anthropogenic radionuclides

Managed by the Radiation Surveillance Division of Health Canada's Radiation Protection Bureau, the Canadian Radiological Monitoring Network (CRMN) is a national network that routinely collects air particulate, precipitation, external gamma dose, drinking water, atmospheric water vapour, and milk samples for radioactivity analysis. Initiated in 1959 to monitor environmental release of radioactivity from atmospheric nuclear weapons testing and accidents at nuclear facilities, the current surveillance activities of the CRMN serve to establish background radiation levels across Canada.

Presently, there are 26 monitoring stations with additional sites located in the vicinity of nuclear reactors. In the past, the CRMN conducted surveillance near all of Canada's nuclear power plants (Darlington, Bruce and Pickering in Ontario, Gentilly in Quebec, and Point Lepreau in New Brunswick).

Investigation of LRTAP -Anthropogenic radionuclides

Health Canada's Radiation Protection Bureau also operates, or contributes to, two other networks that measure airborne radioactivity. The first is the Fixed Point Surveillance (FPS) Network, maintained by the Verification and Incident Monitoring Section. It is a real-time, highly sensitive radiation detection network that provides national surveillance of the dose received by the public from airborne radioactive material. To accomplish this, the FPS network consists of 76 robust scintillation detectors that are located primarily in major population centres and in the vicinity of nuclear power plants.

Health Canada also contributes to the International Monitoring System, an element of the Verification Regime overseen by the Comprehensive Nuclear-Test-Ban Treaty Organization. Health Canada's Radiation Protection Bureau is responsible for four radionuclide monitoring stations that survey airborne radioactivity concentrations on a daily basis. These stations are located in St. John's, Newfoundland (particulate/noble gas), Resolute, Nunavut (particulate), Yellowknife, Northwest Territories (particulate/noble gas), and Sidney, British Columbia (particulate).

Modeling LRTAP - Smog

Modeling of smog transport and chemistry has had a relatively long history in North America. In the US, much developmental work has culminated in the regulatory application of photochemical models. In particular, the US EPA has developed, and promotes the use of, the Urban Airshed Model (UAM). UAM is an urban scale, three dimensional, grid-type numerical simulation model. The model incorporates a condensed photo-chemical kinetics mechanism for urban atmospheres.

Models-3 is an environmental modeling system developed by the US EPA to simulate smog development and transport, among other pollutants. The initial version of Models-3 contains a Community Multiscale Air Quality (CMAQ) modeling system for urban to regional scale air quality simulation of tropospheric ozone, acid deposition, visibility and fine particulate matter. The target grid resolutions and domain sizes for CMAQ range spatially and temporally over several orders of magnitude.

In Europe, the European Monitoring and Evaluation Programme (EMEP) utilizes both Eulerian and Lagrangian modeling techniques.

Modeling LRTAP - Acid Deposition

Numerous models have been developed over the years to investigate acidic deposition. In Canada, two different long-range transport and transformation models have been used by the federal government to investigate acid deposition issues. The first is the LRTAP model, which is a one-and-a-half layer Lagrangian model with linear chemistry and month-dependent process parameterization coefficients. This model has been used in the investigation of acid rain issues in several studies, including transboundary flux of acidifying species in Alberta, Canada, to help locate monitoring stations for the CAPMoN program.

The second model is the Acid Deposition and Oxidant Model which was also developed, in part, by the Canadian government, and is an Eulerian model with (more realistic) nonlinear chemical transformation modeling. Eulerian models has also been developed by USA agencies; the Regional Acid Deposition Model (RADM) and Community Multiscale Air Quality (CMAQ). These two models have been compared during validation field tests and both had shown good prediction accuracy.

Transboundary fluxes in Europe and import/export budgets for oxidized sulfur (SOx), NOx and reduced nitrogen (NHx) are computed with the EMEP Eulerian Acid Deposition Model.

Modeling LRTAP - PM, Anthropogenic radionuclides

In Canada, the NAPS network, provides monitoring data on PM10 and PM2.5. Primary PM can, and has, been modeled using many of the mesoscale dispersal models currently in use, since it requires only considerations of passive dispersal. On the other hand, secondary PM requires the use of chemistry “modules” that simulate the reactions required for PM formation. A number of models with chemistry modules are under development, among those being the Canadian Meteorological Service’s Chemical Tracer Model (CTM; Environment Canada 1997a). Other efforts in Canada are based on incorporating aerosol modules and modifying acid deposition/oxidant models.

