Sarnia • Lambton Environmental Association
Industries Working Together

Ground-level (Tropospheric) Ozone

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.

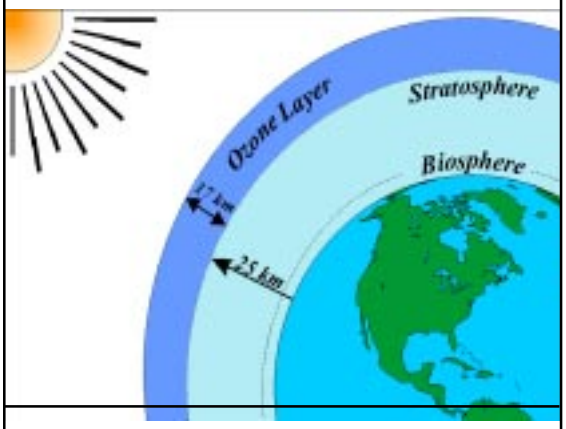
Introduction

Ground-level ozone, a major component of urban smog, is one of the more serious air quality problems in Canada. In summer months, more than one-half of all Canadians are regularly exposed to ozone concentrations which are known to have adverse health effects; in addition, ozone causes significant damage to agricultural crops.

Ozone is distributed throughout the atmosphere, however, concentrations vary greatly with altitude. Most of the ozone is concentrated in the middle stratosphere, in a band commonly called the ozone layer.

Ozone, unlike other pollutants, is not emitted directly into the atmosphere. Increased ozone concentrations at ground-level are produced when reactions occur between two classes of pollutants, nitrogen oxides and volatile organic compounds; these substances react together in the presence of sunlight.

Changing ozone concentrations at both high and low altitudes raises concerns



There is too little ozone in the stratosphere and too much in the biosphere.

Ozone Concerns

Thinning of Ozone in the Stratosphere

"Holes" are areas of decreased ozone concentration which do not adequately screen harmful ultraviolet rays (UV). Excess exposure to UV rays promotes skin cancer and cataracts.

Excess Ozone in the Biosphere

Ozone, a product of photochemical reactions, is a component of smog and is mainly contained within 1 km of the earth's surface; ozone damages organisms

see Monograph A3

Ozone Exceedances* in Lambton County, 2002

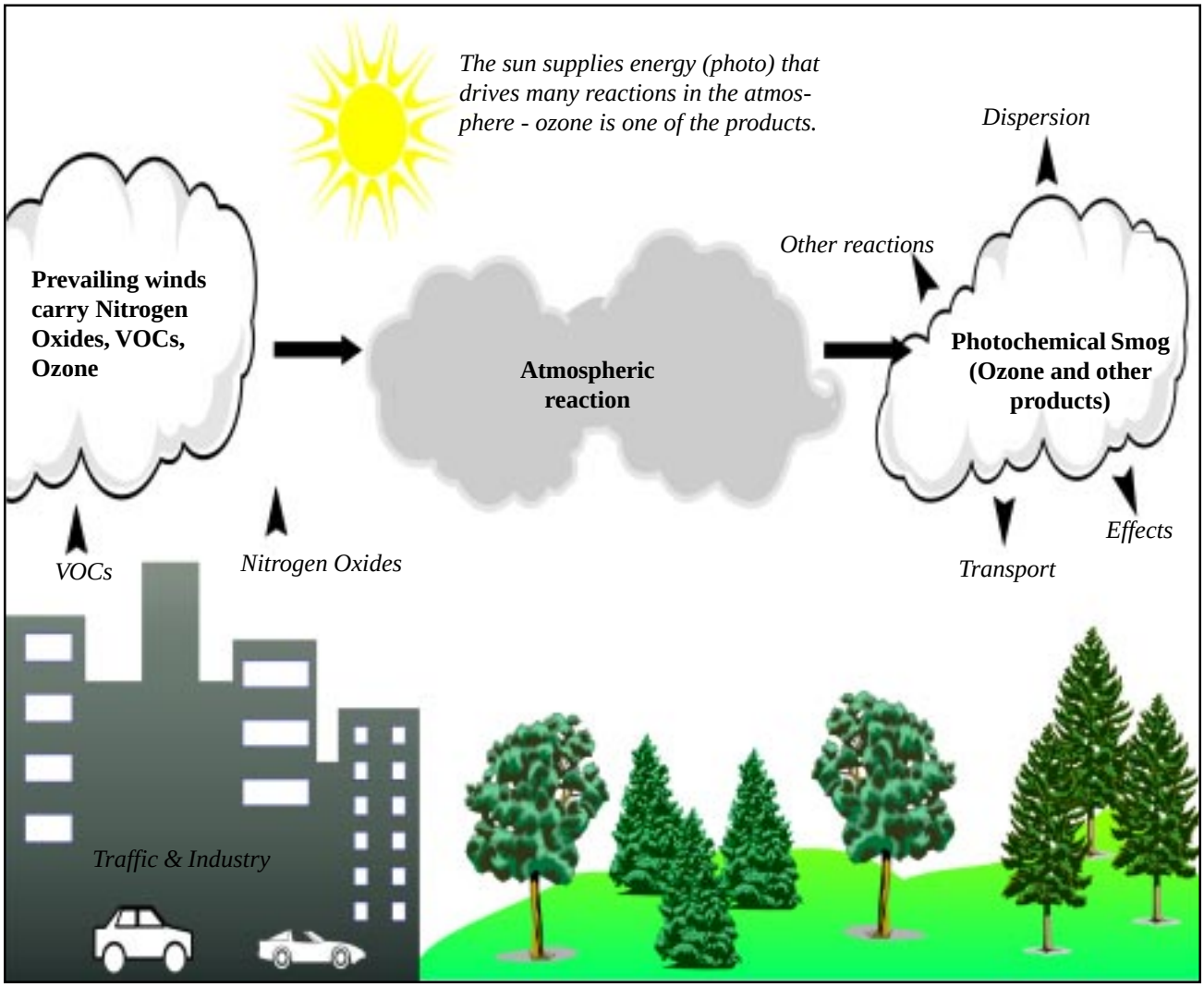
Sarnia recorded 76 hours of exceedance
Corunna recorded 138 hours of exceedance

