

# What do these values mean?

3 million

...people each year are exposed to hazardous indoor air pollution without knowing it.

92%

...of the world population living in areas where air pollution exceeds safety guidelines.

1-3 million

...premature deaths worldwide each year due to air pollution.

88%

...of premature deaths occur in low- and middle-income countries - mainly West-Pacific and SEA.

# Urban Air Pollution (Photochemical Smog)

ESS 2017



# Learning Objectives

I will be able to...

**Outline the types of pollutants that cause urban air pollution**

**Describe the formation of tropospheric ozone**

**Describe the process of formation of photochemical smog**

**Evaluate strategies for reducing photochemical smog**

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# What is this?



Linfen, China  
(coal)



# Other heavily air polluted places on Earth...



Dzerzhinsk, Russia  
(Toxic by-products of chemicals e.g. sarin gas, vx gas)



Norilsk, Russia  
(Particulates and sulphur dioxide)

La Oroya, Peru  
(Sulphur dioxide, lead, copper zinc,...)



# Air pollutants

What's the difference between primary and secondary pollutants?

Primary are active as soon as they are emitted.

Secondary are formed from primary pollutants after chemical reactions.

→ some primary pollutants may also form as secondary...

# Air pollutants

What is the main source of urban air pollution?

Combustion of fossil fuels (coal, petrol, diesel,...)...  
... power plants, motor vehicles and domestic applications

Also, fossil fuel refineries, metal processing plants,...

# Air pollutants

- Sulfur dioxide (SO<sub>2</sub>)
- Nitrogen Oxides (NO<sub>x</sub>) e.g. nitrous oxide (N<sub>2</sub>O), nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>)
- Carbon monoxide (CO)
- Particulate Matter (PM<sub>10</sub> and PM<sub>2.5</sub>)
- Volatile organic compounds (VOCs)
- Lead (Pb)
- Ozone (O<sub>3</sub>) - tropospheric/ground-level
- Peroxyacyl Nitrates (PANs)
- Benzene (C<sub>6</sub>...)
- Toxic metals e.g. cadmium, arsenic and nickel
- Benzo[a]pyrene
- Nitric acid, sulphuric acid, carbonic acid



# Air pollutants

Key for indicating pollution are:

- Sulfur dioxide (SO<sub>2</sub>)
- Nitrogen dioxide (NO<sub>2</sub>)
- Carbon monoxide (CO)
- Particulate Matter (PM<sub>10</sub> and PM<sub>2.5</sub>)
- Lead (Pb)
- Ozone (O<sub>3</sub>) - tropospheric/ground-level

