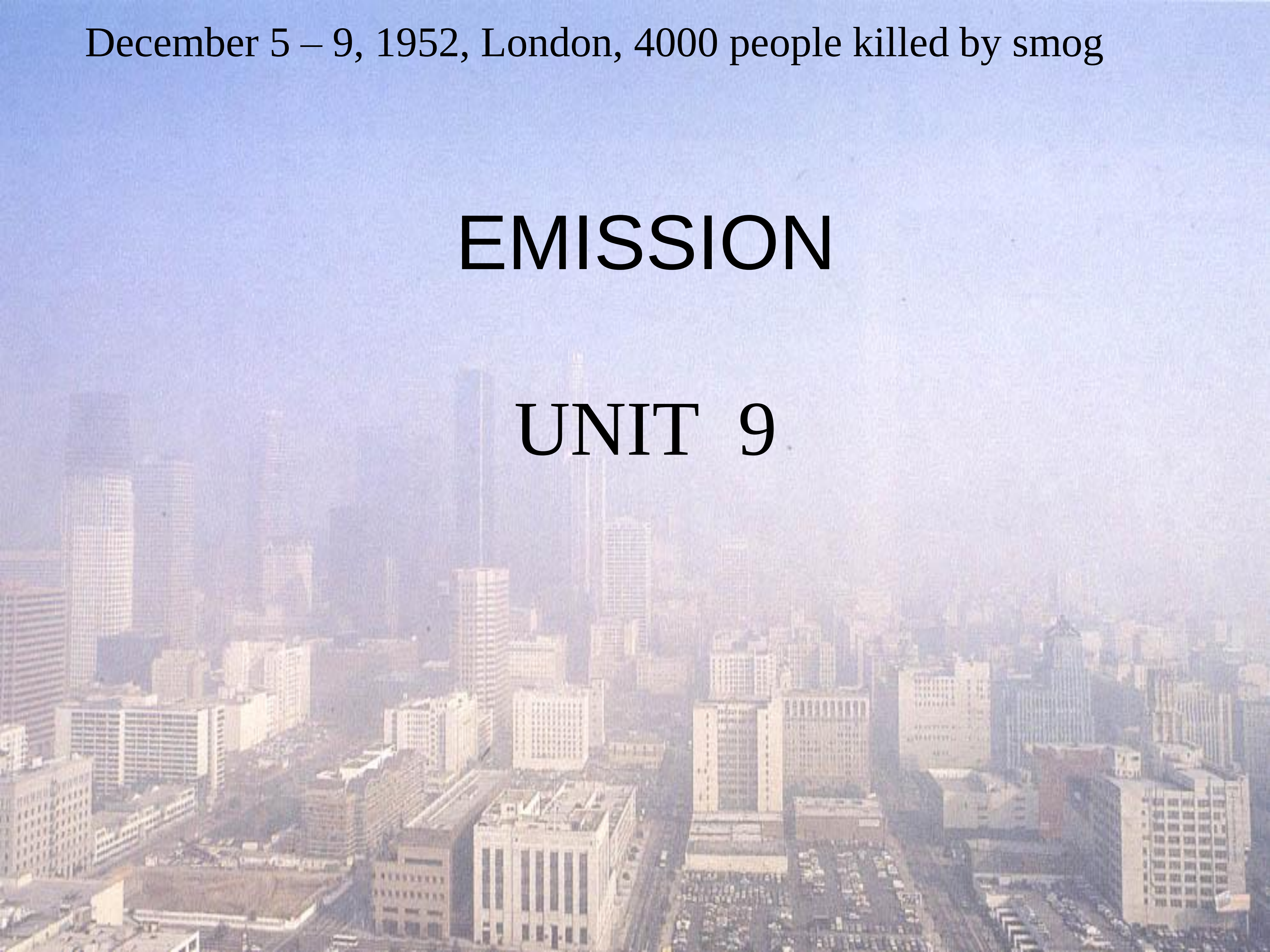
December 5 – 9, 1952, London, 4000 people killed by smog