*** exceedance - average hourly ozone concentration - greater than 80 ppb.**

Key Words:

diurnal variation	- variations observed over a 24 hour period, typically a daily cycle
nitrogen oxides, NO_x	- primarily nitric oxide (NO) and nitrogen dioxide (NO_2); these gases are formed during combustion of fossil fuels such as gasoline, diesel fuel, natural gas and coal
ozone (O_3)	- a blue gas that has a pungent odour; each molecule contains three oxygen atoms, O_3
photochemical reactions	- chemical changes that are influenced or initiated by light, particularly ultraviolet light
VOCs	- Volatile Organic Compounds are compounds that contain carbon and hydrogen primarily; ethylene and toluene are examples. Sources of VOCs include automobile exhaust, gasoline distribution systems, refineries, chemical plants, and applications of some paints and coatings

Ozone is Produced by Photochemical Reactions in the Atmosphere



The Photochemical Process

(outlined in a three-stage simplified mechanism)

1. A nitrogen dioxide molecule in the presence of sunlight breaks down to form a nitric oxide molecule and a single oxygen atom. NO_2 + ultraviolet light $\rightleftharpoons$ NO + O

2. The single oxygen atom reacts with an oxygen molecule (air is 20% oxygen by volume) to form O_3

$$O + O_2 \rightleftharpoons O_3$$

3. The products of reactions 1. and 2. react together to destroy ozone and regenerate nitrogen dioxide and oxygen.

$$NO + O_3 \rightleftharpoons NO_2 + O_2$$

VOCs in the atmosphere may favour the production of ozone

Natural Sources of Nitrogen Oxides

- forests
- volcanoes
- reduction of organic nitrates

Other Sources of Ozone

- lightning
- high voltage equipment
- transportation from the stratosphere

Some Effects of Abnormally High Ozone Levels

Damage to Plants

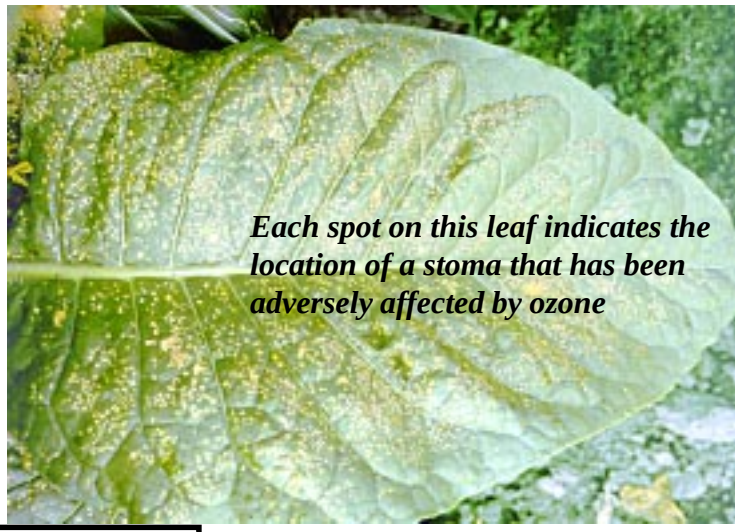
Photo, courtesy of University of Guelph

Crop losses in Ontario due to ozone damage are estimated at between $30 and $70 million annually.

