Sarnia • Lambton Environmental Association
Industries Working Together

Particulate Matter in the Atmosphere

This monograph, one in a series of single issue documents dealing with Lambton County environment, has been prepared by the Sarnia-Lambton Environmental Association in co-operation with the School Boards of Lambton Kent.

Introduction

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets in the air. These particles originate from both stationary and mobile sources and also from natural sources.

(Air Quality - Ontario, page 14)

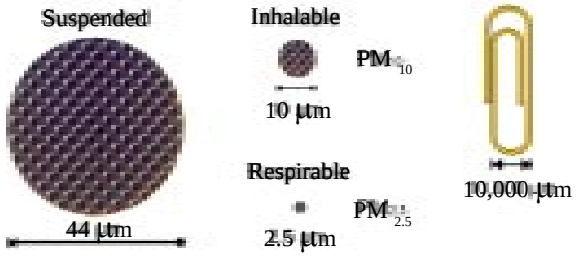
Opinions vary on the extent to which our health is affected by particulate matter and also by co-pollutants such as sulphur dioxide, carbon monoxide and nitrogen oxides. Many co-pollutants have input to the formation of particulate matter in the atmosphere; strategies to limit formation of particles must also include these co-pollutants.

Larger particles tend to have fewer harmful effects; they do not penetrate very far into the lungs. Smaller particles, PM_{10} and $PM_{2.5}$ - particles smaller than 10 micrometres (µm) in diameter and 2.5 µm respectively, are more of a health concern.

Facts

Particulate Matter - A Major Source

Particulate Matter Sizes



4,000 particles, each 2.5 micrometres in diameter, when laid end-to-end, will stretch across the width of a small paper clip.

Key Words

ambient - surrounding, encompassing.

micrometre (µm) - one one-millionth metre.

inhalable - particles that are 10 µm or less in diameter, most do not penetrate deeply into the lungs.

particulate matter - is divided into two classes, primary and secondary.

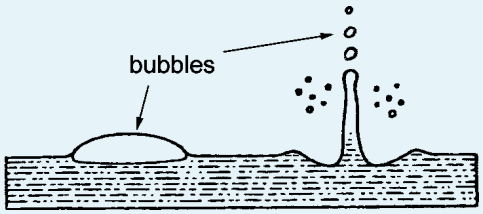
Primary particles are released directly into the atmosphere from sources of generation.

Secondary particles are formed in the atmosphere as a result of reactions that involve gases.

respirable - particles that are 2.5 µm or less in diameter; these can penetrate to the lung's air sacs.

Particles in the Atmosphere

Description	*Examples*
Very Small 0.01 to 5 micrometres (µm)	***paint pigments, tobacco smoke, dust, sea-salt particles****
Larger 5 to 100 µm	***cement dust, wind-blown soil dust, foundry dust, pulverized coal, milled flower***
Liquid (Mist) 5 to 10,000 µm	***fog, smog, mist, raindrops***
Of Biological Origin 0.001 to 0.01 µm	***viruses, bacteria, pollen, spores***
Of Chemical Formation 0.001 to 100 µm	*atmospheric sulphur dioxide oxidizes producing sulphuric acid; the acid attracts atmospheric water forming small droplets* ***(haze)***. ***metal oxides*** *form when fuels that contain metals are burned.*

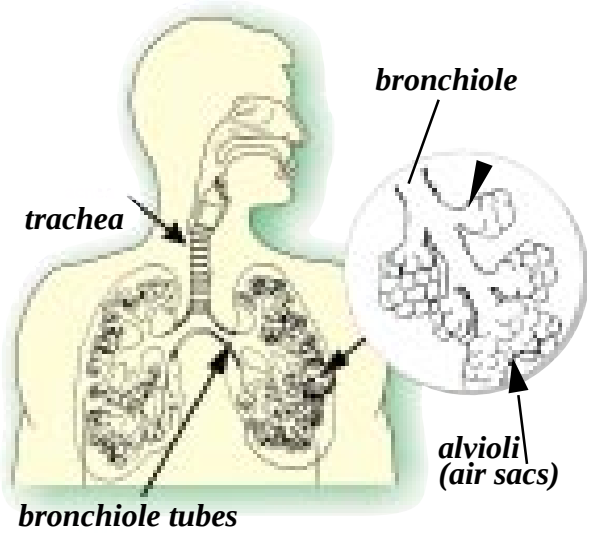


sea-salt particles - bursting bubbles in sea water form small liquid particles, evaporation of water produces small particles of sea-salt.