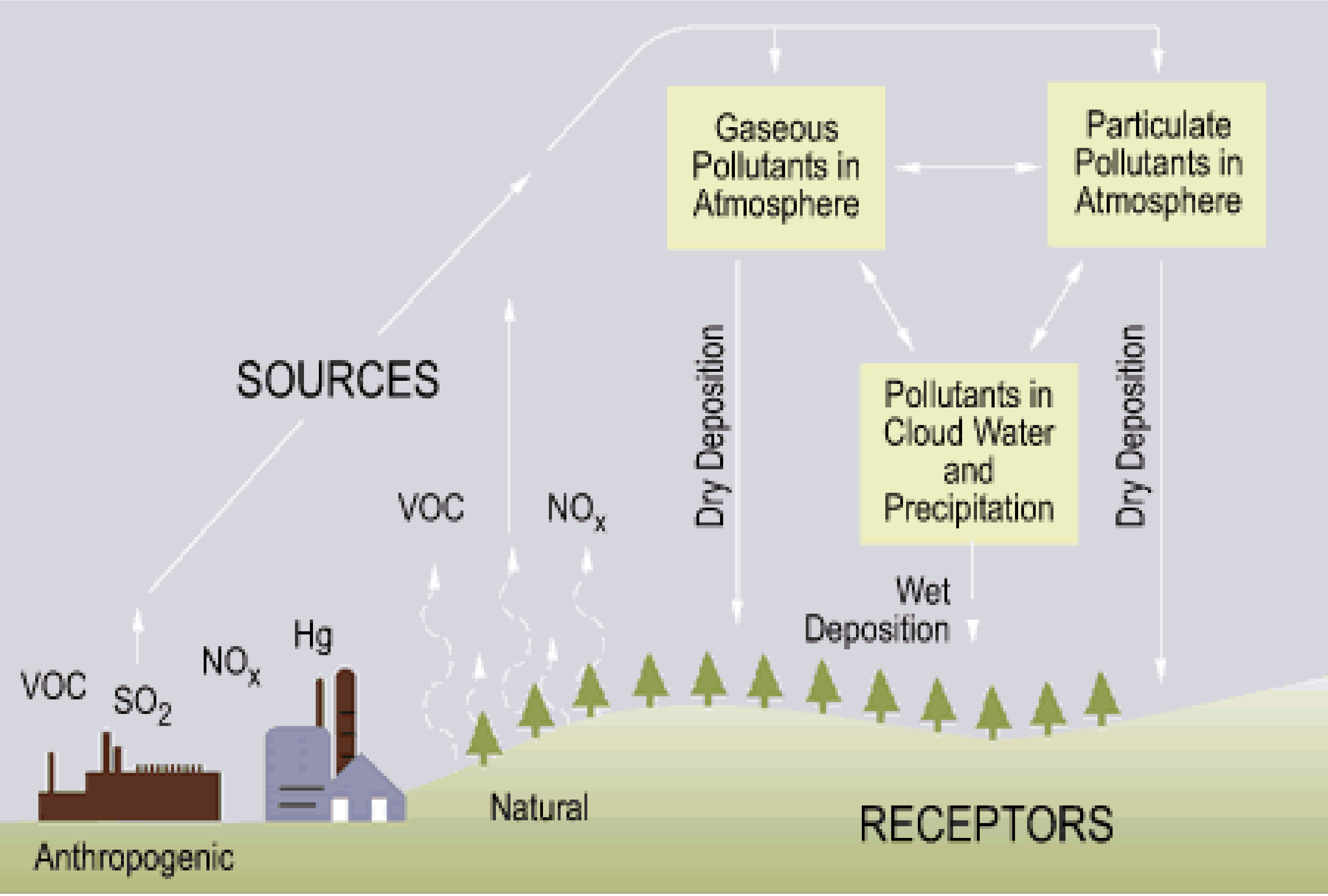
EMISSION

UNIT 9



ACID RAIN

- "Acid rain" is a broad term used to describe several ways that acids fall out of the atmosphere. A more precise term is acid deposition, which has two parts: wet and dry.
- Wet deposition refers to acidic rain, fog, and snow. As this acidic water flows over and through the ground, it affects a variety of plants and animals.
- Dry deposition refers to acidic gases and particles. The wind blows these acidic particles and gases onto buildings, cars, homes, and trees. Dry deposited gases and particles can also be washed from trees and other surfaces by rainstorms. Prevailing winds blow the compounds that cause both wet and dry acid deposition across state and national borders, and sometimes over hundreds of miles.