In the U.S., a number of models are used to simulate pollution episodes. It is possible to estimate annual averages by running episodic models for a number of representative meteorological conditions and uses climatology to extrapolate to longer term averages. The Community Multiscale model within Models-3 treats aerosol transport and formation, and the U.S. EPA funded an upgrade of the Urban Airshed Model (UAM) to include an aerosol module.

In Europe, the EMEP Program has utilized both Eulerian and Lagrangian models to investigate PM.

Modeling LRTAP - Mercury, Lead

Long range transport modeling has been undertaken in the USA to estimate the regional and national impacts of heavy metal emissions, based on the atmospheric chemistry of emitted elemental mercury and lead veapor. The long range transport of mercury was modeled using the Regional Lagrangian Model of Air Pollution (RELMAP) atmospheric model applied to cumulative mercury emissions from multiple mercury emission sources. The results of the RELMAP modeling were combined with a local scale atmospheric model to assess average annual atmospheric mercury concentrations in air and annual deposition rates from selected, individual sources.

In Europe, efforts have also been recently made in modeling mercury transport and deposition under the EMEP program.

Modeling LRTAP - POP

Models for multi-hop compounds are much more complex than for single-hop compounds. In addition to the meteorology, multi-hop models also need to simulate how the contaminant moves between different environmental media, such as the atmosphere, the land, and the ocean. The dispersal domain is compartmentalized in order to simulate varying meteorological and climatic conditions encountered by the moving pollutant, with each compartment including atmospheric, land and water layers. Two models have been applied to orgnao-chlorines; the Bergen and Toronto models, which have also been combined.

LRTAP Reduction action- Smog

Within Canada, as with other airborne pollutants, provincial environment ministries use regulations, standards and approvals to limit industrial emissions of many pollutants, including smog precursors. Voluntary measures by industry, such as the adoption of codes and management practices, are also utilized. A coalition of government, business and other organizations has developed smog reduction plans aimed at lowering emissions of nitrogen oxides and VOCs in regions affected such as southern Ontario. Similar actions are also being taken in the lower Fraser Valley (Vancouver) and the Atlantic region. Other provincial initiatives include mandatory vehicle inspection programs in Ontario ("Drive Clean") and British Columbia, highway patrols which issues warnings and fines to drivers of visibly polluting vehicles, updating air quality standards and air monitoring networks, and establishing an interim air quality criterion for fine PM.

In June 2000, the federal government of Canada, the provinces (except Quebec) and the territories, adopted new Canada-Wide Standards (CWS) for PM and Ozone. To meet its commitments under the CWS, resources have been allocated to implement a NOx emission limit on the fossil fuelled electricity sector in Ontario and Quebec; and reductions have been mandated for other emissions such as VOCs from a range ofproducts including paints and paint coatings, degreasing agents, solvents, printing chemicals and cleaners.

LRTAP Reduction action- Smog

On December 7, 2000, an agreement to reduce transboundary smog was signed between Canada and the U. S. through the Ozone Annex under the 1991 Canada-U.S. Air Quality Agreement. North American government agencies are also devoting resources for modeling of transboundary flows and regional smog formation and transport.

The severest regional smog problems exist in many of the large conurbations (large metropolitan areas with populations greater than 10,000,000) in the developing world where vehicle populations are large, emissions regulations are either non-existent or poorly enforced and environmental conditions are conducive to the production of urban smog. Mexico City (Mexico), Rio DeJaneiro and Sao Paolo (Brazil), Santiago (Chile), Caracas (Venezuela), Calcutta and New Delhi (India), Bankok (Thailand), Jakarta (Indonesia), and Lagos (Nigeria) are among the megacities (as well as most of southern China) identified with the most significant smog problems (Faiz et al 1990).

LRTAP Reduction action- Acidification

The Federal government has signed the Canada-Wide Acid Rain Strategy for Post-2000, and is currently working in collaboration with the provinces and territories on its implementation. The Strategy calls for new emission reduction targets in eastern Canada, pursuing emission reduction commitments from the USA, ensuring the adequacy of acid rain science and monitoring, and minimizing growth in emissions. In addition, the government of Canada is reducing sulfur in gasoline.

So far, Canadian NOX emissions have declined significantly. This is largely a result of industrial process changes, retrofitting of fossil-fuelled power plants, and provincial and federal programs targeting mobile sources.

