

*From air pollution
to indoor air
quality*

Air pollution is the presence in ambient atmosphere of substances generally resulting from the activity of man, in sufficient concentration, presents for a sufficient time and under circumstances which interfere significantly with the comfort, health or welfare of persons or with the full use or enjoyment of property.



The presence of contaminants or pollutant substances in the atmosphere that interferes with human health or welfare, or produce other harmful environmental effects.



Air pollution is the excessive concentration of foreign matter in the air which adversely affects the well being of individual or causes damage to property.



Evolution of air pollution as a problem



Lighting the fire



smoke



air pollution started

Burning of wood was used for cooking, heating of caves and smelting furnaces.



Smoke was most likely tolerated indoors because it helped to keep away the mosquitoes.

The caves was found thick black layer because of air pollution.

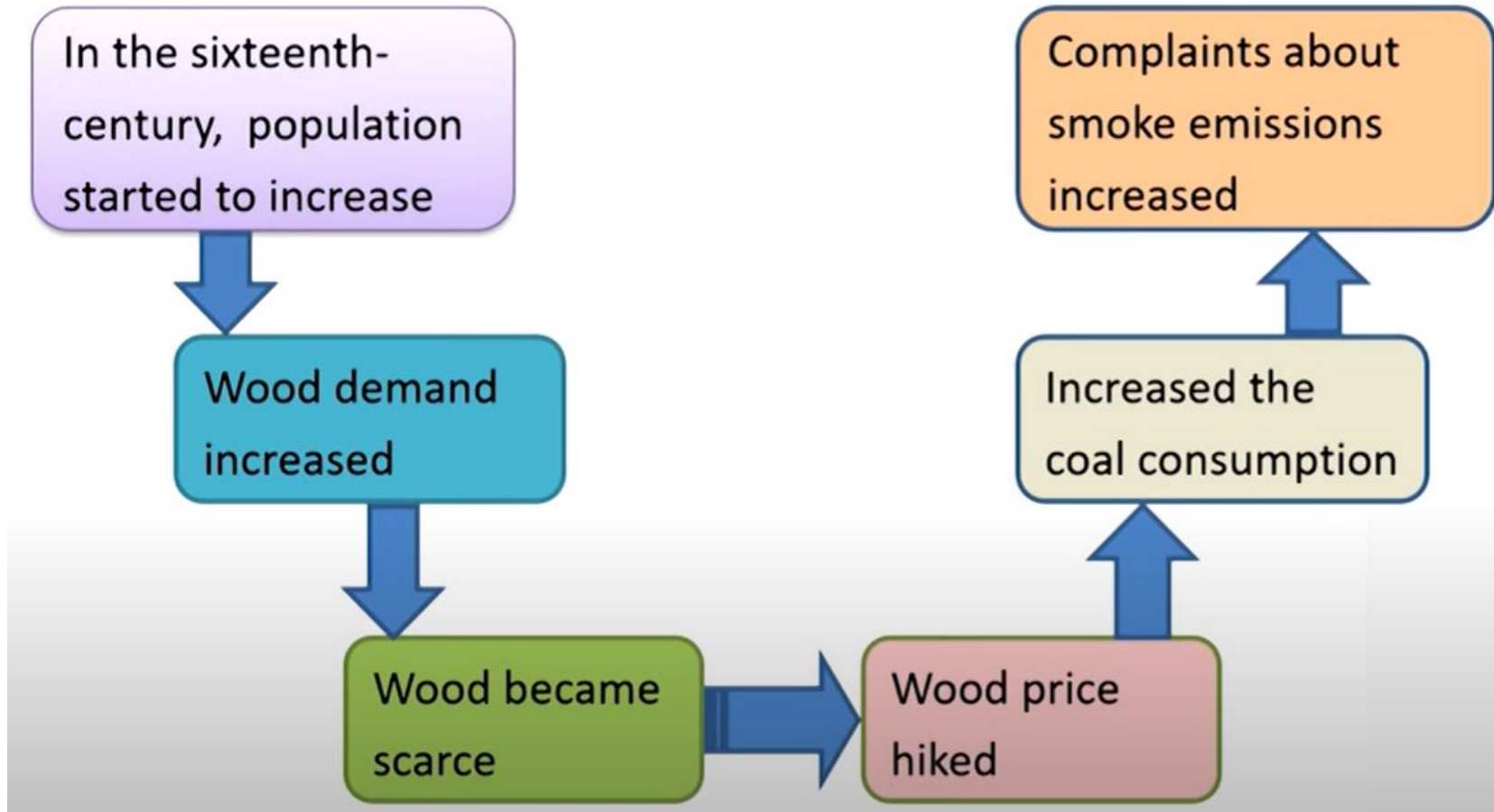




Scientists found blackening of the lungs in the samples of mummified lung tissues from Egypt, Peru and Britain.

That revealed long term exposure to the smoke of domestic fires.







Wood burning



Coal burning
started



Oil started
used as fuel




Severe air
pollution problem
started

By 1900, global coal output had increased by 77 % annually with respect to 1800.



Air pollution rose to unprecedented levels as coal demand increased for industrial and home energy uses.