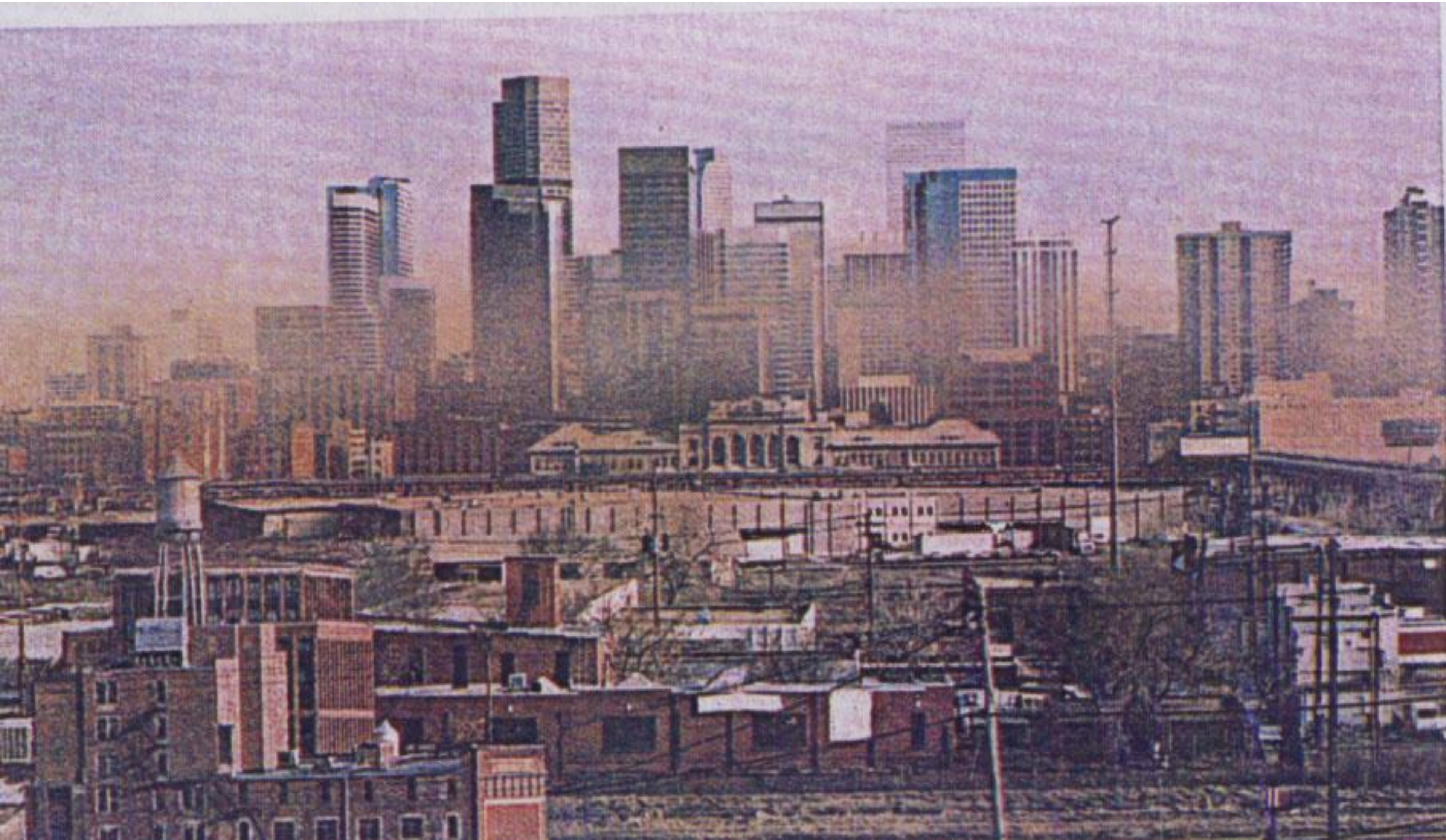


Gaseous Pollutants in Atmosphere
Particulate Pollutants in Atmosphere
Pollutants in Cloud Water and Precipitation
SOURCES
Dry Deposition
Dry Deposition
VOC
NO_x
Wet Deposition
VOC
SO_2
NO_x
Hg
Natural
RECEPTORS
Anthropogenic

Effects of Acid Rain

- Acid rain causes acidification of lakes and streams and contributes to damage of trees at high elevations (for example, red spruce trees above 2,000 feet) and many sensitive forest soils.
- In addition, acid rain accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage.
- Prior to falling to the earth, SO2 and NOx gases and their particulate matter derivatives, sulfates and nitrates, contribute to visibility degradation and harm public health.