Ozone inhibits normal cell activities by
- -destroying cell walls.
- -damaging chlorophyll
- -reducing food production (photosynthesis)

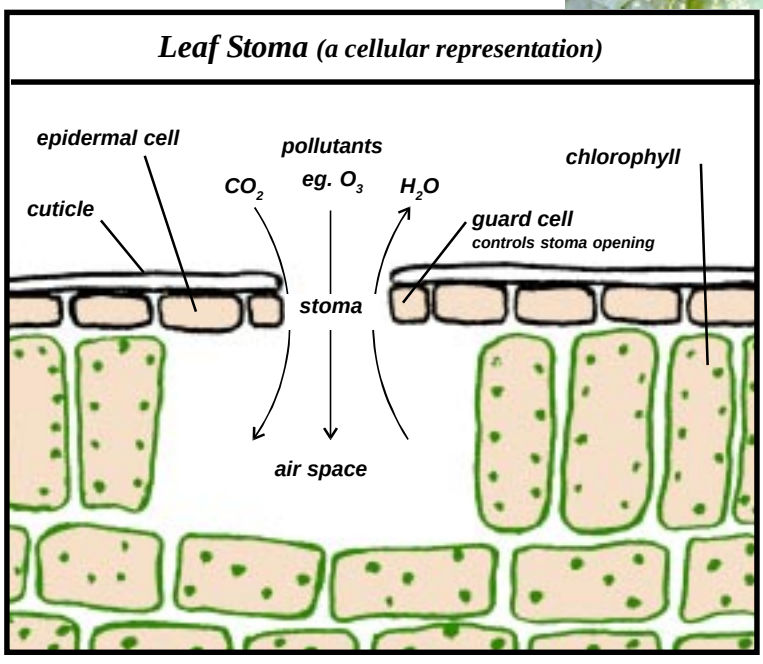
Ozone damage is first observed around stomata on upper and lower leaf surfaces.

Nicotiana tabacum Bel -W3
this species of tobacco is used to monitor 0_3 levels



Photo, courtesy of University of Guelph

Ozone attacks plants after diffusing through stomata and into the leaves. Guard cells control stomata openings, decreasing the size of the openings when moisture content is low. This action reduces the normal loss of water vapour through the stomata (a process called transpiration). Closing of stomata also limits entry of ozone and other pollutants thus decreasing possible leaf damage. Loss of leaves is another possible response to environmental stresses.

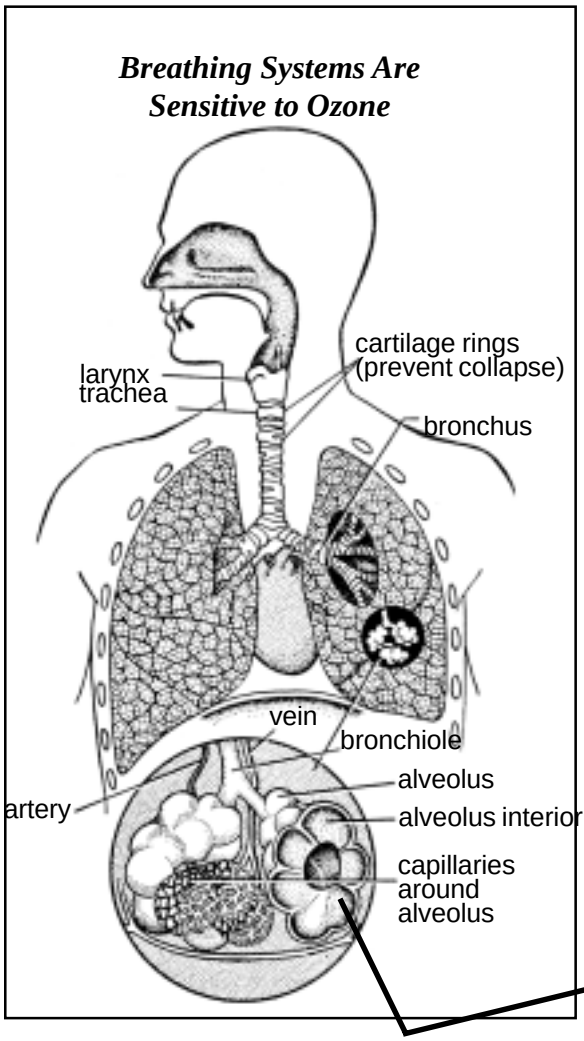


Exchange of Gases in Leaves

Gases (pollutants included)