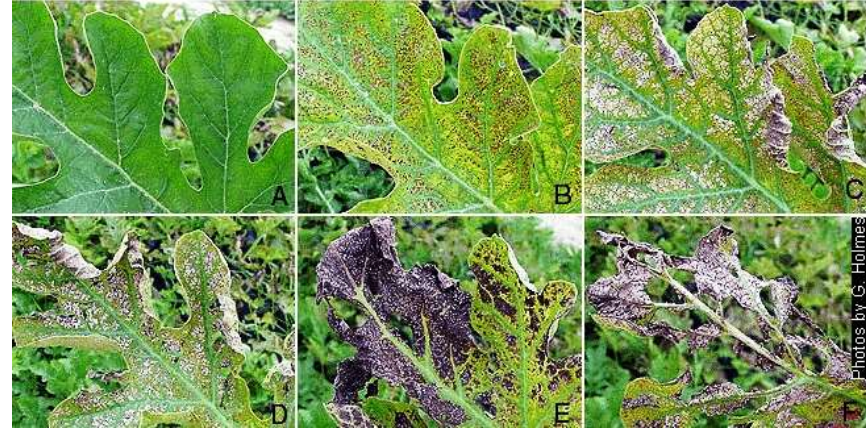
# Air pollutants

## World Health Organisation Guidelines

Pollutant	Concentration	Averaging Period
Particulate matter (PM <sub>2.5</sub> )	10 µg/m <sup>3</sup> 25 µg/m <sup>3</sup>	1 year 24 hour
Particulate matter (PM <sub>10</sub> )	20 µg/m <sup>3</sup> 50 µg/m <sup>3</sup>	1 year 24 hour
Ozone	100 µg/m <sup>3</sup>	8 hour
Nitrogen dioxide	40 µg/m <sup>3</sup> 200 µg/m <sup>3</sup>	1 year 1 hour
Sulphur dioxide	20 µg/m <sup>3</sup> 500 µg/m <sup>3</sup>	24 hour 10 minute

# Tropospheric ozone

Ozone is toxic → damage to cells  
breathing difficulties, irritation,  
increased infection risk  
Ozone damages plants → degrades  
chlorophyll  
Ozone damages materials →  
degrades rubber in tyres and  
plastics

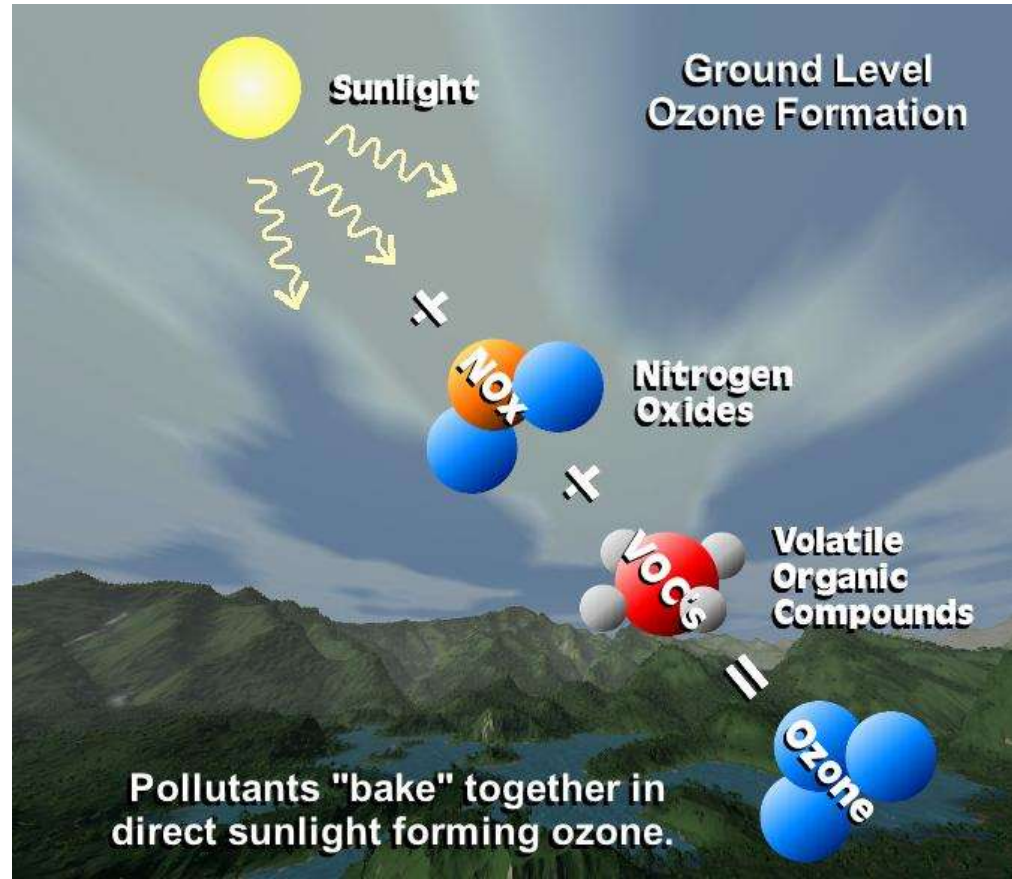


# Tropospheric ozone

Some forms naturally  
e.g. lightning

The rest is man-made...

