Air Pollution: History

Air Pollution: Any atmospheric constituent present as a result of anthropogenic activity or natural processes that causes adverse effects to humans, animals, vegetation, or materials.

Before 1200 AD

- Air pollution results from wood burning, tanning, decaying trash, smelting of ores.
- Greek, Rome:
  - 3rd Century BC Theophrastus (Aristotle student) “smell of burning coal was disagreeable and troublesome”.
  - Seneca (61 AD) noted oppressive conditions of the Roman air.
  - Roman’s invented “beach house” to escape.
  - Rome under strong T inversions called heavy heavens.
  - Roman first chimneys 7 to 8 m tall
  - Evidence of lead (glassware, pipes etc), copper (coins), zinc smelting

Early Smelting Emissions

Mineral deposits typically as sulfides: Cu_2S, PbS, ZnS

E.g.: Smelting for lead (smelting for other metals is the same)

Pulverize and heat

$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$

Reduce further by heating with carbon

$PbO + C \rightarrow Pb + CO$

Pollutants Produced: CO, SO_2

•Hong, et al., Greenland ice evidence of hemispheric lead pollution two millennia ago by Greek and Roman Civilizations, Science, 265, 1994.

•Renberg et al., Pre-industrial atmospheric lead contamination detected in Swedish lake sediments, Nature, 368, 1994.

1200-1700 AD

- London Middle Ages main pollution is limestone kilns heated with oak to produce quicklime: $CaCO_{3\ (s)}$ -> CaO; $CaO + H_2O$ -> $Ca(OH)_{2\ (s)}$ (cement))
  - Pollutants: organic gases, nitric oxide, carbon dioxide, organic PM
- London wood shortages led to use of sea-coal (high sulfur content) for kilns, various industry, and heating, etc
  - Pollutants: SO_2, CO, CO_2, NO, soot, and PM
  - 1285 a commission established to remedy severe pollution
    - 1306 Edward I banned coal use in lime kilns (ignored and not enforced -little effect)
    - Use of sea-coal increased in London with time
  - John Evelyn (1661) wrote “Fumifugium, or the Inconvieniencie of the Aer and the Smoake of London Dissipated”
    - London smoke caused fouling of churches, palaces, clothes, furnishings, paintings, rain, dew, water, and plants
    - Blamed brewers, diers, limeburners, salt and sope-boylers
    - Can ‘Sooner smell than see city”
    - Proposed
      - Limit use of coal
      - Relocate industries
      - Develop new fuels
      - Planting green belts around city

- 1700-1840: The Steam Engine
  - Denis Papin (1647-1712), Thomas Savery (1650-1715), Thomas Newcomen (1663-1729), James Watt (1736-1819)
  - Steam engine -> large centralized energy source -> factory replaces artisan shop = industrial revolution
  - x100 increase in G.B. coal combustion between 1800-1900 estimated air pollution in G.B. killed 7x more people than world wide (Clapp, 1994)
  - Industries centered around coal combustion developed globally (US, Europe, Japan, Australia, Russia, S. Africa)

- Regulation in United Kingdom 1840-1930
  - London: Bills before parliament 1843, 1845, 1846, 1849, 1850 - defeated often by industry
    - (1845 bill, Railway Clauses Consolidated Act - railway engine's must consume their own smoke)
  - Emission classes past in 1851, 1853, 1863, .. Public Health Acts of 1875 and 1891, Smoke Abatement Act of 1926

- Early US Regulation, 1869-1940
  - 1800 US pollution from coal combustion in manufacturing, home heating, and transportation
  - Early pollution control carried out by municipalities
  - 1869 Pittsburgh outlaw locomotive soft coal burning in city - not enforced
  - 1881 Cincinnati passed smoke reduction law and appointment of smoke inspector- not enforced
    - 3 primary causes of death in Cincinnati 1881