Internationally, under Article V of the Canada-U.S. Air Quality Agreement, Canada and the USA are obligated to notify the each other of any proposed actions, activities or projects which, if carried out, would be likely to cause significant transboundary air pollution.The US EPA's Acid Rain Program limits, or "caps," SO2 emissions from power plants at 8.95 million tons annually and allows those plants to trade SO2 allowances.

LRTAP Reduction action- PM

Under the Canadian Environmental Protection (CEPA) act, key industrial sectors in Canada are required to set PM emission reduction targets and timetables to meet those targets. In addition, a Canada-wide Standard for PM2.5 of 30 µg m-3 (24 hour averaging time), was ratified by the Federal and Provincial governments. A wide range of actions to reduce emissions from vehicles, products and industry had to be implemented to meet the Standard. Some of these, like vehicles and fuels, was carried out by the federal government of Canada. Others, such as emission reductions from certain existing industrial sources, was undertaken by provinces and territories (PGAIR). Emission reductions from a limited number of major industrial sectors that are of interest nationally will be achieved through joint efforts by the provinces/territories and the Government of Canada (www.ccme.ca).

In 1997, the U.S. EPA added two new PM2.5 standards, set at 15 µg m-3 and 65 µg m-3 , for the annual and 24-hour standards, respectively. The US EPA is beginning to collect data on PM2.5 concentrations, and beginning in 2002 based on 3 years of monitor data, EPA will designate areas that do not meet the new PM2.5 standards as non-attainment.

LRTAP Reduction action- Mercury

Within Canada federal, provincial and territorial governments have agreed (Canadian Council of Ministers of the Environment, Quebec City, June 2000) to ratify a Canadawide Standard on mercury, paralleling similar actions in the USA Additional Canadawide Standards were also accepted in principle to reduce emissions of mercury in fluorescent lamps and dental amalgam wastes. Canada continues its implementation of mercury management options under the Canada/United States Great Lakes Binational Toxics Strategy in order to virtually eliminate mercury from human activities around the Great Lakes. In addition, Canada has signed and ratified the United Nations Protocol on heavy metals under CLRTAP, obliging Canada to control emissions of mercury, cadmium and lead from major stationary sources and some products.

The US EPA has also issued regulations covering significant emitters that are said to reduce mercury emissions by 50% compared to 1990 levels (http://www.epa.gov/mercury/index.html).

LRTAP Reduction action- POP

An accord to ban 12 POPs was reached in the early 2000’s. However, a health-related exemption was granted for DDT, which is still needed in many countries to control malarial mosquitoes. Also in the case of PCBs, which have been widely used in electrical transformers and other equipment, governments may maintain existing equipment in a way that prevents leaks until 2025 to give them time to arrange for PCB-free replacements. In addition, a number of country-specific and time-limited exemptions have been agreed for other chemicals. Governments agree to reduce releases of furans and dioxins, which are accidental byproducts and thus more difficult to control, "with the goal of their continuing minimization and, where feasible, ultimate elimination.”

International Regulation and Monitoring Agreements

UNECE LRTAP Convention. Although the LRTAP Convention was aimed initially at responding to the challenge posed by acid rain, a total of eight protocols have now been negotiated, identifying specific measures to be taken by the parties for a range of air pollutants:

The 1984 Geneva Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP);

The 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent;

The 1988 Sophia Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes;

The 1991 Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes (targeting the most reactive volatile compounds);

The 1994 Oslo Protocol on Further Reduction of Sulphur Emissions;

The 1998 Aarhus Protocol on Heavy Metals (targeting mercury, cadmium and lead);

The 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs), targeting aldrin, chlordane, chlordecone, DDT, dieldrin, endrin, HCHs, heptachlor, hexabromobiphenyl, hexachlorobenzene, mirex, PAHs, PCBs, PCDDs, PCDFs, pentachlorophenol and toxaphene, with provisions for addition of further substances in the future;

The **1999 Gothenburg Protocol** to Abate Acidification, Eutrophication and Ground-level Ozone (targeting sulphur, nitrogen oxides, ammonia and reactive VOCs).

All of these protocols have been signed and ratified by sub-sets of the parties to the 1979 Convention and all have entered into force.