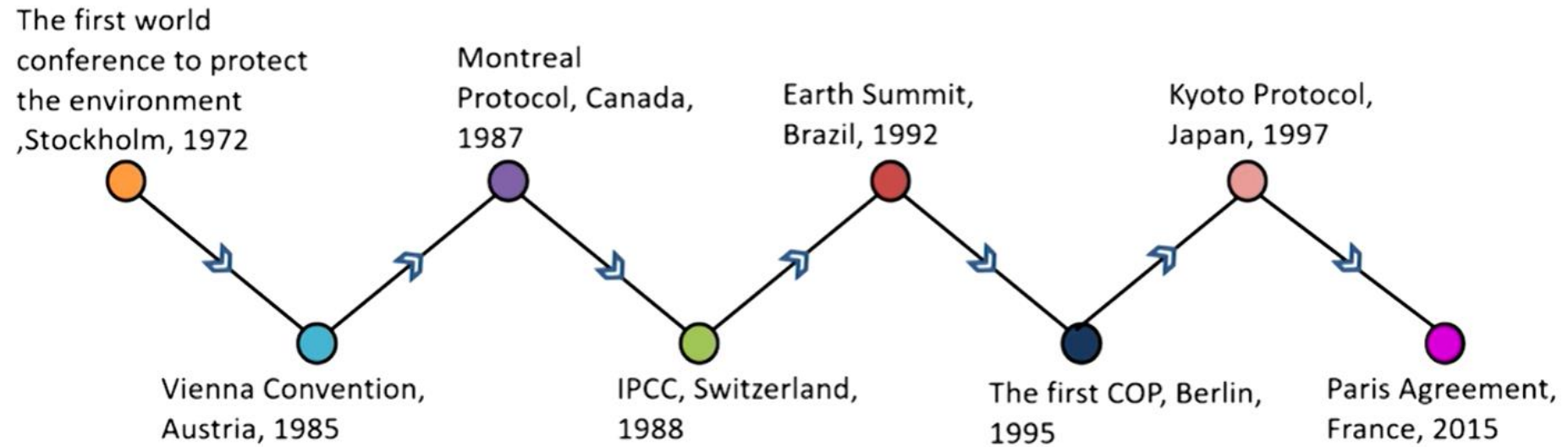


Increased the negative impacts on nature and human health.

Air pollution legislation history

Year	Action
1955	First Federal Air Pollution Control Act (USA)
1960	Motor Vehicle Exhaust Act (USA)
1963	Clean Air Act (USA)
1965	Motor Vehicle Air Pollution Control Act (USA) <ul style="list-style-type: none">• Emission regulations for cars to begin in 1968
1967	Air Quality Act (USA) <ul style="list-style-type: none">• Criteria documents• Control technique documents
1970	Clean Air Act Amendments (USA) <ul style="list-style-type: none">• National Ambient Air Quality Standards• New Source Performance Standards