Manahan 1991 , page 252

Effects of Particles

- reduce and distort visibility
- serve as surfaces on which chemical reactions can occur
- serve as bodies on which water vapour condenses
- may affect health when inhaled



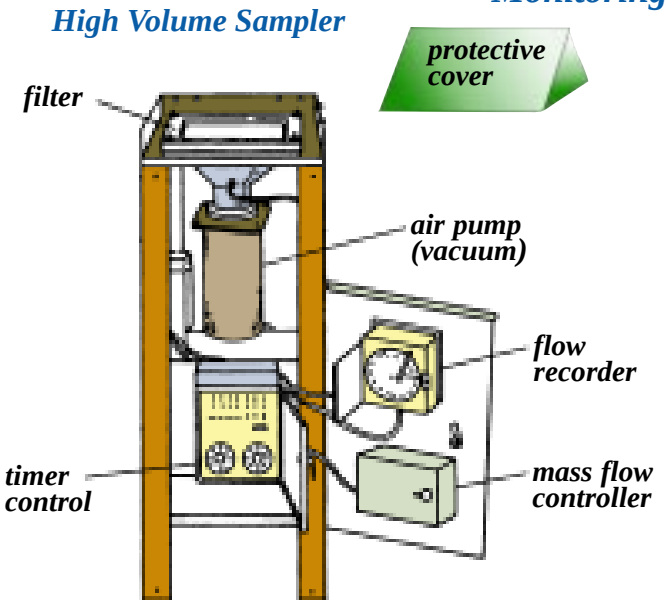
Inhalable particulate matter (PM_{10}) is the portion of the total air particulate matter that is 10 micrometres (µm) or less in diameter. Most particles with diameters greater than 10 µm will be caught in the nose and throat, never reaching the lungs. Particles between 2.5 and 10 µm will be caught by cilia lining the walls of the bronchial tubes; the cilia move the particles up and out of the lungs.

Respirable particles ($PM_{2.5}$) are 2.5 µm or smaller in diameter and can penetrate deeper into the air sacs.

Macrophages are systems of cells throughout the body: their main role is the disposal of noxious substances. Macrophages take up particles in the air sacs and dispose of them, at least in part, by intracellular ingestion.

Monitoring Particles

High Volume Sampler



Ambient air is drawn at a constant flow-rate through a filter; the filter is mounted on the tip of a hollow oscillating glass rod. **From change in oscillation (vibration) frequency, direct measurement of mass accumulation on the filter over time can be obtained.**

Although the *High Volume* and *TEOM* monitors determine masses of trapped particles by different means, for both, the same equation is used to determine concentrations of particles in the air.

$$\textbf{concentration} = \frac{\text{mass of particles on filter}}{\text{vol. of air through filter in specified time}}$$

Ontario's Air Quality Criterion for PM_{10} is 50 µg/m³ over 24 hours.

- a high volume of air (approx. 1600 m³ in 24 hours) is drawn through a filter of known weight; the filter is weighed again at the end of each 24 hour sampling period.
- air inlets are designed so that all suspended particles - up to 50 micrometres (µm) - or specific ranges of particles can be determined - eg. $PM_{2.5}$.
- chemical analyses of particles trapped on the filter may also be done.