- enter leaves through stomata
- move through spaces between cells
- dissolve in fluids and diffuse into all cells; at the same time waste gases diffuse out through cell walls and eventually exit through stomata

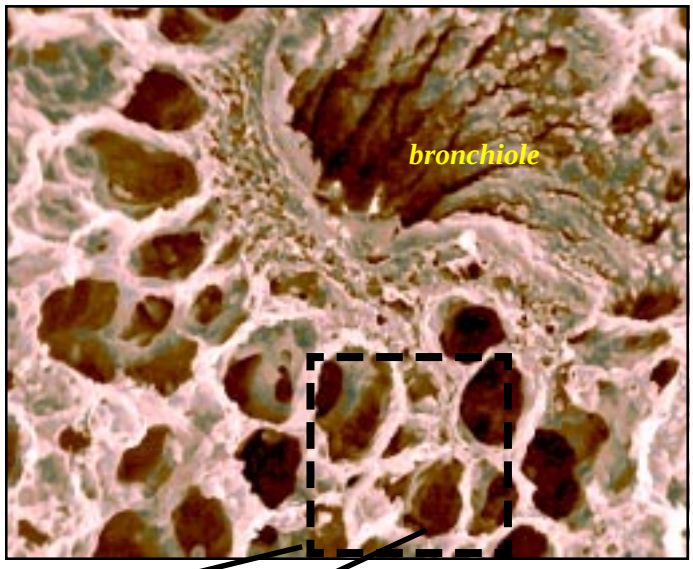
Some Effects of Abnormally High Ozone Levels



Harm to Humans

The respiratory tract is essentially a system of branching tubes which convey air from the mouth and nose to the sites in the lungs where exchange of gases takes place.

Exchange of gases (oxygen and carbon dioxide) occurs in air sacs (alveoli); our lungs contain some 700 million alveoli which have a total surface area comparable to that of a tennis court.



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Alveolus With Accompanying Capillaries

The fine lacework walls of alveoli and a single bronchiole are shown in the photo above. Each alveolus is surrounded by the smallest blood vessels (capillaries). Oxygen diffuses from the capillaries into alveoli while carbon dioxide moves in the opposite direction. Ozone is carried in the air we breathe to all parts of the lungs where it can cause injury. Signs of such injury include dry cough, chest tightness and reduction in lung function. For asthmatics, additional effects include reduced energy levels and increased need of medication.

Exposure to Ozone

Ozone is principally generated outdoors and then infiltrates the indoor environment. The high reactivity of ozone causes it to react with walls and contents of buildings - the result - indoor ozone levels are lower than those outdoors. Copying machines, printers and electrostatic air cleaners are possible sources of ozone.

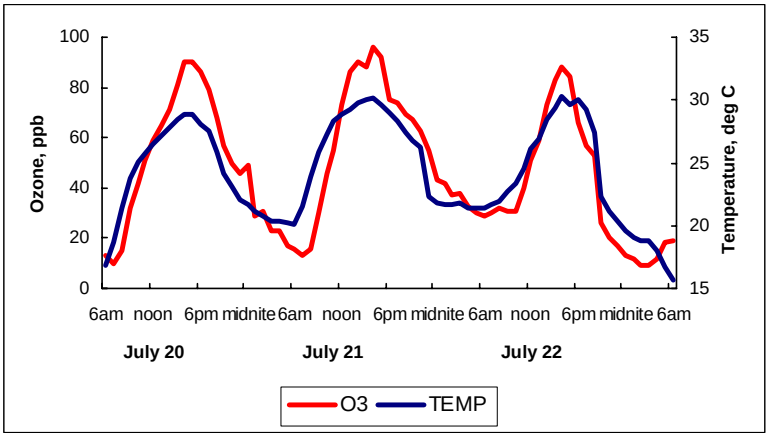
When working or exercising, larger quantities of air are inhaled. As a result, some discomfort may be experienced during times of elevated ozone concentrations.