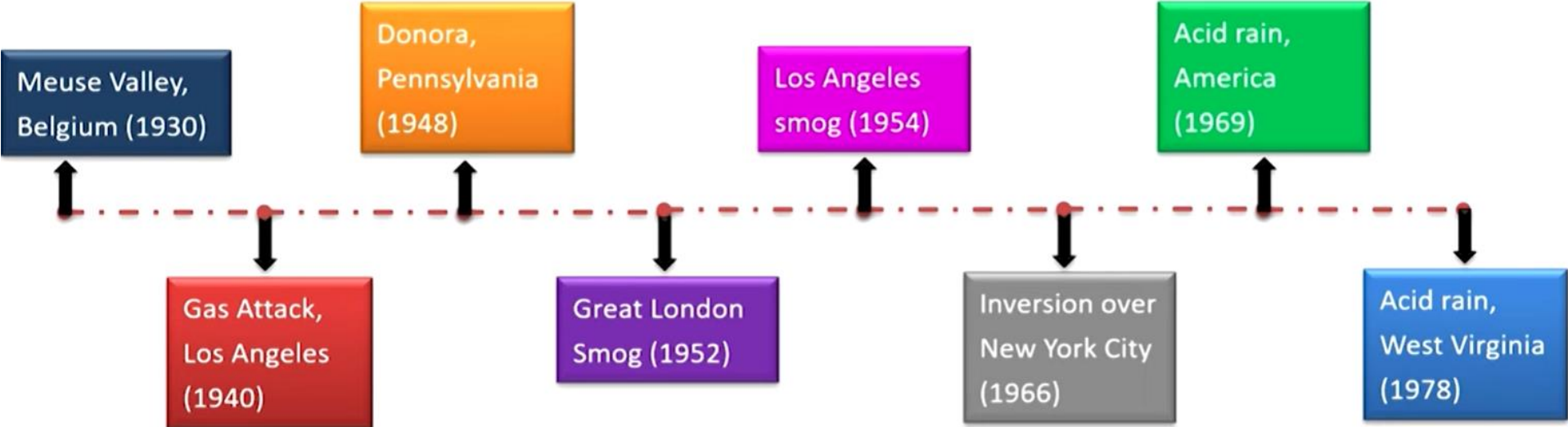
Environmental Protection Programs



IPCC: Intergovernmental Panel on Climate Change

COP: Conference of the Parties

Air pollution episodes

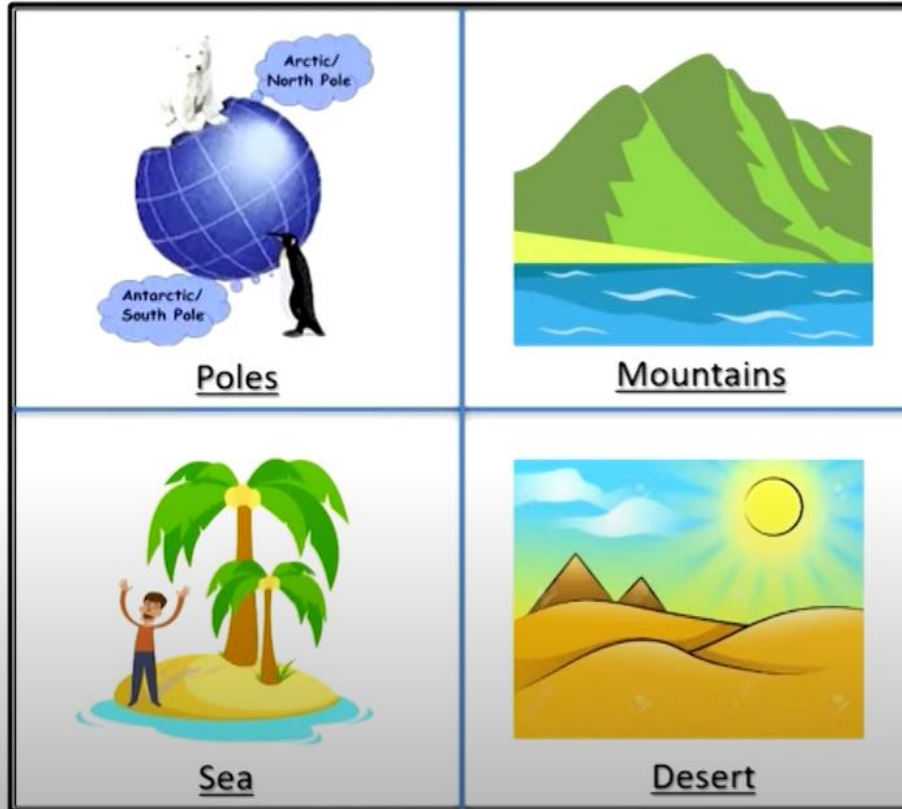


What is Unpolluted Air?

- To determine the extent of pollution in air, we need to establish the baseline for comparison.
- Though, it is not possible to determine the precise composition of unpolluted air.

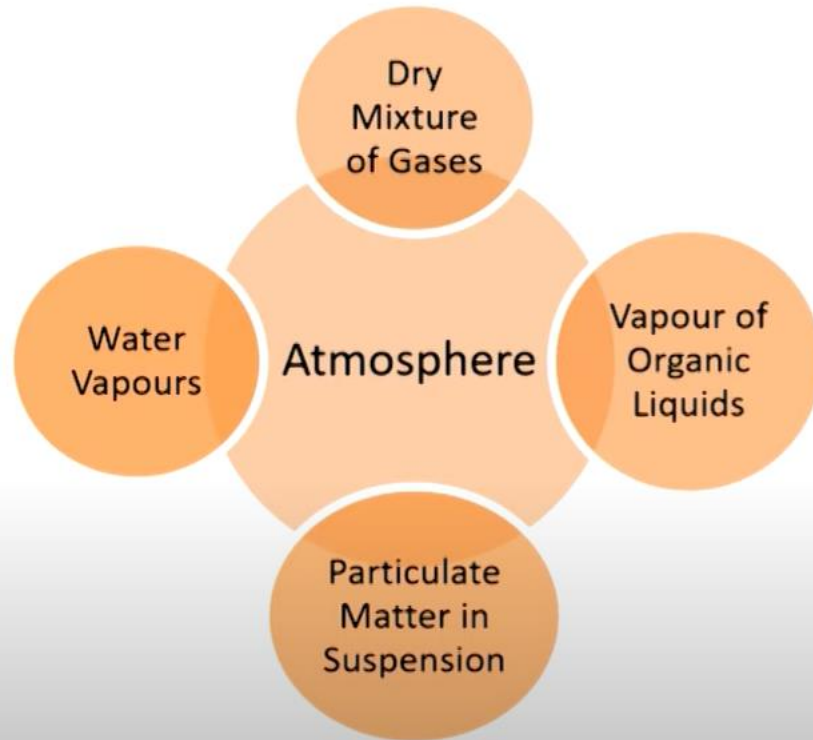


Unpolluted Air: Concept



- Unpolluted air may closely be approximated with remote locations.
- Although these places may contain indication of aged man-made pollution.

Composition of Unpolluted Air

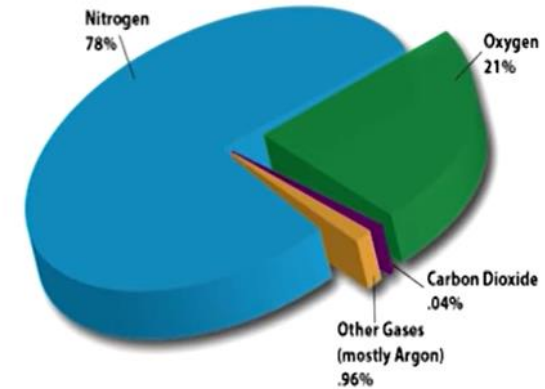


- The real atmosphere is more than a dry mixture of permanent gases.
- The quantity of water vapor in the air varies greatly from almost complete dryness to supersaturation (0% - 4% by weight)

Gaseous Composition of Unpolluted Air

Name of Gases	Wet Basis ppm (vol.)	Dry Basis ppm (vol.)	Dry Basis $\mu\text{g}/\text{m}^3$	Wet Basis $\mu\text{g}/\text{m}^3$
Nitrogen	756500	780000	8.95×10^8	8.67×10^8
Oxygen	202900	209400	2.74×10^8	2.65×10^8
Water	31200	--	--	2.30×10^7
Argon	9000	9300	1.52×10^7	1.47×10^7
Carbon dioxide	305	315	5.67×10^5	5.49×10^5
Neon	17.4	18	1.49×10^4	1.44×10^4
Helium	5	5.2	8.50×10^2	8.25×10^2
Methane	0.97 - 1.16	1.0 - 1.2	$6.56 - 7.87 \times 10^2$	$6.35 - 7.63 \times 10^2$
Krypton	0.97	1	3.43×10^3	3.32×10^3
Nitrous oxide	0.49	0.5	9.00×10^2	8.73×10^2
Hydrogen	0.49	0.5	4.13×10^1	4.00×10^1
Xenon	0.08	0.08	4.29×10^2	4.17×10^2
Organic vapors	0.02	0.02	--	--

Source: (Fundamentals of Air Pollution, R W Boubel)



Source: (<https://scied.ucar.edu/learning-zone/air-quality/whats-in-the-air>)

What is Polluted Air?