TEOM

Tapered Element Oscillating Microbalance

air inlet

through use of different inlets, particle size cut-offs of 10, 2.5 and 1 µm are possible.

sample filter

oscillating glass rod

mass flow controller

exhaust

filter

vacuum pump

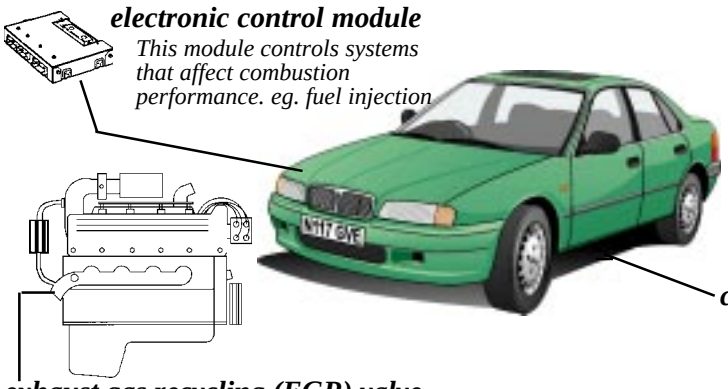
Some Monitoring Results - Distribution of PM_{10} expressed in µg/m³

Month	Less than 20	20 to 30	31 to 40	41 to 50	More than 50*
Jan	29	2	0	0	0
Feb	26	2	0	0	0
Mar	27	3	1	0	0
Apr	27	3	0	0	0
May	13	14	4	0	0
Jun	14	6	7	3	0
Jul	14	11	3	2	1
Aug	24	5	2	0	0
Sep	17	7	3	3	0
Oct	20	8	3	0	0
Nov	20	6	4	0	0
Dec	27	3	0	0	1
Total	258	70	27	8	2
Comparison of Percent Frequency with Previous Year's Data					
1999	71	19	7	2	1
1998	78	13	5	3	1
1997**	80	14	3	2	1

This table presents the PM_{10} daily average data distributed among five concentration ranges. These daily averages were recorded at the Moore Line monitor; 70% of the daily averages were less than 20 µg/m³.

Two days in 1999 had daily averages that were greater than 50 µg/m³. On both of these days the winds were from the south west at speeds of 14 km/hr and higher.

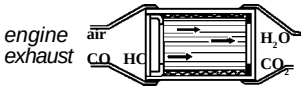
Controlling/Capturing Particle Emissions



electronic control module
This module controls systems that affect combustion performance. eg. fuel injection

exhaust gas recycling (EGR) valve
Controlled amounts of exhaust gases are mixed with air and fuel. Recirculated exhaust gases absorb heat thus reducing peak combustion temperatures. Lower temperatures reduce production of nitrogen oxides.

catalytic converter
Catalysts help oxygen to combine with carbon monoxide (CO) and unburned hydrocarbons (HC); carbon dioxide and water are produced.



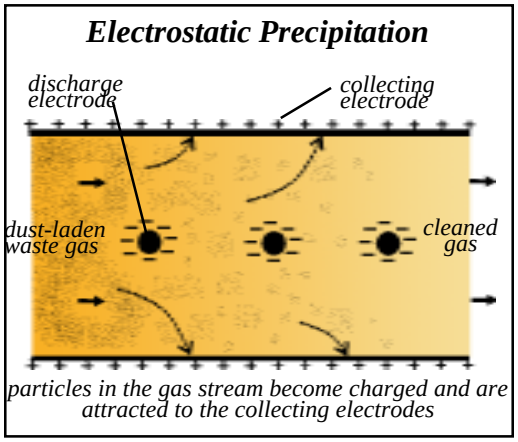
Motor vehicles are major contributors to particle concentrations in the air.

