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Air and Atmosphere

Particulate Matter

Key Findings

- Airborne particulate matter (PM) is an underlying cause of some serious human health problems, including cardiac and respiratory diseases. PM also adversely affects vegetation and building materials and contributes to regional haze and poor visibility. PM and its precursor chemicals are carried through the air across state, provincial, national and continental boundaries.
- PM has many natural and anthropogenic sources, among them direct releases to air from heavy equipment, fires, burning waste and dust from unpaved roads, stone crushing and construction sites. PM is also formed from precursor chemicals emitted by vehicles, power plants and industrial facilities.
- In certain areas of North America, levels of PM exceed national standards for the protection of human health.
- Since 1990, total emissions of PM and its precursor chemicals have declined in North America, but the trend in human exposure across the three countries is mixed, reflecting differences in local conditions and reporting methods.

Particulate matter **is a mixture of solid particles and liquid droplets found in the air. Its components include sulfates, nitrates, ammonium, organic carbon, black carbon, metals and soil dust.**

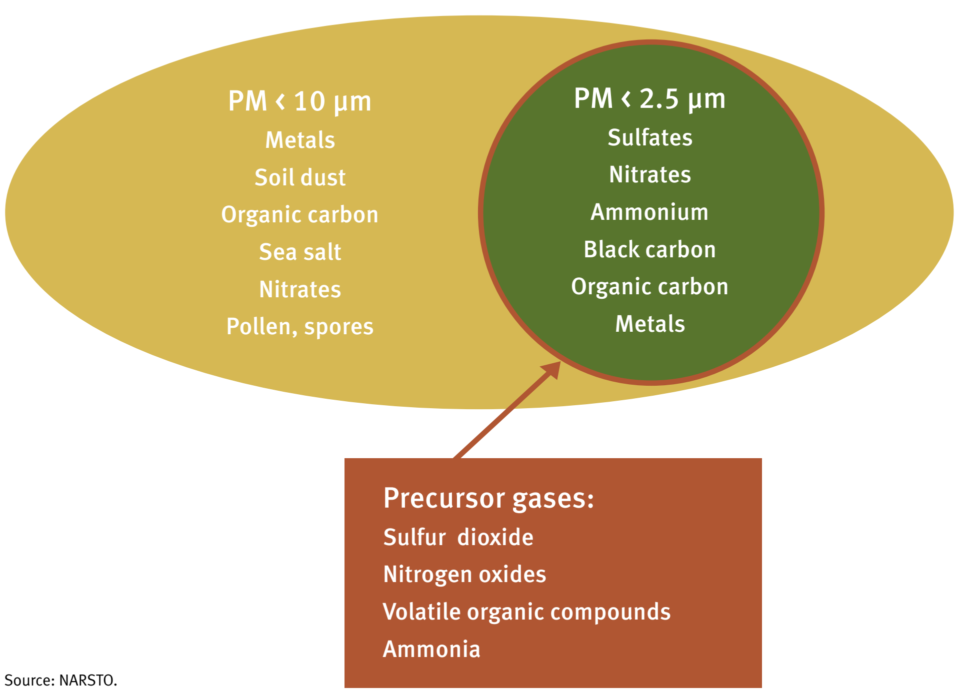
What Is the Environmental Issue?

Particulate matter (PM), made up of solid particles and liquid droplets in the air, can be both large enough to appear as dirt and much smaller than the diameter of a human hair. Ambient PM mass is a complex mixture that is strongly dependent on source characteristics.

Particles are commonly tracked within two size ranges: $PM_{2.5}$ or "fine" PM, which has aerodynamic diameters less than or equal to 2.5 micrometers (µm) and PM_{10}, which includes fine PM as well as larger "coarse" particles up to 10 µm (about one-seventh the diameter of a human hair)—see figure. Particles of different sizes behave differently in the atmosphere. Smaller particles can remain airborne for long periods and travel hundreds of kilometers. Larger particles do not remain airborne as long because they tend to deposit closer to their point of origin.