Air is said to be polluted when there is a presence of undesirable substances (contaminants / pollutants) which interfere with human health or welfare, or produce other harmful environmental effects.



Contamination vs Pollution

Contamination is simply the presence of a substance where it should not be or at concentrations above background.

Pollution is contamination that results in or can result in adverse biological effects to resident communities.

All pollutants are contaminants, but not all contaminants are pollutants.

Classification of air pollutants

- ✓ Based on sources
 - Natural pollutants
 - Anthropogenic (man-made) pollutants

- ✓ Based on origin
 - Primary Pollutant
 - Secondary Pollutant

- ✓ Based on state of matter
 - Gaseous air pollutants
 - Particulate air pollutants

Sources of air pollutants

- Natural sources
 - e.g., natural fog, pollen grains, bacteria, and volcanic eruptions.
- Anthropogenic sources
 - e.g., Industrial fumes, vehicular emissions



1. Volcanic Eruption



2. Pollen grains



3. Industrial Fume



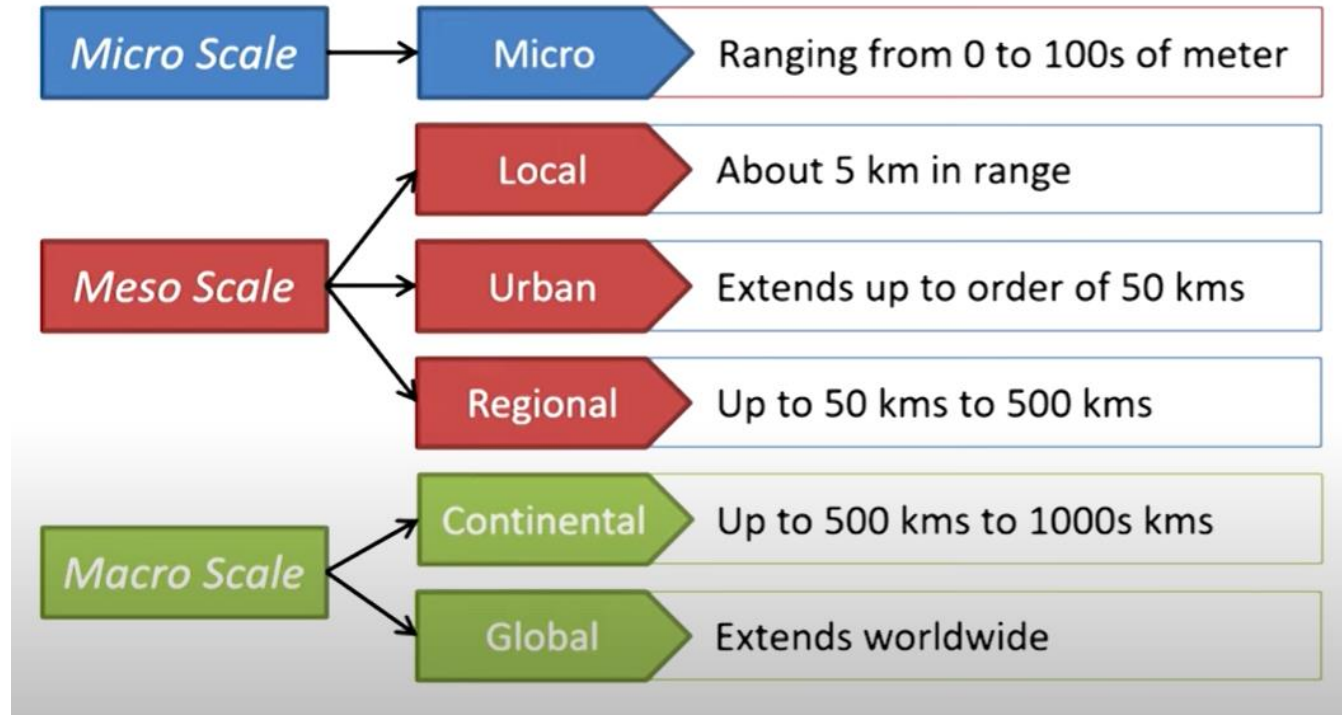
4. Vehicle emission

INTERACTIONS BETWEEN ENERGY SYSTEMS AND THE ENVIRONMENT

It will clearly emerge that, in the context of energy systems, the problems related to the limitation of gaseous emissions into the atmosphere are now preponderant over other aspects.

- Gas emissions
- liquid emissions
- solid emissions
- thermal emissions
- noise emissions
- other environmental interactions (land occupation, visual impact, etc.)

Scales of air pollution



Scales of air pollution: Examples

Micro Scale

- Indoor air pollution
- Dust particles

Meso Scale

- Photochemical smog
- Acid rain
- Visibility
- Exposure to traffic

Macro Scale

- Ozone depletion
- Green House Gases
- Global warming

Scales of air pollution: Local

- Characterized by one or several large emitters or a large number of relatively small emitters
- Example: Carbon monoxide emitted from motor vehicles, waste treatment ponds
- Usually, the effects of accidental releases are confined to the local scale.