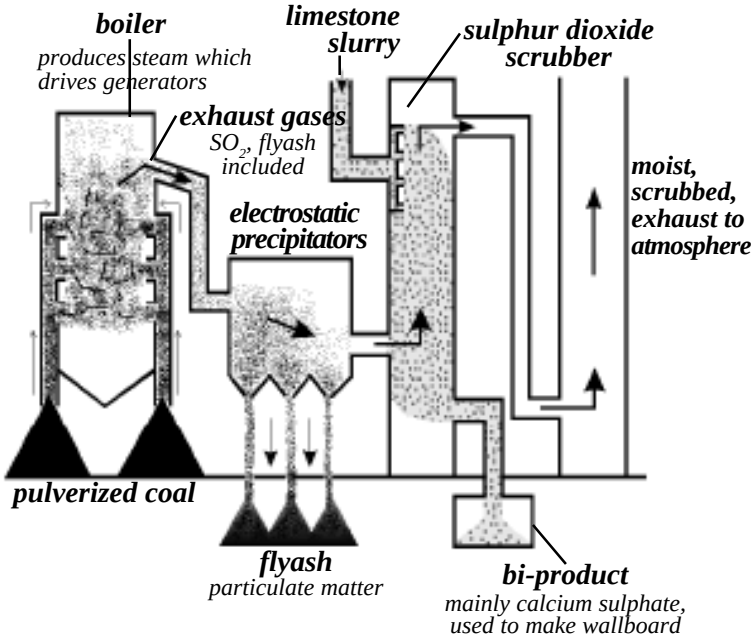
Fine particles are directly emitted (primary particles); vehicles also emit co-pollutants such as hydrocarbons and nitrogen oxides which react to form secondary particles, contributing to smog formation.

A Coal-Fired Generating Station with Electrostatic Precipitators and Scrubbers

Scrubbers

Flue Gas Desulphurization equipment or "scrubbers", as they are commonly called, remove sulphur dioxide gas. Limestone slurry, a mixture of water and powdered limestone, is sprayed into the flue gas; approximately 90% of the sulphur dioxide is removed.





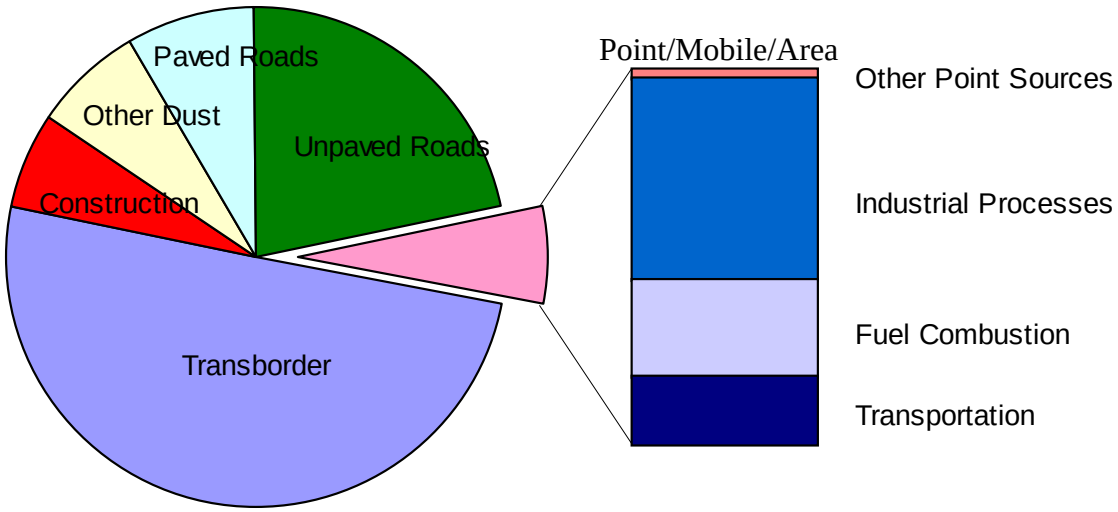
Electrostatic precipitators remove 99% of the flyash from waste gas streams by imparting negative charges to particles in the gas stream; the particles are then attracted to positive collecting plates. Periodic rapping of the collecting plates removes the particles. Ontario Hydro, 198 page 44 and Godish, page 273

Fabric filters are used to control dust emissions from a variety of industrial sources, including the collection of flyash. The system consists of multiple tubular collecting bars suspended inside a housing (baghouse). As waste gases enter the bags, dust is collected on the inside surface and the filtered gas is discharged to the atmosphere.