Credits to: NASA,  
[https://aura.gsfc.nasa.gov/outreach/garden\\_faq.html](https://aura.gsfc.nasa.gov/outreach/garden_faq.html)



# Tropospheric ozone

Order the steps in the process of tropospheric ozone formation (cut-and-paste or number)

# Particulate Matter

Particles of carbon and other substances

Two types are measured:

PM<sub>10</sub> - size ranging from 2.5 to 10  $\mu\text{m}$

PM<sub>2.5</sub> - size range is less than  $< 2.5 \mu\text{m}$

# SEA Haze (origin: mainly Indonesia, also Malaysia and Singapore)

1. Slash and burn...



2. Forest catches fire...



3. Peatland burns...



4. Massive PM clouds form...



5. People choke...



# SEA Haze: causes

- Low-income families/communities resort to subsistence slash-and-burn agriculture
- Not enough government investment in opportunities and solutions
- Multinational oil palm companies invest in local plantations but...
- ...do not necessarily enforce environmental guidelines and best practices → profit-driven
- Indonesian government reticent to act → development



# Particulate matter

- smallest particles can penetrate into cells/tissues → cancer
- aggravates severity of chronic lung diseases → rapid loss of airway function
- inflammation of lung tissue → release of chemicals that can impact heart function
- changes in blood chemistry → clots that may lead to heart attacks
- susceptibility to viral and bacterial pathogens → pneumonia in vulnerable persons

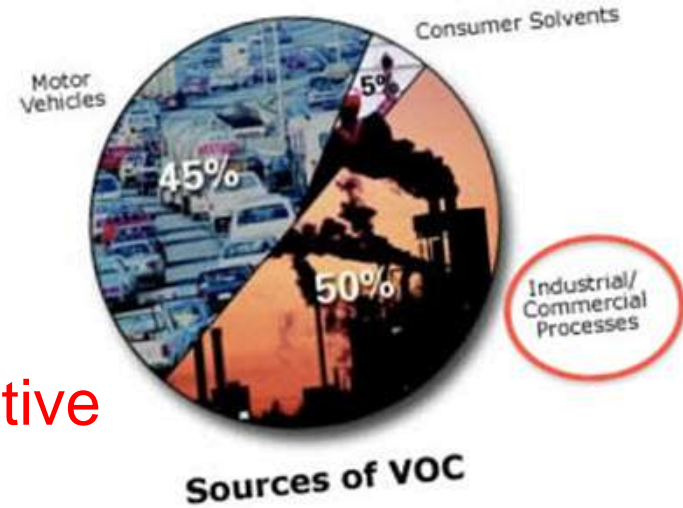
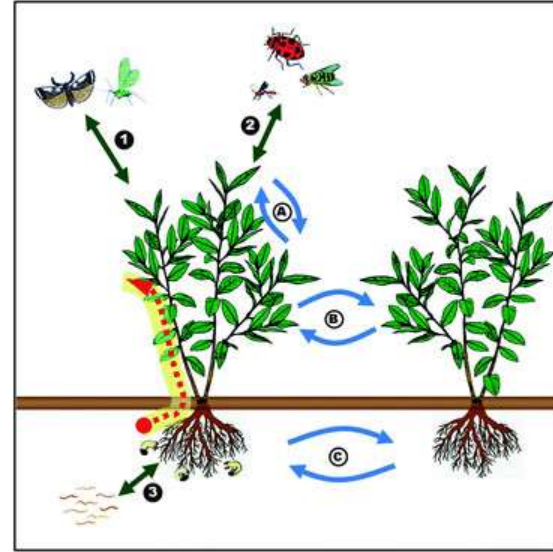
# VOCs

Volatile organic compounds

→ easily become  
gas/vapour

→ contain carbon and...

