



## Air Pollution

### What is Air Pollution?

- the presence of a substance in air that can be harmful to human health and/or damaging to organisms and the environment



- The substances released are called emissions and can consist of gases or tiny particles.

### What is Air Pollution?

- Air pollution can occur indoors or outdoors and be from man-made processes or natural processes.



### Why Should We Care?

## The Great Smog of 1952

- In 1952, an unusually cold winter struck London, England.
- City dwellers were burning high amounts of sulfur-containing coal.
- In December, weather conditions were such that air pollutants became trapped over the city for days, creating a thick smog.



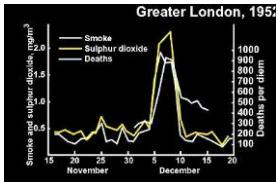
Mid Day  
Central London, December 1952

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## The Great Smog

- Londoners breathed the heavily polluted air for days, causing many thousands to become sick.

- Especially dangerous for people with respiratory or heart problems, the smog caused over 4,000 deaths (some estimate up to 12,000).



## Why Should We Care?

The World Health Organization estimates:

- A billion people live in places where the air is substandard.
- Air pollution kills 7 million people each year
  - ( 1 in 8 deaths are due to air pollution! )



## Why Should We Care?

- ~ 90% of deaths occur in developing countries.
- But air pollution doesn't stay in one place – it can be transported 100s of km making it a global problem.



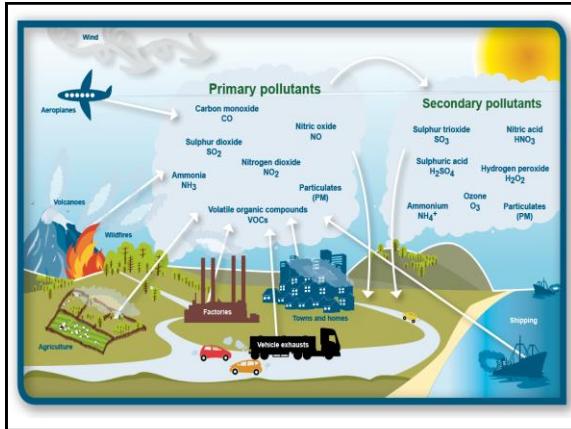
## Causes of Outdoor Air Pollution

- Natural processes such as volcanic eruptions and forest fires.
- Human sources as the vehicles we drive, our industries, and how we produce electricity.



## Primary vs Secondary Pollutants

- A primary pollutant is an air pollutant emitted directly from a source.
  - Carbon monoxide from vehicle exhaust
- A secondary pollutant forms when primary pollutants react in the atmosphere, either with water vapour or with sunlight.
  - Smog

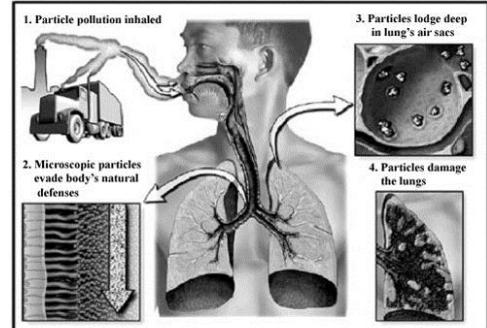


## Carbon Monoxide, CO

- Colourless, odourless gas formed when wood, gasoline or other fuels are burned
- Primary pollutant coming mostly from vehicle exhaust
- Very dangerous to human health because it reduces the amount of oxygen that blood can carry to cells

## Particulate Matter

- Solid particles (ash, dust, soot, molds) or liquid droplets (chemical aerosols) suspended in air
- Range in size from small to microscopic
  - Particles up to 10 microns PM<sub>10</sub>
  - <2.5 microns in diameter are labeled PM<sub>2.5</sub>



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## Nitrogen Oxides, NO<sub>x</sub>

- Reddish brown gas that readily reacts with other compounds
- Primary pollutant coming from vehicle exhaust, burning fossil fuels and even forest fires

## Nitrogen Oxides

- Can also be a secondary pollutant when it reacts with sunlight to produce smog



## Smog

- $\text{Smoke} + \text{Fog} = \text{Smog}$
- Smog is the unhealthy mixture of air pollutants that may form over cities and nearby areas.
- Two types: Industrial and Photochemical

## Industrial Smog

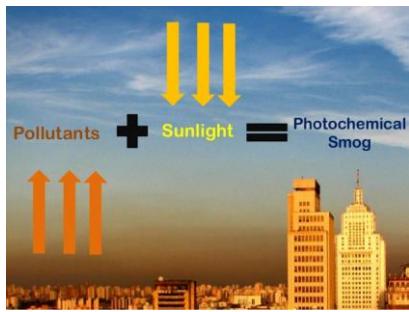


Shanghai People Square, China.

### 1. Industrial Smog

- Industrial smog is a whitish-grey haze produced when sulfur-rich coal is burned and the sulfur compounds combine with water droplets in air.
- Due to government regulations and advances in technology, this type of smog is less common in developed nations and more common in developing nations like China.