Scales of air pollution: Urban

- Air pollution problems in urban areas generally are of two types; release of primary pollutants and formation of secondary pollutants.
- Tropospheric ozone is the dominant urban problem resulting from the formation of secondary pollutants
- Example: formation of ozone from photochemical reactions of oxides of nitrogen and various species of hydrocarbons

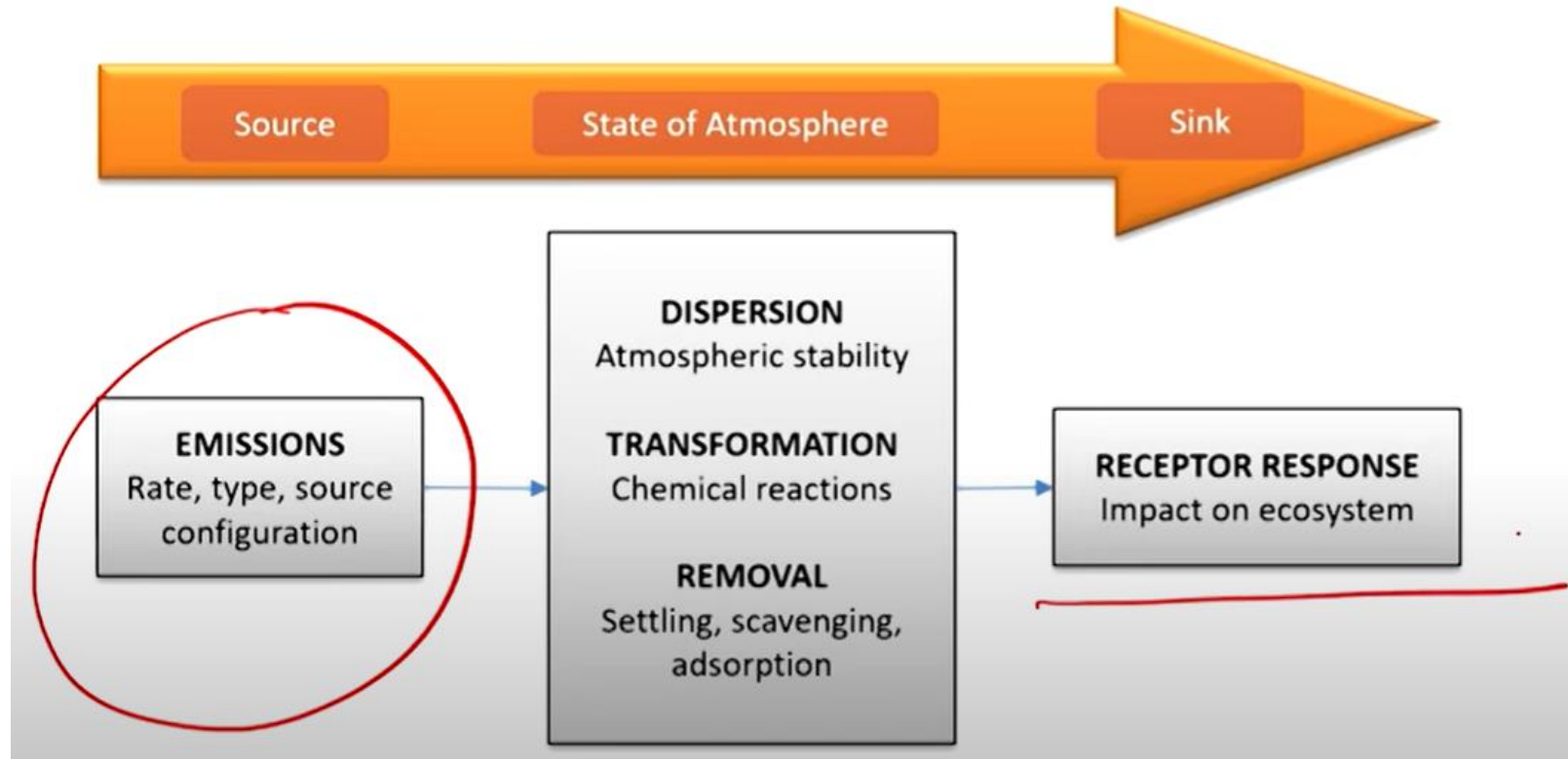
Scales of air pollution: Regional

- Three types of problems contribute to air pollution problems on the regional scale.
 - blend of urban oxidant problems (one city to another)
 - release of relatively slow-reacting primary air pollutants. (transformation of SO_2 to SO_3)
 - Visibility (due to plumes and PM)

Scales of air pollution: Continental

- For smaller continents, there is little difference in regional and continental scale
- However, there is substantial difference in case of larger continents
- Air pollution policies of a nation are likely to create impacts on neighboring nations.
- Example: Acid rain in [Scandinavia](#) has been considered to have had impacts from [Great Britain and Western Europe](#)

Role of atmosphere in source-sink relationship



Sources and Sink

- The places from which pollutants get emitted are called **sources**.
- The places to which pollutants get absorbed or converted/transformed in some other constituents/forms are called **sink**.



Receptor

- A receptor is **something** which is adversely affected by polluted air.