→ hydrogen, oxygen,  
flourine, chlorine, bromine,  
sulphur, nitrogen, ...  
paint thinners, moth repellents, air  
fresheners, wood preservatives, automotive  
products, and dry cleaning fluids



# VOCs

Detection is critical...

Industrial Pollution



USEPA Superfund sites  
Active (red), Proposed (yellow), Deactivated (green)

Bacterial  
Detection/Typing



Chemical Weapons  
Detection



Benzene



Formaldehyde



Tetrachloroethylene



Acetaldehyde



Sarin

# VOCs

- Level and length of exposure
- benzene, formaldehyde, toluene, styrene and perchloroethylene (or tetrachloroethylene)
- Long-term exposure: damage to the liver, kidneys, and CNS.
- Short-term exposure
  - eye and respiratory tract irritation, headaches and dizziness
  - visual disorders
  - fatigue and loss of coordination
  - allergic skin reactions, nausea and memory impairment

# Air pollutants

Research teams of 3-4 → share answers

Search in your textbook (pg 287-291) or online

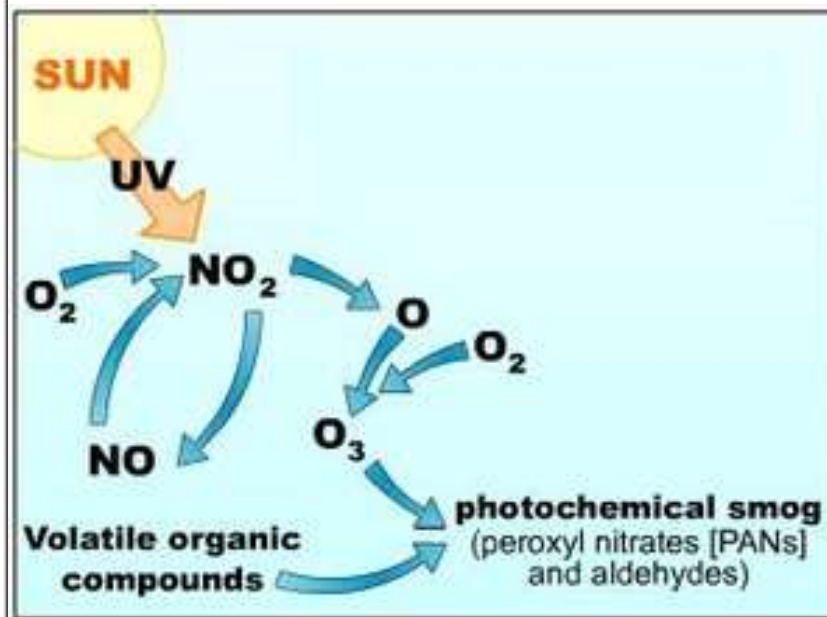
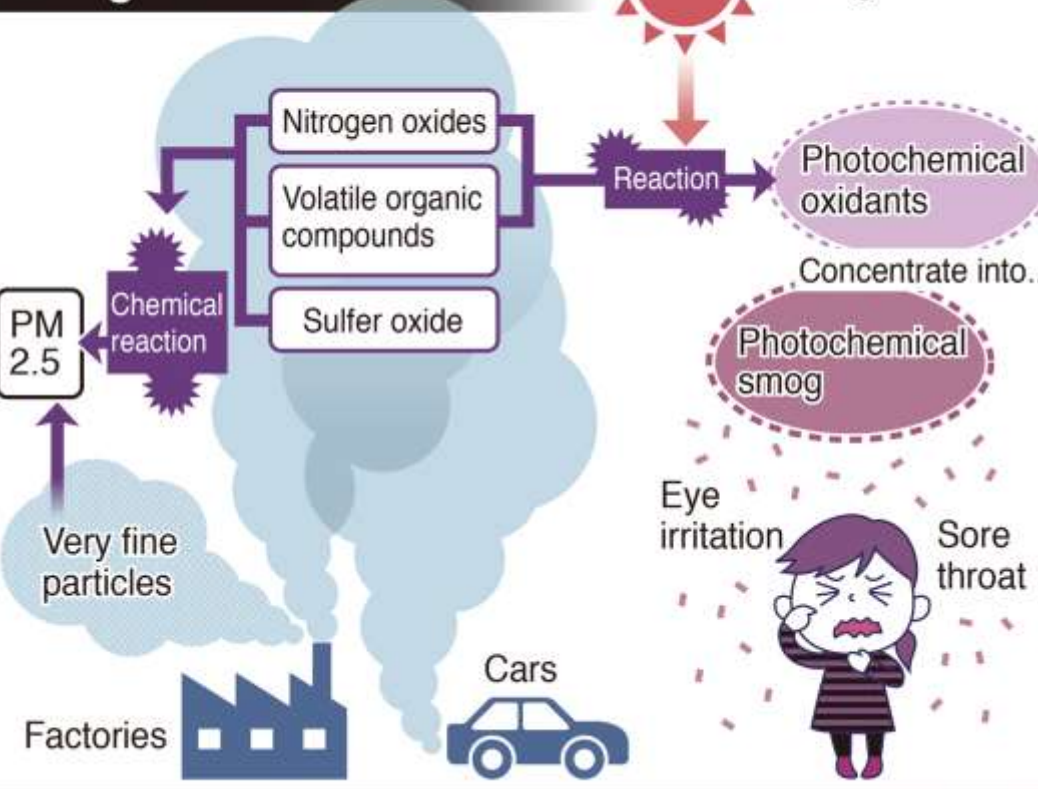
At least one possible health and/or environmental effect from the pollutants in your table