## Photochemical Smog

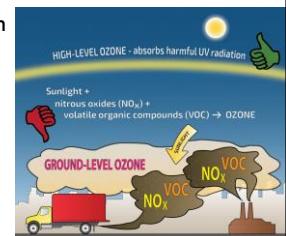


## Photochemical Smog

- Photochemical smog is brown-orange haze formed when sunlight acts on certain air pollutants, such as nitrogen oxides.
- Because the initial air pollutants come from vehicle emissions, photochemical smog is associated with large cities in developed nations.
  - Worse during summer months to increase in sunlight

## Photochemical Smog

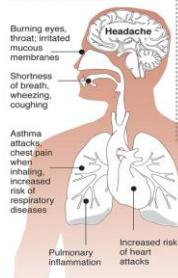
- A major pollutant in photochemical smog is ozone. “good up high, bad nearby”
- “good” ozone occurs high in the atmosphere to absorb UV radiation
- “bad” ozone is ground level and can damage living tissue



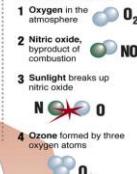
### Why smog is harmful

Ozone, the main ingredient in smog, is one of the most widespread air pollutants and among the most dangerous.

#### Effects on health



#### How ozone forms



| U.S. ozone limits    |       |
|----------------------|-------|
| In parts per billion |       |
| • 1997-2008          | 84    |
| • 2008-present       | 75    |
| • New EPA proposal   | 60-70 |

© 2010 MCT  
Source: American Lung Association, State of the Air 2008,  
AP Graphic Staff

### Effects of Ozone Exposure

Leaf metabolism & physiology  
- Antioxidant metabolism up-regulated  
- Decreased photosynthesis  
- Decreased stomatal conductance or sluggish stomatal response

Leaves & canopy  
- Visible leaf injury  
- Altered leaf senescence  
- Altered leaf chemical composition

Plant growth (Fig 9-8)  
- Decreased biomass accumulation  
- Altered reproduction  
- Altered carbon allocation  
- Altered crop quality

Belowground processes (Fig 9-8)  
- Altered litter production & decomposition  
- Altered soil carbon & nutrient cycling  
- Altered soil fauna & microbial communities

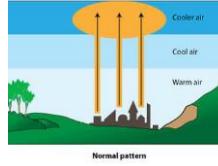


Ecosystem services  
- Decreased productivity  
- Decreased C sequestration  
- Altered water cycling (Fig 9-7)  
- Altered community composition (i.e., plant, insect & microbe)

### Smog and Temperature Inversions

#### Background:

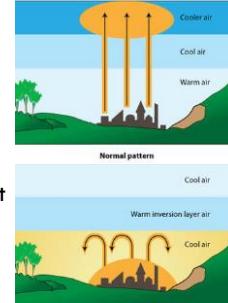
- Air temperature usually decreases with distance above the ground.
- Since warm air rises, airborne pollutants are often carried up into the atmosphere where they disperse.



### Smog and Temperature Inversions

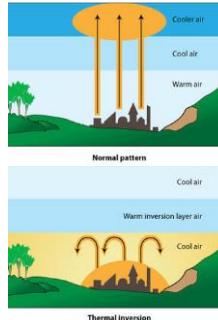
#### In a Temperature Inversion:

- The normal pattern switches and a layer of cool air is trapped beneath a layer of warm air.
- Since cool air is more dense, it cannot rise and thus air pollutants are trapped near Earth's surface.



### Smog and Temperature Inversions

- Temperature inversions (also called thermal inversions) can thus worsen air pollution.
- It was a thermal inversion that lead to the Great Smog of 1952.

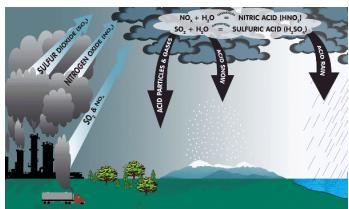


### Sulfur Dioxide, $SO_2$

- Colorless gas with a strong "rotten eggs" odor
- Primary pollutant coming from coal-burning power plants
- Can be a secondary pollutant when it reacts with water vapor to produce sulfuric acid (acid deposition)

## Acid Deposition

- Results when primary pollutants ( $\text{SO}_2$ ,  $\text{NO}_x$ ) combine with water in the atmosphere to form sulphuric acid, nitrous acid, and nitric acid



## Acid Deposition

- Wet deposition occurs when this acidic solution falls in various forms onto the landscape.

- In areas where the weather is dry, acid chemicals may attach to particles and fall to the ground through dry deposition.

## Effects of Acid Deposition

- Acidic soils have their nutrients washed away, slowing the growth of plants.



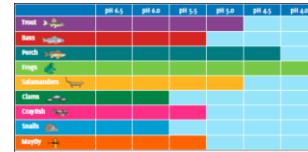
- Acid weakens plant tissues, resulting in defoliation and plant death.

## Effects of Acid Deposition

- Certain aquatic plants and animals cannot survive in low pH



- Effects felt up the food chain
- Large loss of biodiversity



## Effects of Acid Deposition



- Corrosive effects on buildings, statues and road structures.

## Conclusions

- An air pollutant is any gas or particle in the atmosphere that can cause harm or damage to organisms and the environment.
- Primary pollutants are released directly into the air and include  $\text{CO}$ ,  $\text{PM}$ ,  $\text{SO}_2$ , and  $\text{NO}_x$ .
- Secondary pollutants result from the interaction of primary pollutants and include smog and acid precipitation.