Smog over a city



Smog & transport of Ozone

- Smog is the brownish haze that pollutes our air, particularly over cities in the summertime. Smog can make it difficult for some people to breathe and it greatly reduces how far we can see through the air.
- The primary component of smog is ozone, a gas that is created when nitrogen oxides (NOx) and VOC react with other chemicals in the atmosphere, especially in strong sunlight.
- NOx is produced due to burning of as coal in a power plant or gasoline in a car's engine.

Smoky Mountain

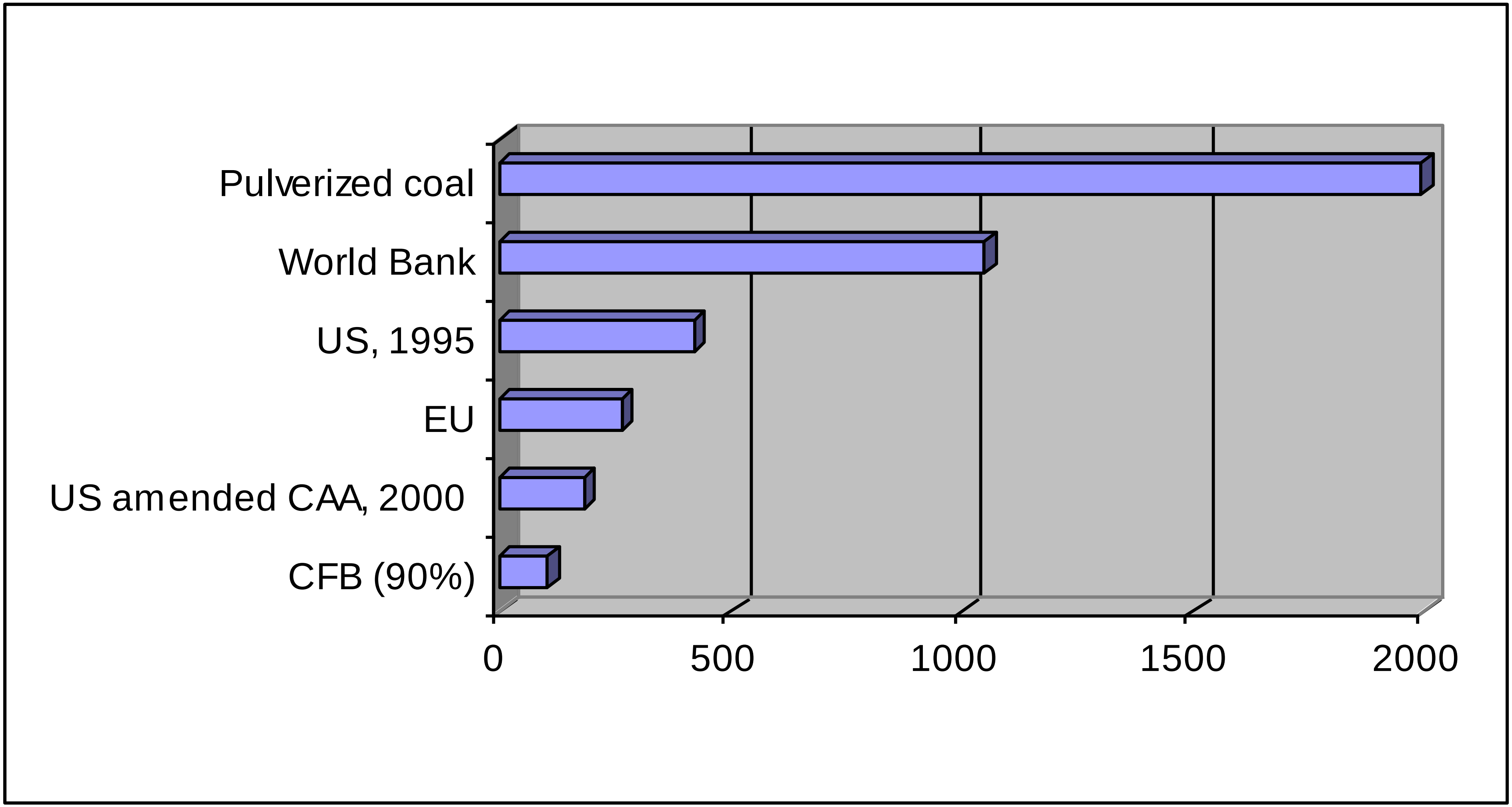
Clear day

Hazy day

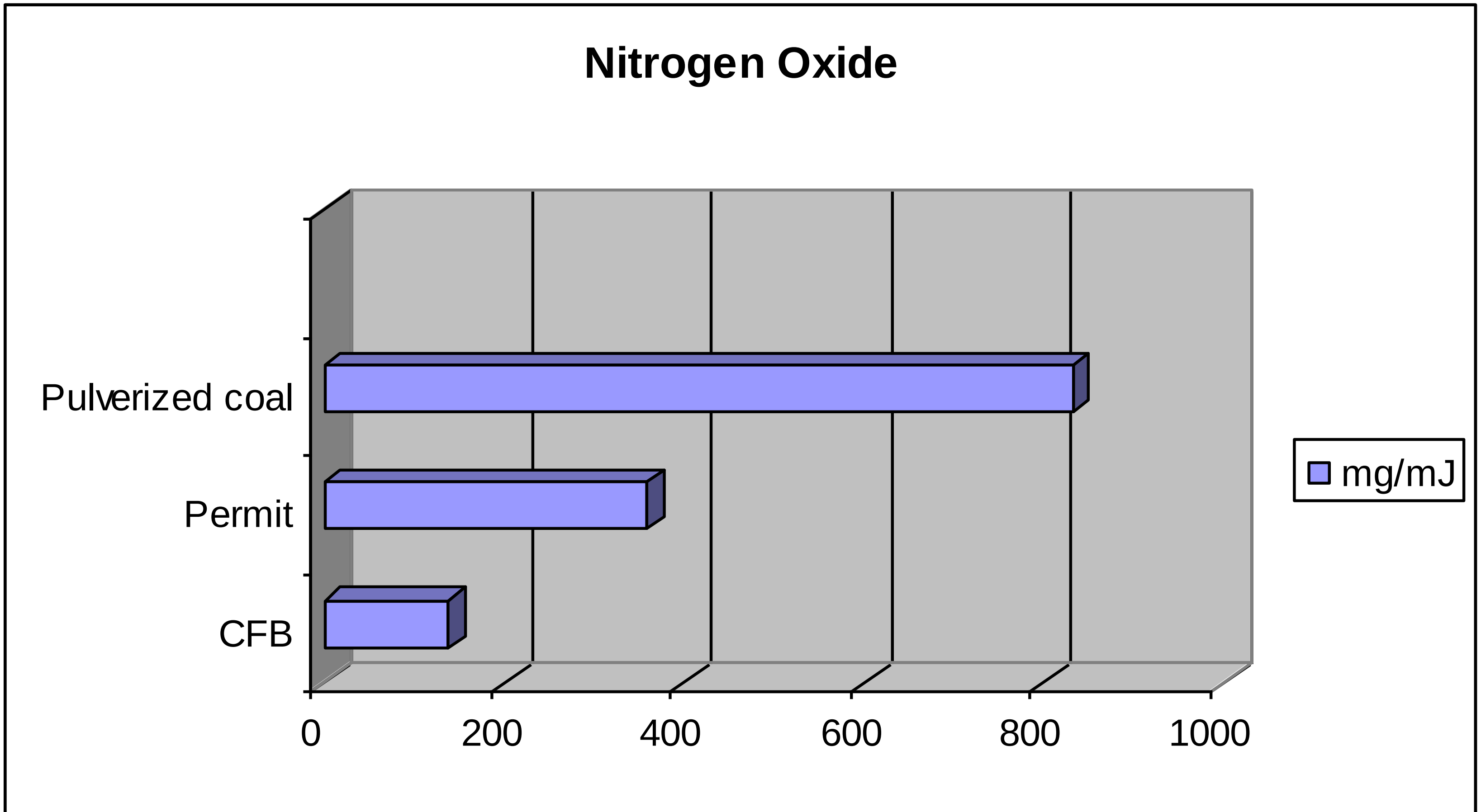
What is Haze

- Haze is caused when sunlight encounters tiny pollution particles in the air. Some light is absorbed by particles. Other light is scattered away before it reaches an observer.
- More pollutants mean more absorption and scattering of light, which reduce the clarity and color of what we see. Some types of particles such as sulfates, scatter more light, particularly during humid conditions.