# Photochemical smog



# Photochemical smog

## How photochemical smog is formed



## FORMATION OF PHOTOCHEMICAL SMOG

# Photochemical smog

A complex mix of chemicals and reactions

Formed from release of hydrocarbons:

- Fossil fuels
- Trees

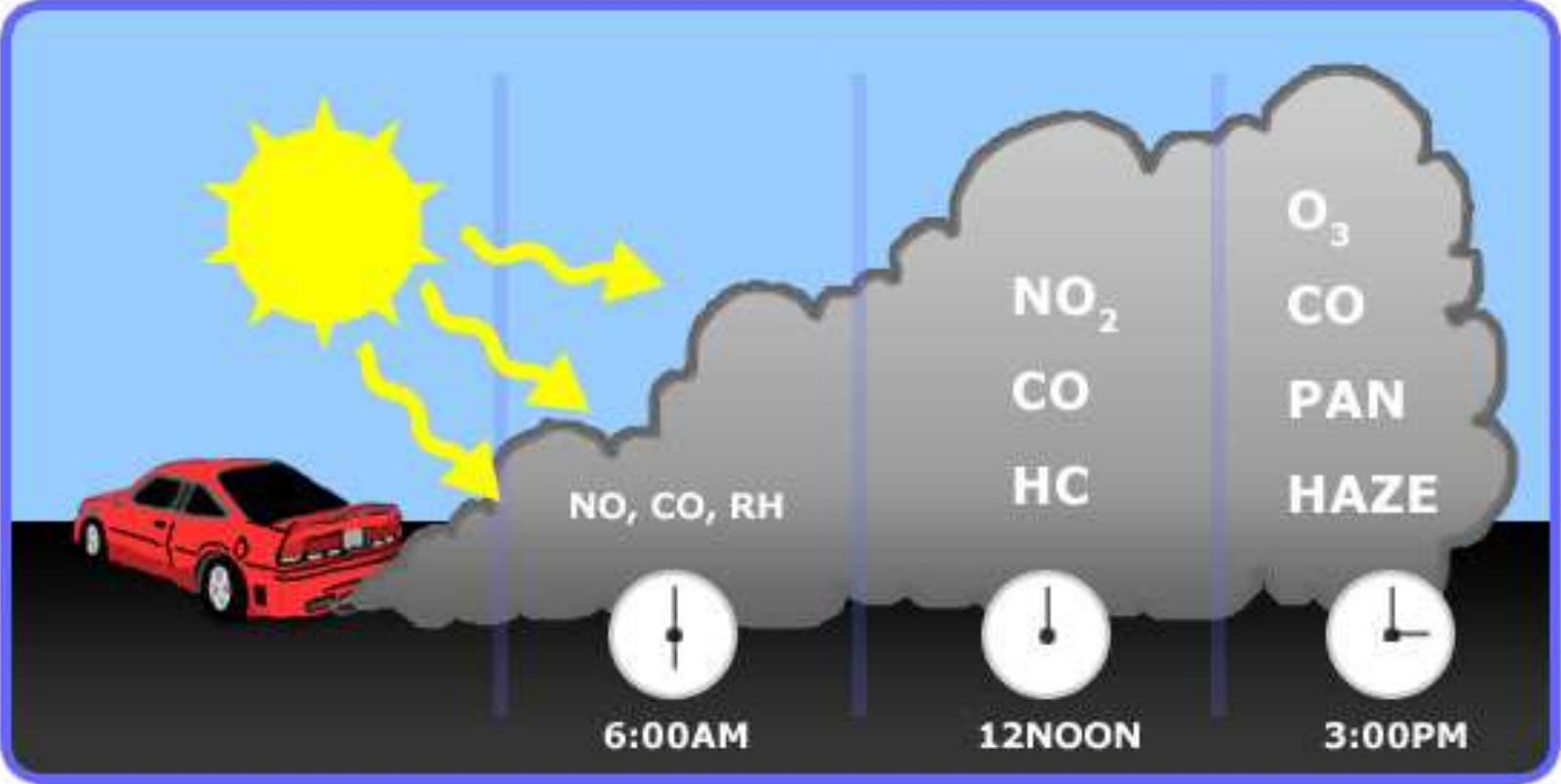
Reaction between  $O_3$ ,  $NO_x$ , and hydrocarbons driven by sunlight

Products are

- VOCs
- PANs
- Aldehydes
- More  $O_3$  and CO