International Regulation and Monitoring Agreements

In 1976, the environment ministers from the Nordic countries proposed a European convention on transboundary air pollution that emphasized sulphur compounds (Convention on Long-range Transboundary Air Pollution (CLRTAP)). After negotiations, 34 countries and the European Commission signed this Convention in 1979 in Geneva.[3] The convention came into force in 1983, and has now been ratified by 47 European countries, two North American countries (Canada and the United States) and Armenia.[4] The CLRTAP now includes eight protocols that identify specific obligations to be taken by Parties. The Gothenburg Protocol was signed on 30 November 1999 in Gothenburg, Sweden, to support the CLRTAP. The **Gothenburg Protocol** entered into force on 17 May 2005.

The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (known as the Multi-effect Protocol or the Gothenburg Protocol) is a multi-pollutant protocol designed to reduce acidification, eutrophication and ground-level ozone by setting emissions ceilings for sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia to be met by 2010. As of August 2014, the Protocol had been ratified by 26 parties, which includes 25 states and the European Union.

The Protocol is part of the Convention on Long-Range Transboundary Air Pollution. The Convention is an international agreement to protect human health and the natural environment from air pollution by control and reduction of air pollution, including long-range transboundary air pollution.

International Regulation and Monitoring Agreements

UNEP POPs – **Stockholm Convention**

An important milestone in international cooperation on global dispersion and impact of pollutants was the conclusion in 2001 of the United Nations Environment Programme's Stockholm Convention on Persistent Organic Pollutants (http://www.pops.int/).

This agreement, whose geographical representation is much broader than that of the UNECE POPs protocol – since it includes many non-European and developing states – entered into force in 2004 and currently has 112 parties.

It targets the following 12 compounds or families of compounds: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, PCBs, PCDDs, PCDFs and toxaphene. There are provisions for the addition of further substances.

International Regulation and Monitoring Agreements

U.S. - Canada Air Quality Agreement

The 1991 “Agreement Between the Government of the United States of America and the Government of Canada on Air Quality”
was negotiated mainly to reduce emissions of SO_2 and NO_x and hence the transboundary acid deposition caused by these gases. However, an annex to the agreement also provides for the monitoring of other air pollutants of concern.

The Great Lakes Binational Toxics Strategy

The Canada - United States “Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes”, was approved in 1997. It is based on the “Revised Great Lakes Water Quality Agreement” of 1978 and covers not only a range of organochlorines, PAHs and other POPs/PBTs, but also certain compounds of mercury, cadmium, lead and tin. Although the focus of the treaty is on pollution of the Great Lakes by emissions from within the United States and Canada, LRT from worldwide sources is also considered explicitly.

The International Joint Commission (U.S. - Canada)

The International Joint Commission assists the United States and Canada in the protection of the transboundary environment, including the implementation of the “Great Lakes Water Quality Agreement” and the improvement of transboundary air quality.

International Regulation and Monitoring Agreements

North American Agreement on Environmental Cooperation

In 1993, the NAFTA countries Canada, Mexico and the United States signed the North American Agreement on Environmental Cooperation (NAAEC). A draft "North American Agreement on Transboundary Environmental Impact Assessment" was published in 1997
and the current "Agenda for Action" of the North American Commission for Environmental Cooperation includes provisions for addressing air pollution problems within transboundary airsheds.

ASEAN Agreement

In 1994, the 10 Southeast Asian nations belonging to the ASEAN partnership agreed to the formulation of a "Cooperation Plan on Transboundary Pollution". Although not restricted to atmospheric pollution, a major motivation of this agreement was clearly combating the haze from forest fires and biomass burning that regularly affects the whole region. Indeed, a specific "ASEAN Agreement on Transboundary Haze Pollution" was signed in 2002.

East Asia Network

The "Acid Deposition Monitoring Network in East Asia" was initiated in 1998 by 12 East Asian Nations, including Japan, China, Korea and Russia. This cooperation covers only scientific activities on acid deposition and atmospheric oxidants, without any regulatory prerogatives.