SULFUR DIOXIDE EMISSIONS (mg/MJ) for 4% S, 15 MJ/kg Coal]



NITROGEN OXIDE EMISSION



How SO_2 is produced

- Sulfur in the fuel readily combines with O_2 to form sulfur dioxide
- $S + O_2 = SO_2$
- Limestone in added to absorb SO_2
- $CaCO_3 + SO_2 + ½ O_2 = CaSO_4$, but this reaction is effective in temperature around 850 C

- Post-combustion cleaning is done at lower temperature with the overall reaction
- $2CaCO_3 + 2SO_2 + H_2O = 2CaSO_3 + H_2O + 2CO_2$

Amount of limestone needed for sulfur capture in CFB boiler

- It is a function of several factors

$$\frac{F_{sor}}{F_{fuel}} = \frac{3.12\eta_{sor}\rho_{bav}H_{fur}.S - 100\alpha U_g A\eta_{cy}\ln(1-\eta_{sor})}{\eta_{cy}[\delta_{\max}X_{caco3}\rho_{bav}H + 100\alpha U_g \ln(1-\eta_{sor})]}$$

- Where α is a limestone reactivity parameter (α= C_{SO2} x Pore plugging time constant). For Calpo it is 13.46 m3/kmol.s

Generation of Nitrogen Oxide

- Oxidation of nitrogen in combustion air and fuel contributes to the generation of NO or NO_2 (NOx).
- The oxidation of air-nitrogen is appreciable only above 1500 C