      Tuberculosis, pneumonia, bronchitis - all lung related
  - 1881 Chicago smoke reduction law - had no effect
  - 1893 St Louis: Law forbidding “dense black or thick gray smoke” and inspector appointed - overturned by MO State Supreme Court ordinance exceeded the “power of city under its charter” and was “wholly unreasonable”
  - By 1920 air pollution ordinances existed in 175 municipalities, by 1940 increased to 200
  - Invention of the electric motor relocated pollution in some cities by centralizing power production versus production at each factory

Example of early instrumentation to measure atmospheric pollutants

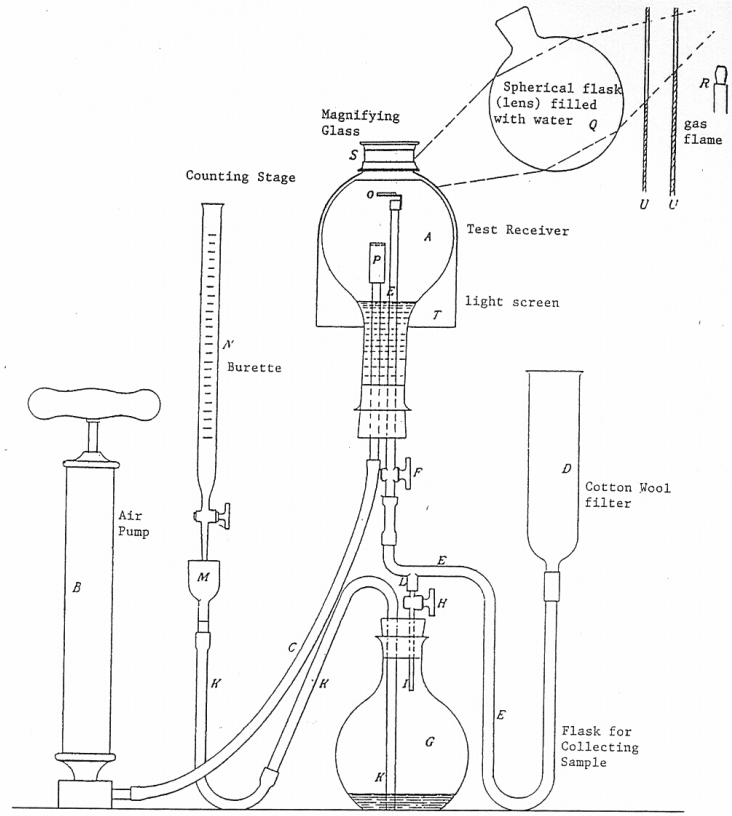


FIGURE 2. John Aitken's Dust Counter for measuring particle concentrations. Reproduced by permission of the Royal Society of Edinburgh from *Transactions of the Royal Society of Edinburgh*, volume XXXV (1887–1890), pp. 1–20.

"Though this investigation clearly shows that the sun produces certain kinds of fogs, yet it is by no means here contended that it is to be censured for their appearance. It would rather appear that it is doing its best to show us the state of pollution into which our modern civilization has brought our atmosphere, as it only inflicts these fogs on the areas upon which man has thrown the waste products of his industries and converted the atmosphere into a vast sewer, as a penalty for something wrong in his methods."

C. T. R. Wilson developed a refined expansion cloud chamber that he initially used to study homogeneous nucleation. His early work involved precise measurements of expansion ratios that led to cloud formation in the presence of dust-free air saturated with water vapor (Wilson

John Aitken's Dust Counter, 1888

Used instrument to investigate photochemical aerosol formation. His atm. exp. showed aerosol concentrations were higher when the wind was blowing from industrial sources and that the impact of these pollution sources was exacerbated by sunlight, high RH, and low wind speeds. Conducted controlled experiments to confirm the hypothesis ….he demonstrated that sulfurous gases emitted by coal combustion contributed to air pollution.