In general, the coarse fraction of PM_{10} is composed largely of primary particles released directly into the atmosphere by both natural events (e.g., forest fires and volcanoes) and human activities (e.g., agriculture, construction activities, dust from unpaved roads, residential wood burning and industrial activities). Conversely, $PM_{2.5}$ tends to be composed of more secondary particles. These secondary particles are formed in the atmosphere from chemical reactions involving

Representative composition of particulate matter



Source: NARSTO.

Note: This publication was prepared by the Secretariat of the Commission for Environmental Cooperation.
The views contained herein do not necessarily reflect the views of the governments of Canada, Mexico or the United States of America.

Diesel Emissions in the US-Mexico Border Region

Diesel emissions are a source of particulate and hazardous air pollution. The trucking, shipping and rail industries are responsible for a significant share of diesel emissions within the US-Mexico border region. Other important sources of on-road diesel emissions are school buses, garbage trucks and municipal buses. Of non-road diesel engines, construction vehicles and agricultural equipment are the largest mobile sources of PM_{10} and $PM_{2.5}$.

As the US-Mexico border opens more widely under terms of the North American Free Trade Agreement, cross-border truck transportation is expected to increase. Diesel emissions will become worse if the majority of Mexican diesel truck fleets continue to consist of vehicles built before 1993—the year engine manufacturers began to incorporate technology to reduce emissions and improve performance and fuel economy.

Because diesel emissions contribute so significantly to pollutants, retrofits and collaboration to reduce these emissions are under way. In January 2006, Mexico modified its fuel standard for gasoline and diesel fuels. An accelerated calendar was included for the border region, with the goal of providing the region with ultra-low sulfur diesel by January 2007.

Meanwhile, the San Diego Air Pollution Control District is retrofitting 60 heavy-duty diesel trucks from Tijuana with diesel oxidation catalysts. These devices reduce PM_{10} by 25 percent. In addition, the Laredo (Texas) Independent School District is modifying 50 school buses to burn ultra-low sulfur diesel fuel, and the Rio Rico, Arizona, school district is implementing a similar project. These two projects will reduce the exposure of schoolchildren to fine PM and serve as a demonstration project for other school districts on both sides of the border.

the precursor emissions of nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOCs) and ammonia (NH_3).

Why Is This Issue Important to North America?

Particulate matter has harmful effects on human health and the environment. Despite the efforts of all three North American countries to reduce PM, it still exceeds national air quality standards in some areas.

Effects of Particulate Matter

Research indicates that exposure to PM air pollution is linked to thousands of excess deaths and widespread health problems. Numerous studies have linked PM to aggravated cardiac and respiratory diseases such as asthma, bronchitis and emphysema and to various forms of heart disease. Fine PM has greater effects on human health than coarse PM because the smallest particles can travel deepest into the human lung, causing the greatest harm. Sensitive groups that appear to be at the greatest risk of such PM effects include older adults, individuals with cardiopulmonary disease, such as asthma or congestive heart disease, and children.

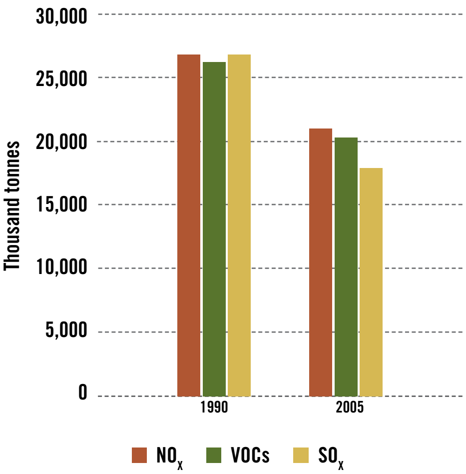
PM deposition also affects the environment by altering nutrient and chemical cycles in soils and surface water. For example, the deposition of particles containing nitrogen and sulfur may change the nutrient balance and acidity of aquatic environments, thereby altering species composition and buffering capacity. Some particles can corrode leaf surfaces or interfere with plant metabolism. PM also soils and erodes materials and buildings, including monuments, statues and other objects of cultural importance.