- But, oxidation of fuel nitrogen can occur at lower temperatures. It can be reduced by staging the combustion air. (Low NOx burner)
- Ammonia can convert NOx to N_2 in presence of catalyst (SCR)

$4NO + 4\ NH_3 + O_2$ - $4\ N_2 + 6\ H_2O$

Pollution control technologies

- Nitric oxide:
  - Low NOx burner
  - Fluidized Bed boiler
  - Selective Catalytic Reactor
- Sulfur dioxide
  - Flue gas desulphurization Scrubber
  - Fluidized Bed Boiler
  - Limestone injection

Flue gas scrubber

- Sulfur dioxide absorption
- $CaCO_3 + 2SO_2 + H_2O = Ca^{+2} + 2HSO^-_3 + CO_2$
- Solid precipitation
  $CaCO_3 + Ca^{+2} + 2HSO^-_3 = 2CaSO_4.2H_2O$
  For in-situ absorption
- $CaCO_3 = CaO + CO_2$
  $CaO + SO_2 + 1/2O_2 = CaSO_4$

Catalytic reducers

- With ammonia
- $2NO = 2NH_3 + 1/2O_2 = 2N_2 + 3H_2O$
- With Urea

  $2NO + CO(NH_2)_2 + 1/2O_2 = 2N_2 + 2H_2O + CO_2$

Conversion Table for pollutants

coal	1 mg/ Nm^3	1 g/GJ	lb/10^6 BTU			
ppm NO	2.05	0.718	8.14x 10^{-4}			
ppm SO2	2.86	1.0	2.33 x 10^{-3}	mg/ Nm^3	g/GJ	lb/10^6 BTU
		oil	ppm NO	2.05	0.575	1.34 x 10^{-3}
			ppm SO2	2.86	0.801	1.86 x 10^{-3}