AS&T, McMurry, 33, pg 297, 2000

Disasters Leading to Changes

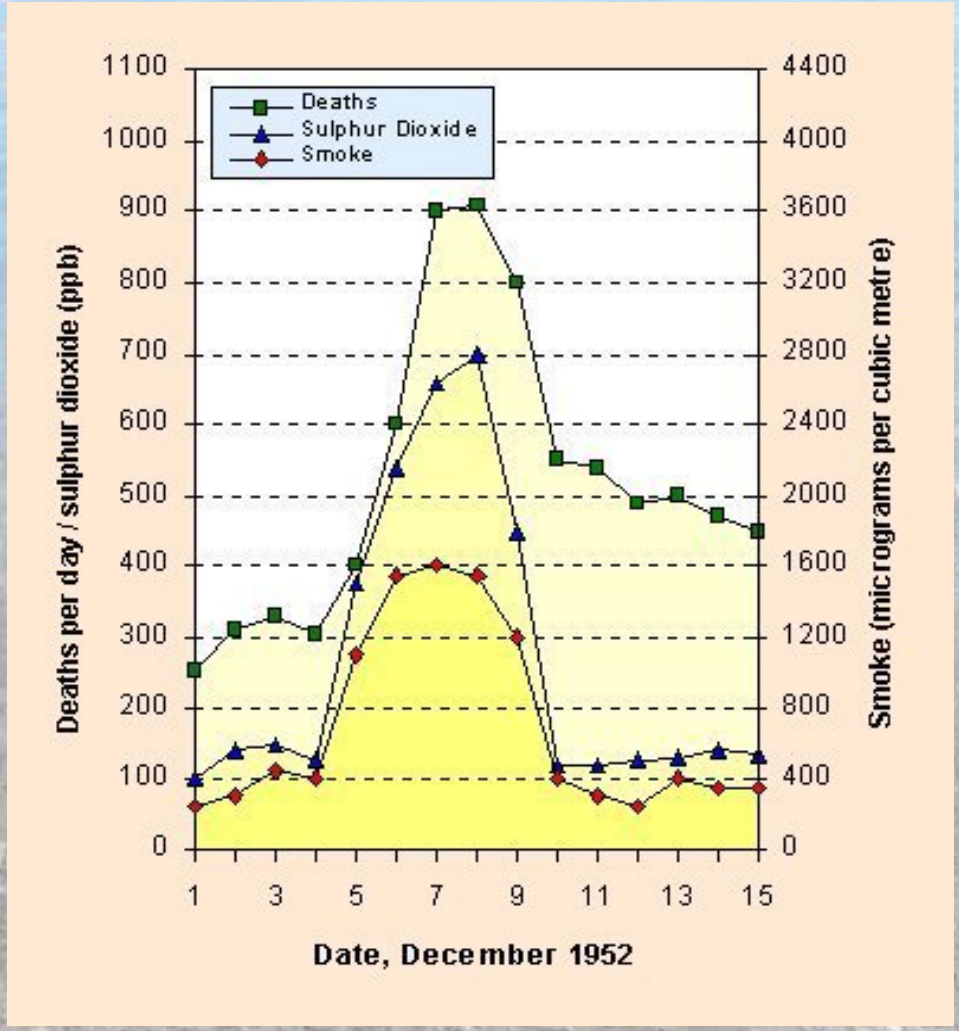
London-Type Smog

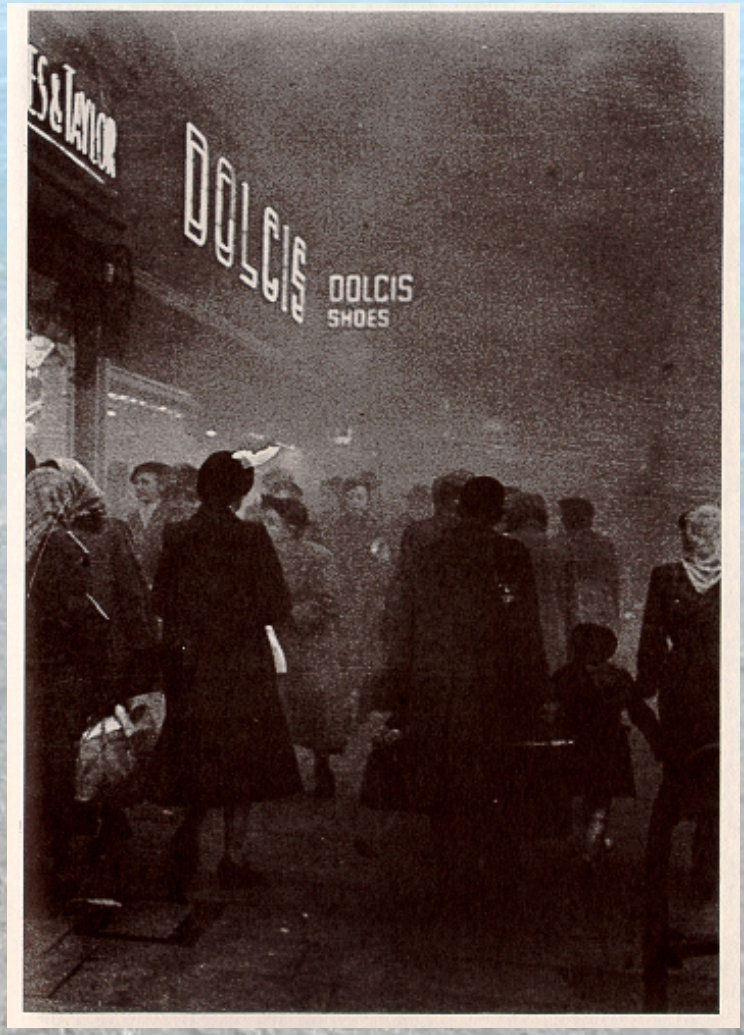
- H. Des Voeux described the combination of smoke and fog that was visible in cities throughout GB. Presented a paper in 1911 describing Autumn 1909 Glasgow and Edinburgh events that killed more than 1,000
- Led to term smog: smoke-fog
  - Then: smoke in smog was mainly from coal combustion and other raw materials
  - Now: pollution from coal and other combustion in presence of fog or low-lying T inversion is called London-type smog

- London Events
  - Dec. 1873: 270 - 700 more deaths than average rate
  - Jan 1880 : 700 - 1,100 excess deaths
  - Dec 1892: 1,000 excess deaths
  - Nov. 1948: 300 "
  - Dec. 1952: 4,000 "
  - Jan 1956: 480 "
  - Dec 1957: 300 - 800 "
  - Dec 1962: 340-700 "

  - Worst Case was Dec 1952
    - Excess deaths in all age groups, but greatest for those over 45
    - 80% of the dead had history of heart or respiratory problems
    - Cause, T inversions + fog + heavy emissions (esp. coal combustion)
    - Peak SO_2 ~1.4 ppmv (EPA 24hr avg 0.14 ppm)
    - Peak PM 4,460 µg/m3 (EPA 24 hr avg. PM10 150 µg/m^3)
    - At noon - streets so dark buses guided by lantern light.

The London Fog Incident of 1952





Adapted from: Wilkins, 1954

- Meuse Valley, Belgium, Dec 1930
  - 5-day fog event + T inversions + heavy SO_2 emissions from coal combustion
  - 63 excess deaths (mainly during last days of event), mainly elderly and previous heart or lung diseases.
  - 6,000 became ill
  - Chest pain, cough, shortness of breath, eye irritation

- Donora, Pennsylvania, US, Oct 26-31, 1948
  - Allegheny County:
    - large coal deposits
    - Iron and glass then later steel manufacturing with uncontrolled coal burning until abatement laws passed in 1941 - suspended due to WWII, but never did have much effect
  - **Read hand-out (see class web page)**

Donora, Pennsylvania, US, Oct 26-31, 1948

Figure 4.3. Noontime photograph of Donora, Pennsylvania, on October 29, 1948, during a deadly smog event. Courtesy of the Pittsburgh Post-Gazette.