Arctic Council activities

The "Plan to Eliminate Pollution of the Arctic", approved in 2000 by the Arctic Council, i.e. an intergovernmental forum of the nations bordering the Arctic, was created to address pollution sources identified through the Arctic Monitoring and Assessment Programme, established in 1991. The transboundary nature of such pollution is self-evident. First-phase priority will be given to POPs/PBTs, heavy metals, radioactivity and ozone-depleting substances. The "Programme for the Protection of the Arctic Marine Environment (PAME)", established in 1983, is another initiative of the Arctic Council involving transboundary pollution

International Regulation and Monitoring Agreements

Agreements in which Long-Range Transport is Implicitly Included:

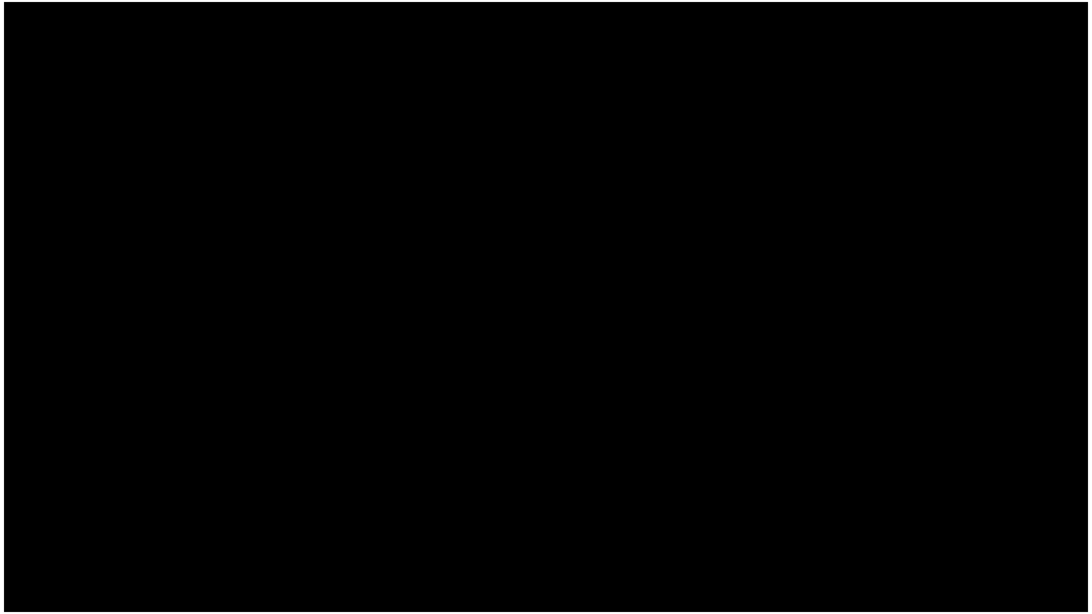
Montreal Protocol

UNEP's 1987 "Montreal Protocol [to the 1985 Vienna Convention] on Substances that Deplete the Ozone Layer", together with the various Amendments and Adjustments agreed since its entry into force in 1989, aims at reducing emissions of ozone-depleting substances and ultimately phasing them out. The target compounds are CFCs, HCFCs, halons, carbon tetrachloride, 1,1,1-trichloroethane and methyl bromide.

Kyoto Protocol

UNEP's 1997 "Kyoto Protocol to the United Nations Framework Convention on Climate Change" has the objective of reducing emissions of the main greenhouse gases: CO2, CH4, N2O, HFCs, PFCs and SF6. Despite their significant contribution to global warming, CFCs are not included, since they are scheduled for phase-out under the Montreal Protocol.

LRTAP and its political implications



LRTAP and its political implications

An international team led by atmospheric chemist Qiang Zhang of Tsinghua University in Beijing looked at emissions data across 13 global regions for 2007, the last year comprehensive information was available. They concentrated on something called PM2.5, particulate matter with a diameter less than 2.5 micrometers. These fine particles, which are blamed for some 90% of premature deaths from air pollution, can lodge deep in the lungs, causing respiratory and cardiovascular diseases.

The group then integrated four different models for industrial and agricultural emissions, production and consumption patterns, the atmospheric transport of pollution, and the number of premature deaths likely caused by air pollution in different regions. Their conclusion: In 2007, PM2.5 caused 3.45 million premature deaths worldwide. About 2.52 million of those deaths were attributed to production activities like manufacturing, transportation, and agriculture. The remaining deaths resulted from windblown dust, wildfires, chemicals released by plants, and emissions from international shipping and aviation.

The researchers further found that about 12% of the premature deaths—or 411,100—resulted from air pollution that had drifted across borders. But 22% of premature deaths—or 762,400—could be blamed on emissions from producing goods and services in one region that were consumed in another. In effect, international trade shifts the human health impacts of manufacturing from countries that import goods to those that produce them, the team writes in a letter posted in Nature.