Building/monuments



Human

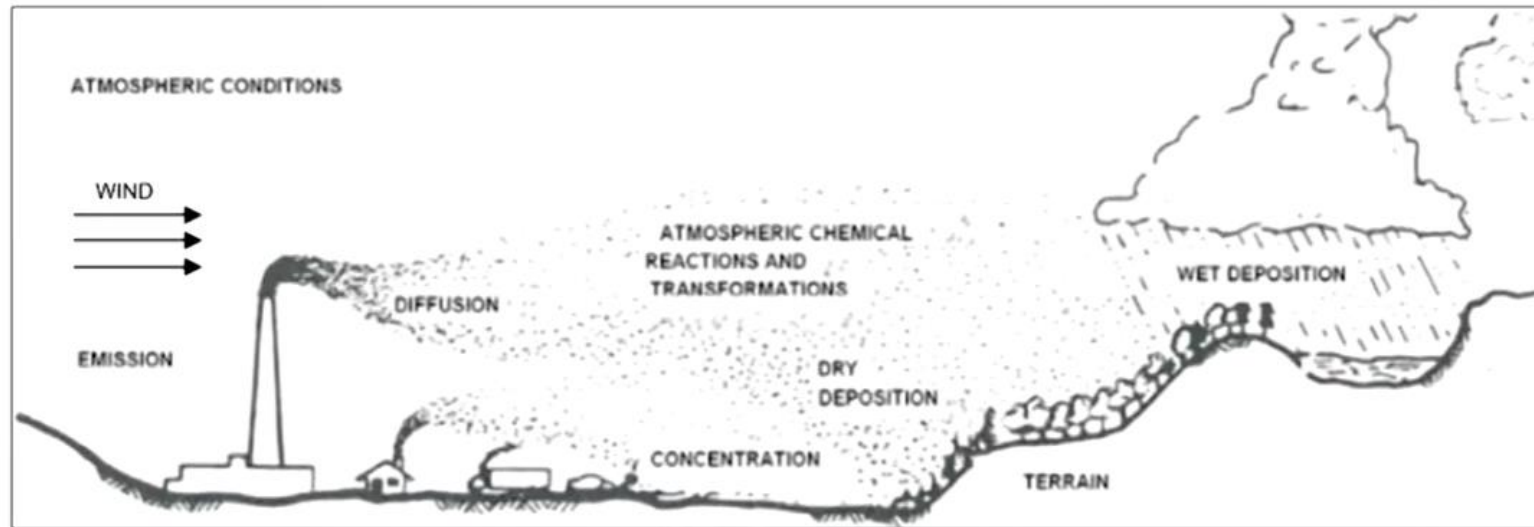


Plants



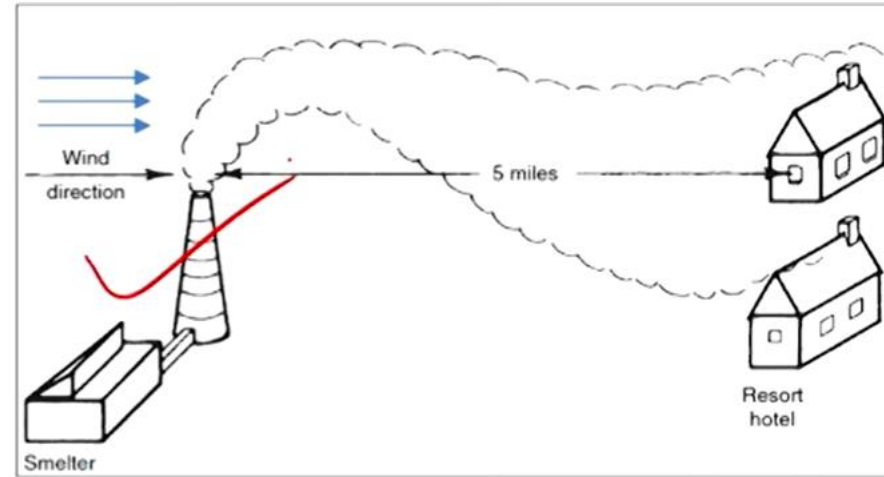
Animals

Processes and Fate of an Air Pollutants



Transport of an Air Pollutant

- *Transport* is the mechanism that moves the pollution from a source to a receptor.
- The simplest **source–receptor** combination is that of an isolated point source and an isolated receptor.

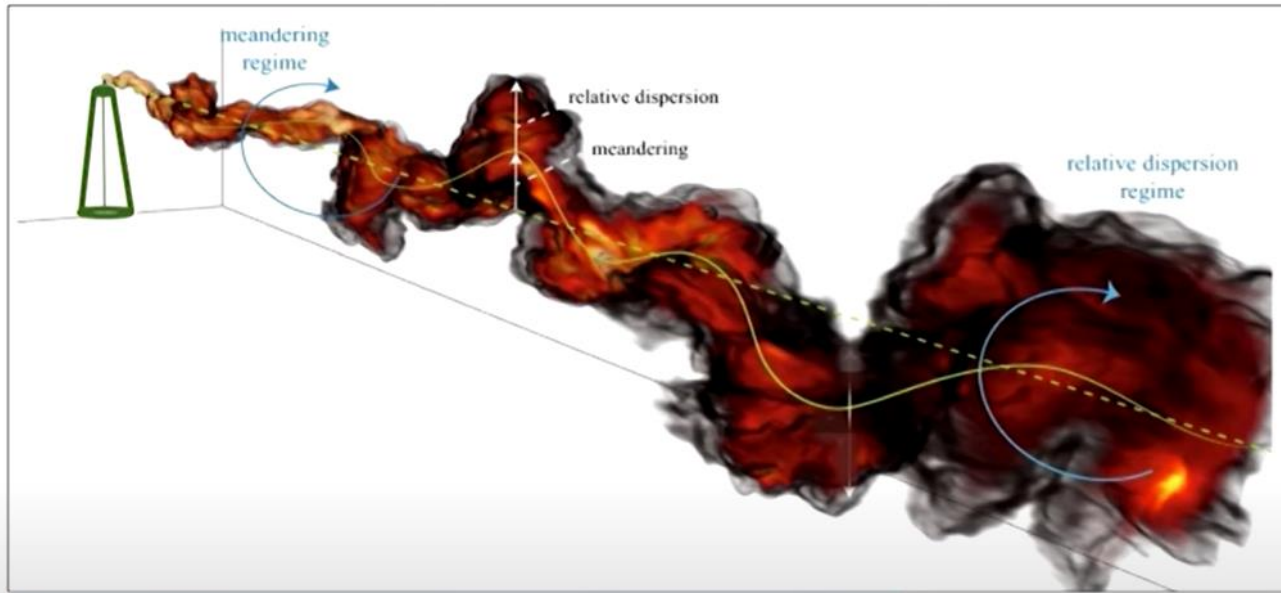


Transport of a pollutant from source (stack) to receptor (resort hotel)

Diffusion and Dispersion

Dispersion of smoke plumes in the horizontal by means of the crosswind component (fluctuations) of the horizontal wind speed.