# Photochemical smog

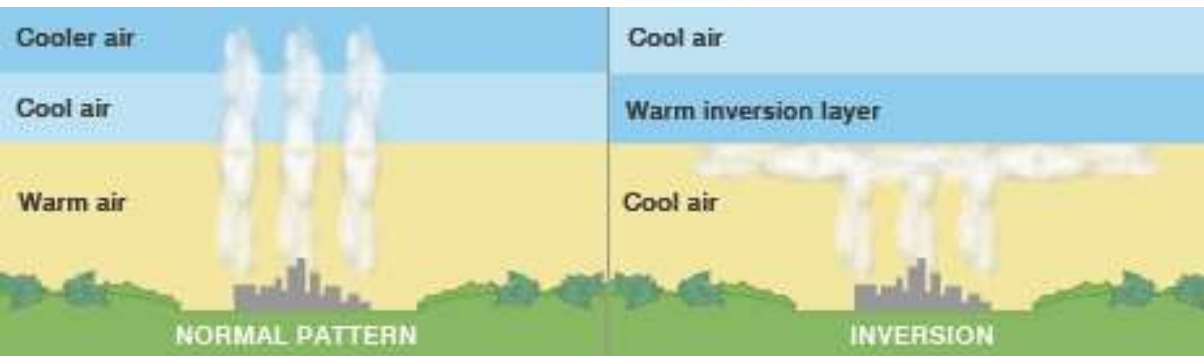


# Photochemical smog

Highest levels reached in the afternoon because...

...photochemical load peaks when the sunlight is more direct → more solar energy (ultraviolet)

**Thermal inversion** is a serious problem...



Warm, dry climate → higher layer of warmer air (inversion)  
Prevents rising of pollutants  
Trapped in a bubble around cities