Photochemical Smog (LA)

- Persistent pollution problems in sunny regions (note, very different from short deadly event discussed above)
- Most prominent was a pollution layer formed almost daily over LA.
  - Juan Rodirguez Cabillo (Oct 1542 - 50 yr after Columbus) called it Bahia de los Humos (bay of smoke) from Native's fires
- Early 1900's LA pollution due to smoke (London-type smog) + chemically formed pollutants called photochemical smog.
- 1903 factory smoke so thick people think there is a solar eclipse
- 1905 and 1912 LA city council adopt regulations controlling smoke emissions
- Relative influence of photochemical smog to London-type smog increases with increase use of cars
- 1943 visibility reduced to 3 city blocks
- 1945 emission of dense smoke banned
- 1947 over opposition of chamber of commerce and oil companies legislation passed to allow counties to set up air pollution control districts
  - Major industries required to obtain emission permits
- Late 40s early 50s
  - Regulated open burning such as backyard incinerators, burning in garbage dumps, SO2 from refineries, emissions from industrial gasoline storage tanks
  - Problems still persisted.

- 1948 studies plant damage by smog (CalTech)
- 1950 finds plants in sealed chamber exposed to ozone react in same way as those exposed to outdoor smog -> concludes ozone a component of smog
- Also found ozone causes eye irritation, damage to materials, respiratory problems
- CalTech workers find rubber cracks within minutes when exposed to ozone
- 1952 Haagen-Smit discovers ozone formation mechanism
  - Oxides of nitrogen+reactive organic gases + sunlight
  - Suggests ozone + precursors main constituent of LA smog
  - Oil companies, business leaders argue ozone from stratosphere, but ozone low in nearby Catalina Is.
- Photochemical smog still a problem in many cities world-wide, Atlanta, LA, Houston, Mexico City, Tokyo, Beijing, Athens, etc.

- Photochemical smog does not require smoke or fog
- Photochemical and London-type smog are exacerbated by strong T inversions.

Other Air Pollution Tragedies

Industrial accidents, e.g., Union carbide - India

Natural “Pollution” Events

- Volcanic Eruptions
- Lake Nyos Tragedy, Aug. 21 1986, 1,800 asphyxiation deaths from sudden release of CO_2 from cold deep waters of crater lake over “extinct” volcano, (EOS, 85, No 30, 27 July 2004) - warning for carbon sequestration?

Similar situations to this day: Tension between Industries and Environmental Concerns

E.g., Power plant emissions, (coal) ~ 1/3 of nations pollution (not considering CO2),

TABLE 2.2. Air Pollution Episodes

Location	Date	Pollutants	Symptoms and Effects
Meuse Valley, Belgium	Dec. 1–5, 1930	SO_2 (9.6–38.4 ppm)	63 excess deaths, chest pain, cough, eye and nasal irritation, all ages affected.
Donora, PA	Oct. 26–31, 1948	SO_2, particles (0.5–2 ppm)	20 excess deaths, chest pain, cough, eye and nasal irritation, older people mainly affected.
Poza Rica, Mexico	Nov. 24, 1950	H_2S	22 excess deaths, 320 hospitalized, all ages affected.
London	Dec. 5–9, 1952	SO_2, particles	4000 excess deaths.
New York	Nov. 24–30, 1966	SO_2, particles	168 excess deaths.

Table 6.4. *Air pollution disasters*

	Meuse Valley, Belgium 1930	Donora, Pennsylvania 1948	Pozo Rico, Mexico 1950	London, UK 1952	Bhopal, India 1984	London, UK 1991
Mortality and morbidity						
Deaths	60	15	22	4000	2500?	160
Ill	6000	5900		>20000	10000?	
Age groups affected						
	elderly	elderly	all ages	elderly at first		patients with respiratory illness
Weather						
	anticyclonic inversion and fog	anticyclonic inversion and fog	nocturnal inversion, low winds	anticyclonic inversion and fog	nocturnal low winds(?)	anticyclonic inversion and fog as in 1952
Geographical setting						
	river valley	river valley	coastal	river plain		river valley
Sources						
	steel and zinc manufacture	steel and zinc manufacture	sulphur recovery (accident)	domestic coal burning	fracturing of tank (accident)	vehicles
Pollutants						
	SO_2, smoke	SO_2, smoke	H_2O	SO_2, smoke	methyl-isocyanide	NO_2, particles

Conclusions: Meteorology + pollution sources play a large role in determining ambient pollution levels: this class will investigate both