The result is a plume that wanders from side to side. When averaged over a finite time period, the result is plume spreading in the horizontal.



- Diffusion is combined process of-
 - mixing by turbulence
 - stretch-out of the plume
 - meandering of plume

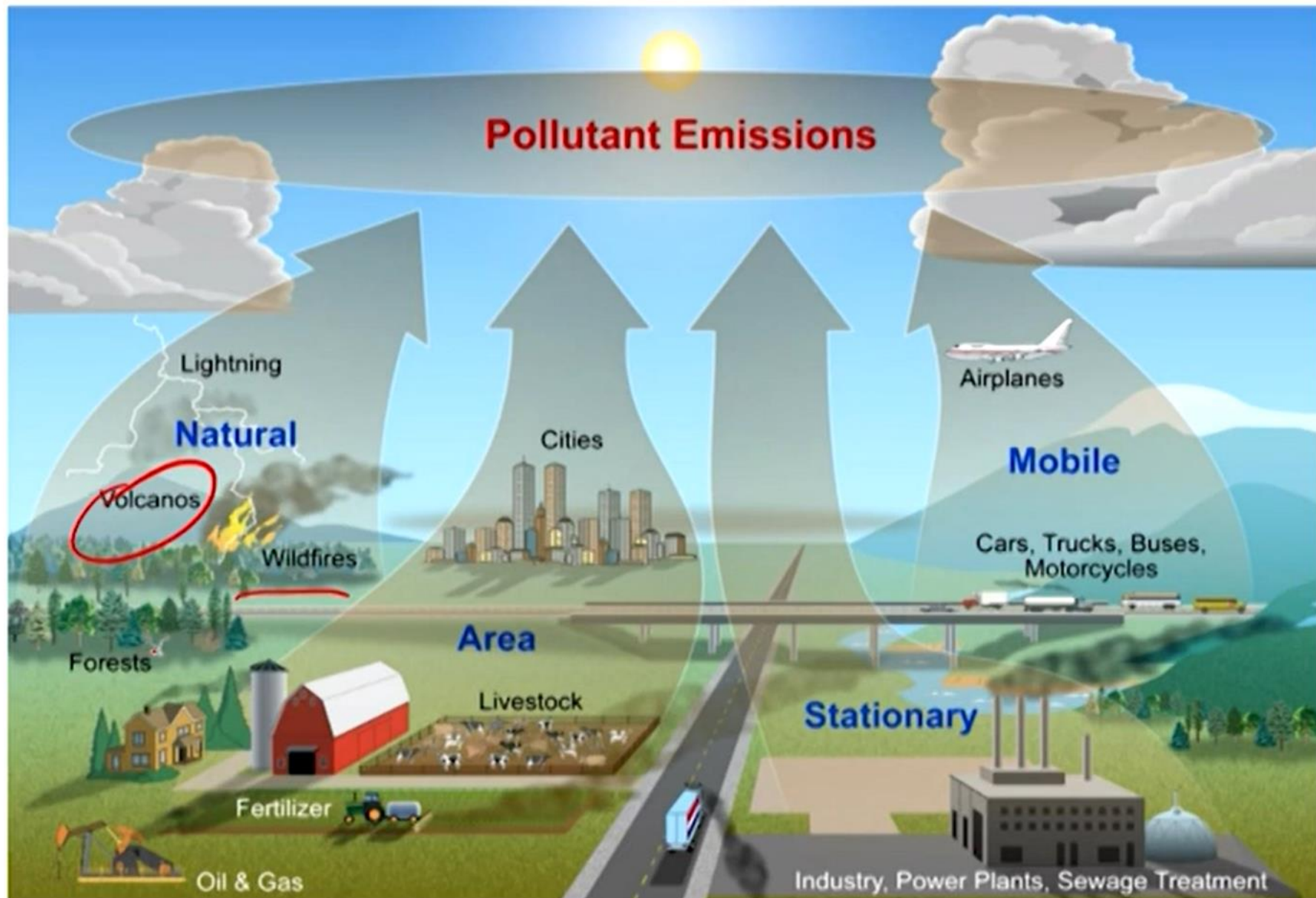
- In Dispersion, the concentration diminishes with distance from the source, known as concentration gradient.

Source: (Cassiani, 2020)