In addition to its effects on human health and the environment, fine PM is a main contributor to reduced visibility. This kind of haze is often noticeable in parks and wilderness areas, where periods of poor visibility result in lost tourist revenues.

Reducing Emissions

Between 1990 and 2005, direct fine PM air emissions in Canada and the United States declined by about a third (see graph). Important sources of direct fine particle emissions are diesel engines, burning activities and industrial sources. Only the Canadian and US $PM_{2.5}$ emissions can be displayed over this time period because $PM_{2.5}$ emission estimates for Mexico are available only for 1999. As of that year,

Air emissions of PM precursor chemicals in North America

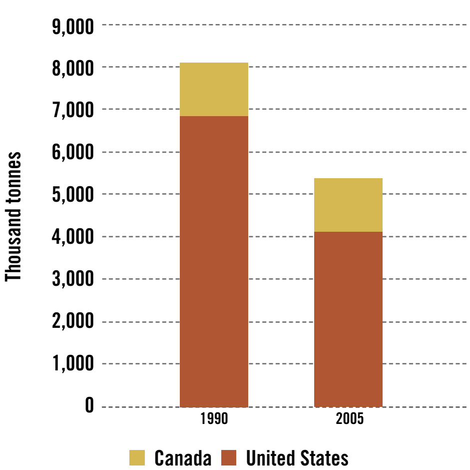


Sources: Environment Canada, *Instituto Nacional de Ecología* (latest data for Mexico from 2002, not 2005), US Environmental Protection Agency.

Mexico's contribution to North America's total $PM_{2.5}$ emissions was about 7 percent.

Because PM is also formed in the atmosphere by precursor emissions, it is important to understand which human activities contribute to precursor emission inventories. For NO_x emissions, fossil fuel–fired power plants are important sources in the United States and Mexico, and all three countries count the transportation sector as a key contributor. For SO_2 emissions, coal-fired power plants in the United States and Mexico and smelters in Canada are large sources. Volatile organic compounds are produced by similar sources in all three countries—fuels, solvents and oil and gas development—but in Canada residential wood burning also makes a large contribution. For ammonia, agriculture is a common source throughout North America. Across the continent, air emissions of PM precursors have declined since 1990 (see graph).

Air emissions of $PM_{2.5}$ in Canada and United States



Sources: Environment Canada, US Environmental Protection Agency.

Monitoring PM Trends

At present, considerable PM data for North America are available from various networks using a number of different measurement techniques. Characterization of North American trends and patterns is limited, however, by the inconsistency of these data sets, lack of monitoring stations and suitable measurement technology in certain areas, as well as by differing methods for preparing and reporting results. It is also difficult to derive meaningful North American trends because conditions vary greatly on regional basis. In all three North American countries, however, the existing monitoring reveals that ambient levels of PM exceed national standards in certain areas.

Although concentrations of PM in the United States have generally fallen nationwide, they still exceed national standards in dozens of metropolitan areas. In 2006 some 14.7 million people were living in counties with PM_{10} levels above the national air quality standard, and 66.9 million people were living in counties that exceeded both the annual and daily standards for $PM_{2.5}$.

Transboundary Flows

Efforts to reduce PM to meet air quality standards in North America are confounded by the fact that PM levels are affected by local pollution, as well as pollution transported across state, provincial and national borders. PM can remain in the atmosphere for days to a few weeks, depending on the size and rate at which it is removed from the atmosphere through, for example, precipitation. Therefore, particles in any given area may originate locally or from sources hundreds to thousands of kilometers away. Regional contributions from sources distant to eastern North American urban areas can account for 50–75 percent of the total observed $PM_{2.5}$ mass concentration within a specific urban area.

Despite the efforts of all three North American countries to reduce PM, it still exceeds national air quality standards in some areas.

In Canada, there was no statistically significant increasing or decreasing trend in $PM_{2.5}$ exposure either nationally or regionally during the years 2000–2005. Between 2003 and 2005, at least 30 percent of Canadians lived in communities with $PM_{2.5}$ levels above the Canada-wide Standard target. The communities affected were located in southern Ontario, southern Quebec and British Columbia.

