Ambient Air Quality Basics

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• Chemistry basics;
• Atmospheric structure and processes;
• Pollution source, transformation, and fate;
• Monitoring.
Chemistry basics
\[ \text{CO}_2 \text{ amu} = 12.0 + 2(16.0) = 44 \text{amu} \]

@STP 273K and 1 atm; \( R = 0.0821 \ \text{L*atm/(mol*K)} \); \( n = 1 \text{mol} \)

\[ PV = nRT = 22.4 \ \text{L} \]

\[ 1000 \text{g/1kg} \times \frac{1 \text{mole}}{44 \text{g}} \times \frac{22.4 \text{L}}{1 \text{mole}} = 509 \text{ litres of gas / kg} \]
Driving a 2003, ULEV Toyota Matrix about 20,000 km/yr

<table>
<thead>
<tr>
<th></th>
<th>CO₂</th>
<th>CO</th>
<th>NO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg/yr</td>
<td>3,805</td>
<td>61</td>
<td>3.4</td>
</tr>
<tr>
<td>2L bottles</td>
<td>~ 1 million</td>
<td>24,400</td>
<td>828</td>
</tr>
</tbody>
</table>
• Avg. Household uses 15kWh of electricity per day;
• About 980g of CO$_2$e emitted at the power plant for each kWh produced.

\[
509\text{L}/1\text{kg} \times 0.98\text{kg}/1\text{kwh} \times 15\text{kWh/day} = 7,482.3\text{L/day}
\]

then divide by 2 to calculate number of 2L pop bottles/day = 3,741
Concentrations of pollutants measured by ambient monitoring are often expressed as

1.000 ppm = 100 pphm = 1000 ppb

10 ppb is like 10 cents out of 10 million dollars.
1 litre $\text{H}_2\text{O} = 1$ kilogram
1000 ml = 1 litre
1 ml $\text{H}_2\text{O} = 1$ gram

1,000,000 $\mu$g = 1 gram

1 metre = 1,000 mm
1,000 $\mu$m = 1 mm
Atmospheric structure and processes
Dry Tropospheric Air

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percent by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.08</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.95</td>
</tr>
<tr>
<td>Argon</td>
<td>0.934</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>&lt;0.036</td>
</tr>
<tr>
<td>Many trace gases</td>
<td>About 0.0025%</td>
</tr>
</tbody>
</table>
Inversions

Yarmouth Ozonesonde with Temperature - June 9, 2004 2320 UTC

[Diagram showing ozone and temperature profiles with an inversion layer indicated.]
Pollution source, transformation, and fate

The Prime Suspects
The common air contaminants - Pm2.5

Vitals: Other aliases include “aerosols” and “fine particulate.” Consists of airborne liquid or solid particles (other than water) with an aerodynamic diameter of less than 2.5 microns.

M.O.: Gets deep into lungs. Acid based; oxidative; or rearranges valence structure. Exacerbates asthma and COPD.

Source: Directly emitted from wood-burning, road dust, sea salt, to name a few. Secondary formation from coagulation and chemical reactions with some gas species.
The common air contaminants - nox

Vitals: Also known as “Nitrogen Oxides.” This is a pair of gaseous pollutants of oxidized nitrogen species, namely Nitric Oxide (NO) and Nitrogen Dioxide (NO₂) are hired guns that associate with other in the smog world.

M.O.: In the presence of sunlight they react with an associate, “VOCs,” to form ground-level ozone. Also form secondary PM2.5 when they combine with ammonia (NH₃). NO₂ combines with atmospheric water to form Nitric Acid – a type of acid precipitation. NO attaches to hemoglobin and reduces oxygen transport in the blood. NO₂ causes lung inflammation.

Source: High temperature combustion.
The common air contaminants - voc

Volatile organic compounds
Vitals: Nickname, “VOCs.” VOCs are hydrocarbons, that is, they have Carbon-Hydrogen bonds. These hydrocarbons are volatile, evaporating into the air under normal temperature and pressures. Varying life spans from seconds to years.

M.O.: There are thousands of different Voc compounds. React with NOx in the presence of sunlight to form ground-level ozone. Also contribute to the formation of secondary PM2.5. Some, Benzene and 1,3-butadiene, for examples, are toxic.

Source: Vapours from motive fuels, solvents, wood-burning, industry. Also naturally emitted from vegetation. Methane a natural VOC in clean air. In polluted atmospheres, alkanes, alkenes, aryl compounds are present.
The common air contaminants – O3

Ground-level ozone
Vitals: Aliases, “GLO” and “O3.” The evil twin of stratospheric ozone. Distinct smell. It is a strong “oxidant.”

M.O.: Oxidizes organic compounds, converting them to carbon dioxide and water. Causes plants to close their stomata and causes direct cell damage to plants and lungs. Also degrades some synthetic materials, tires for example.

Source: In the stratosphere ozone absorbs high-energy ultraviolet radiation, protecting life on Earth. Some Ozone may be present in the troposphere from stratospheric intrusion or from lightening, but primarily from interaction with NOx and VOCs in the presence of sunlight. It is not emitted directly.
The common air contaminants – SO2

Sulphur dioxide

Vitals: Known as “SO2.” A gaseous pollutant of oxidized sulphur. Short life span as a gas, but persistent as acid compounds or sulphate particulate.

M.O.: Can convert to sulphuric acid in the respiratory tract. Also an eye irritant. Combines with ammonia to form PM2.5. Also, through a series of oxidative reaction and in the presence of water, forms Acid Rain.

Source: Major natural source is volcanoes. Principal source is from human activities. These include natural gas processing, burning coal that contains sulphur, fuels,..
The common air contaminants - CO

Carbon Monoxide
Vitals: Colourless and odourless gas. Deadly.

M.O.: Displaces oxygen in the bloods haemoglobin. Muscular paralysis and death result at high concentrations.

Source: Incomplete combustion of fuel or burning of biomass (wood, for example).
Monitoring

Ambient Monitoring
• Strategically placed to gather data on background air
• Continuous (1-hour averages)
• VOCs on 6-day cycle and analyzed at a lab
• Some filter based PM measurements

Perimeter Monitoring
• Required of industry
• Industry maintains their own network, reports to government

Emissions Monitoring
• Continuous Emissions Monitoring (CEM)
• Emission Factors – NPRI reporting.