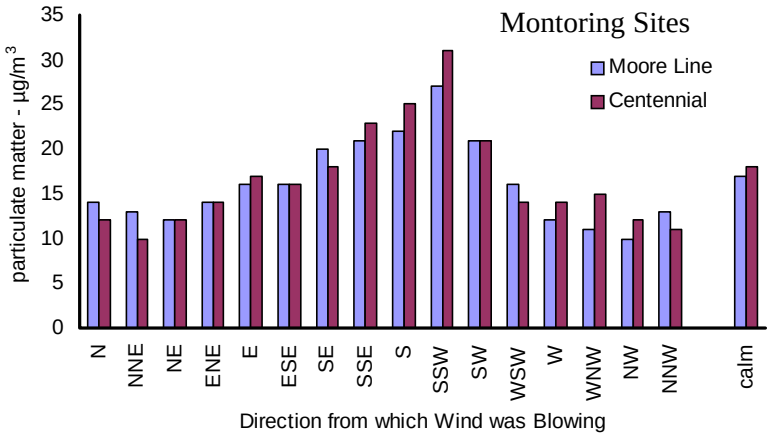
Primary Sources of Atmospheric Particles

Natural	**Activities of Man**
wind-blown soils	industrial processes
sea spray	fuel combustion
volcanoes	incineration of waste
forest fires	fertilizer application

Primary Sources of Inhalable (PM_{10}) Particles - Ontario, 1995



Inhalable Particulate Matter vs Wind Direction, 1999



This graph shows that inhalable particulate matter (PM_{10}) can be transported great distances by air currents. The graph gives annual averages of particle concentrations relative to wind direction, eg. SSW winds were recorded 10% of the time in 1999; the average of inhalable particle concentrations during these hours was 32 µg/m^3 at Centennial Park, Sarnia and 27 µg/m^3 by the monitor located three km west of Mooretown. Comparison of these concentrations to those when winds are out of the north clearly shows that southerly winds bring large quantities of particulate matter from heavily populated areas to the south of Sarnia-Lambton.

Links Between Environmental Issues

Primary Pollutant	Environmental Issues				
	Inhalable/ Respirable Particulate Matter	Ground-Level Ozone	Acid Precipitation	Climate Change	Stratospheric Ozone Layer Depletion
Nitrogen Oxides	X	X	X	X[1]	
Sulphur Dioxide	X		X		
Inhalable/Respirable Particulate Matter	X			x	
Volatile Organics	X	X		X[2]	X[2]
Carbon Dioxide				X	
Chlorofluoro-carbons				x	X

X = significant contributor in Ontario airshed x = less significant contributor

X[1] = Nitrous oxide (N_2O) only X[2] = only certain VOCs are active

The issue of inhalable and respirable particulate matter encompasses most if not all of the other main air quality issues. A substantial amount of particulate matter formed in the atmosphere results from atmospheric transformations which produce sulphuric and nitric acids. Much of the chemistry of particle formation is also common to the chemistry of ozone as it is formed in the troposphere (at ground level).

Air quality problems can be linked to a number of airborne toxic pollutants; many sources of NOx and VOCs also emit metals and other toxic compounds, (eg smelting processes, diesel vehicles). *OME, 1999 page II.3-1*

Conclusion

Inhalable and respirable particulate matter present difficult air management challenges because of the wide range of sources which give rise to fine, airborne particles. This monograph and the resources listed below introduce some of the actions and means that are being used to meet air management challenges.

Resources

Canadian ORTECH Environmental, 1999 - 2002, Sarnia Air Monitoring Report

Manahan, Stanley E., 1991 & 2000, Environmental Chemistry

Godish, Thad, 1985, Air Quality

Ontario Hydro, 1988, Flue Gas Desulphurization

Ontario Ministry of Environment, 1999, A Compendium of Current Knowledge on Fine Particulate Matter

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