Data on the levels of concentrations of $PM_{2.5}$ are not available for most Mexican cities. However, PM_{10} measurements are available in various metropolitan areas. In 2005 the standard for PM_{10} was exceeded on 173 days in Toluca, 163 days in Monterrey, 51 days in Guadalajara, 34 days in Mexico City and 11 days in Puebla. Over the past decade, most monitored cities have experienced a tendency toward fewer days of exceeding the standard, with the exception of Monterrey and Toluca. In 2005 at least 27 percent of Mexicans lived in municipalities where PM_{10} concentrations were above the national standard at least 11 days a year.

Transboundary flows are important in the border region shared by Canada and United States. In 2005 the concentrations at stations in southern Ontario were influenced by significant contributions flowing from the United States, and in southern Quebec levels were affected by pollution from both the United States and Ontario. At the same time, $PM_{2.5}$ and its precursor emissions from Canada led to elevated concentrations of $PM_{2.5}$ in the eastern United States.

Along the US-Mexico border, the Rio Grande Valley remained consistently below the annual US standard for PM_{10} from 2001 to 2005, but four other monitoring areas exceeded the standard (Ambos Nogales, Tijuana/San Diego, Ciudad Juarez/El Paso, and Mexicali/Imperial Valley). During this period, the Mexicali/Imperial Valley area consistently experienced annual PM_{10} concentrations more than four times the US standard.

Fires in the Yucatán Peninsula and southern Mexico, 2003. Photo: National Aeronautics and Space Administration.

On a periodic basis, fires in one country can contribute to high PM concentrations in a neighboring country. For example, during April and May 2003 air quality in Texas, Oklahoma and other states suffered from large amounts of aerosol PM carried as smoke from fires in the Yucatán Peninsula and southern Mexico (see photo). The smoke plumes, which significantly degraded visibility and air quality in coastal regions along the Gulf of Mexico, were large enough to create circulation patterns in the atmosphere that trapped smoke aerosols and other PM in the lower atmosphere, further worsening air quality.

Particle pollution can also cross into North America from outside the region. Intercontinental transport of PM in the form of dust and desert sand has been tracked from Africa and Asia to North America. Although this transport of dust from both Asia and Africa does not contribute significantly to annual average concentrations in North America, it may occasionally contribute significantly to daily concentrations. For example, in the summer of 1997 a plume from North Africa contributed to PM_{10} concentrations at sites in the Houston, Texas, area by as much as 15–20 micrograms per cubic meter over two days.

What Are the Linkages to Other North American Environmental Issues?

Particulate matter plays a role in various environmental issues, especially ground-level ozone, climate change and water quality.

Ground-level Ozone

$PM_{2.5}$ and ground-level ozone are closely related through common precursors, sources and meteorological processes. Because of this close relationship, changes in the emissions of one pollutant can lead to changes in the concentrations of PM or ground-level ozone. This finding is particularly important because certain regions, such as the eastern United States and southeastern Canada, experience high PM and ozone concentrations during the same season, whereas other regions, such as the San Joaquin Valley in California, have high PM and ozone levels in opposite seasons.

Climate Change

All particles affect climate change by scattering incoming and, to a lesser degree, outgoing radiation. Black carbon and other dark particles absorb radiative energy. Coarse particles and cloud droplets formed by the condensation of water vapor on particles also have radiative effects, which can have local and global impacts on climate change.

Water Quality

Particles and their precursors—particularly sulfur dioxide, nitrogen oxides and ammonia—can be carried long distances by the wind and eventually be deposited on the ground or in water. Their deposition makes lakes and streams acidic, changes the nutrient balance in coastal waters and large river basins and encourages eutrophication, depletes the nutrients in soil, damages sensitive forests and farm crops, and affects the diversity of ecosystems. Particles also carry toxic components such as mercury, which can degrade water quality and aquatic ecosystems.