Diurnal Variation in Ozone Concentrations

A high ozone episode July 2004

Where photochemical smog occurs, ozone concentrations are generally low at night; they increase to a maximum in the afternoon, and decrease in the evening.

Where possible, it is advisable to perform strenuous outdoor activities when ozone levels are lower.



Air monitoring programs have been recording ground-level ozone since 1975. The graph shows unusually high results recorded over a three day period in July, 2004.

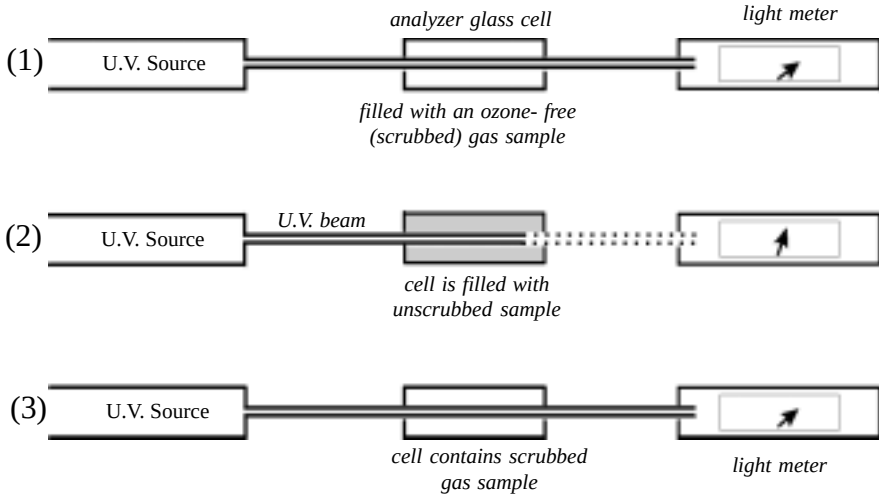
The graph shows:

1. recurring high and low ozone concentrations over 24 hour periods – diurnal variation
2. elevated ozone concentrations occurring when temperatures are high – photochemical reactions make ozone
3. locally elevated ozone concentrations occur when winds are out of the south to southwest – evidence of long-range transport. Winds were from the S-SW throughout this episode until 18:00 on July 22, when they switched to northerly. On the following days, ozone reached concentrations in the mid 30 ppb range.

Measuring Ozone Concentrations

One type of ozone analyzer determines the amount of ozone in a gas sample by measuring the amount of ultraviolet light (U.V.) absorbed by the sample. Samples containing higher ozone concentrations absorb much of the U.V. A glass cell within the analyzer is alternately filled with scrubbed and unscrubbed samples of air, (scrubbing removes ozone from the sample).

The Measurement Cycle



Light intensities of steps (1) and (3) are averaged to obtain a reference standard or zero. When the intensity of light transmitted in (2) is compared with the reference/zero, the ozone concentration in the sample can then be determined.

This 3-step cycle is repeated (every 30 seconds) at four Lambton County monitoring stations. (Monograph A1)

Ozone Attacks (Degrades) Materials

Ozone produces surface cracks on some molded rubber products. The severity of such attacks depends on the ozone concentration and also on the stress (tension) on the tire.

Rubber that is used to make tires is specially manufactured to make it resistant to ozone attacks; this resistance is attained through additives that include substances such as chlorine and bromine.

Attacks on natural rubber can also be countered through the use of waxes and chemical antiozonants.
Wax - a physical barrier that blocks ozone at the tire's surface.
Antiozonant - a chemical barrier; it reacts with ozone.

What Each of Us Can Do to Reduce Ozone Levels

- Drive less - consolidate trips, walk, cycle, use mass transit.
- Purchase fuel-efficient vehicles, keep them properly tuned.
- Keep paint cans and other solvent-containing products tightly sealed when not in use.
- Recycle, refrain from burning refuse.

Long Range Transport

More than 50% of Ontario's ozone levels during widespread ozone episodes are due to long-range transport of ozone and its precursors from neighbouring U.S. states.

Env. Ont.1997, page 8

Conclusion

When such a major portion of the ozone concern is a direct result of individual choices, it appears that modification of these choices (expectations) will be necessary if the problem of increased production of ground-level ozone is to be solved.

References

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Sarnia-Lambton Environmental Association - Monograph A1

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** references available in our resource centre*

** additional copies of this monograph are available from the Sarnia-Lambton Environmental Association or on-line at http:\\www.sarniaenvironment.com*

2005 *Monograph A2*

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