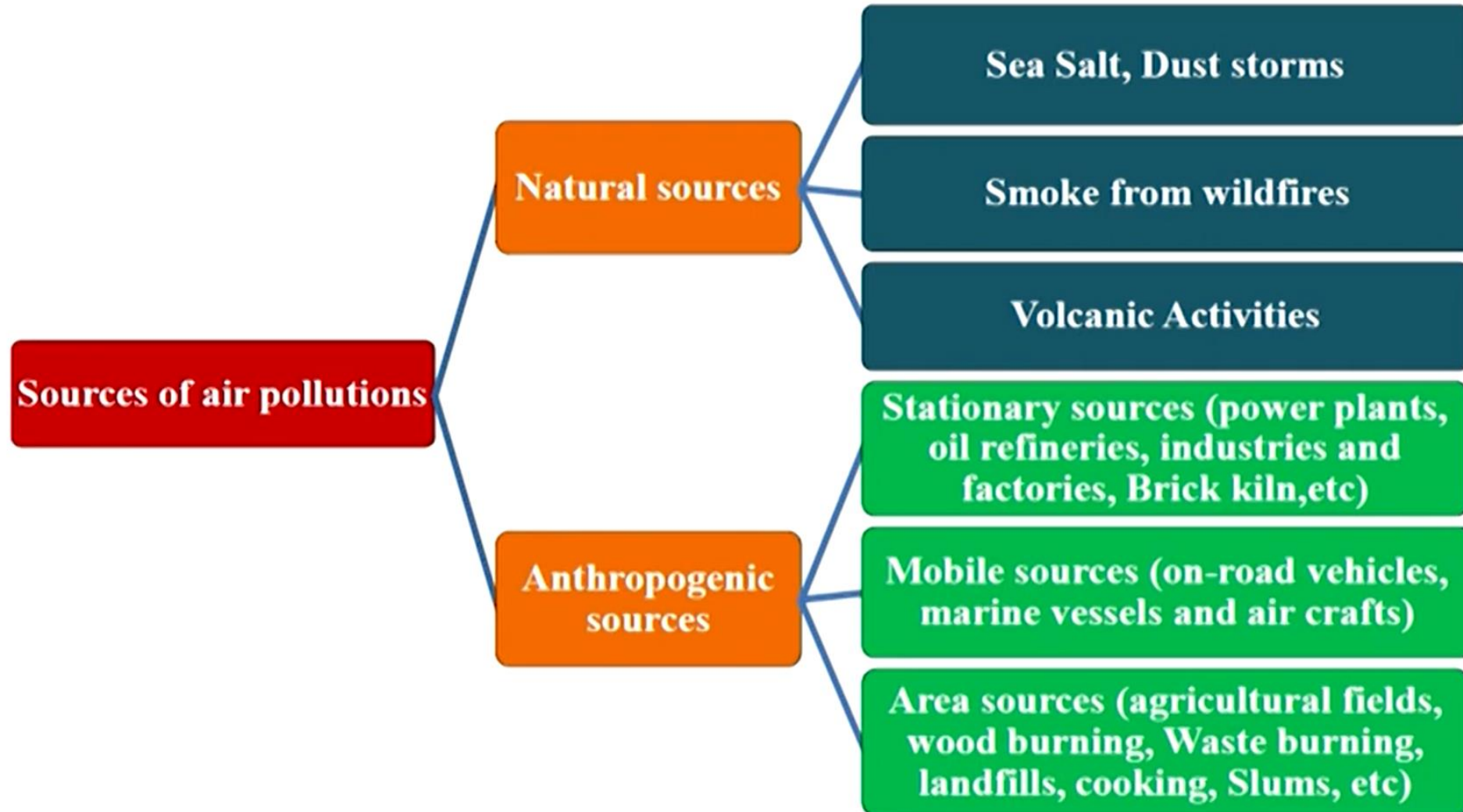
- The atmosphere plays a vital role in transforming the fate of a pollutant from its source to sink.
- Unpolluted air is a concept, it is merely a benchmark to show the extent and trend of air pollution.
- The spheres of air pollution exists at all scales, from extremely molecular (microscale) to planetary (global scale).

SOURCES AND CLASSIFICATION OF AIR POLLUTANTS

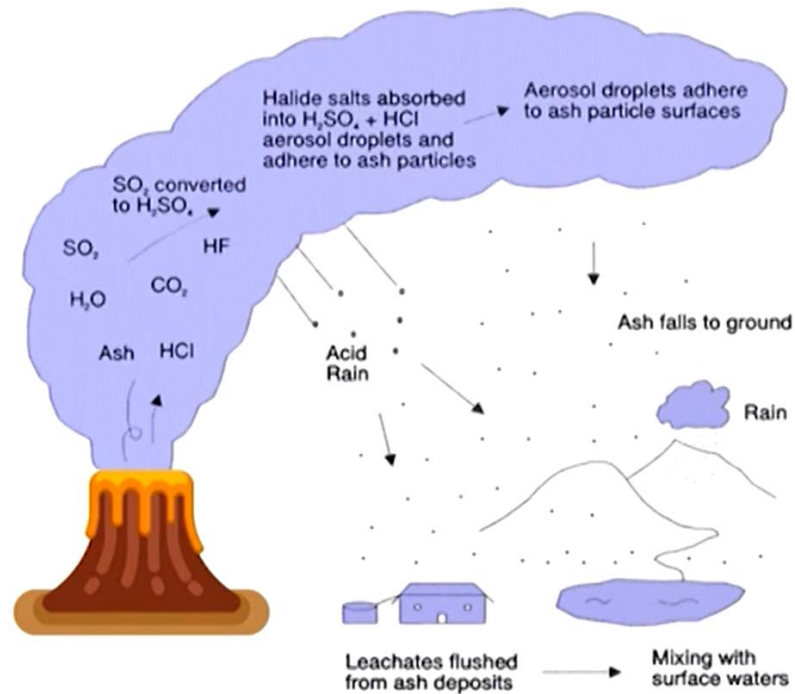
Sources of air pollution



Sources of air pollution



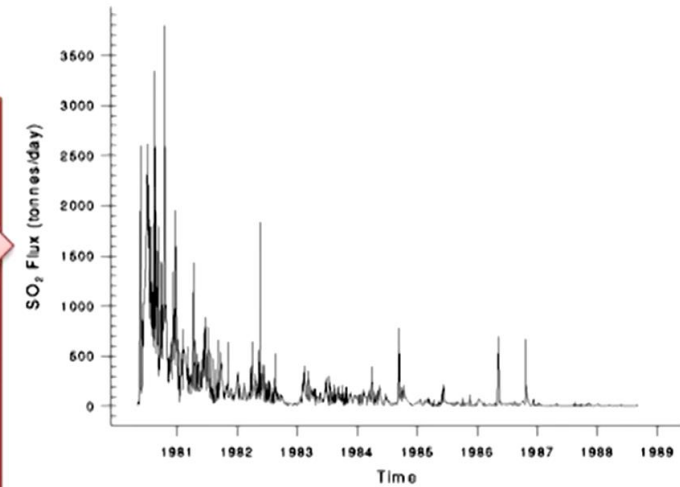
Natural sources of air pollution; Volcanic Eruption



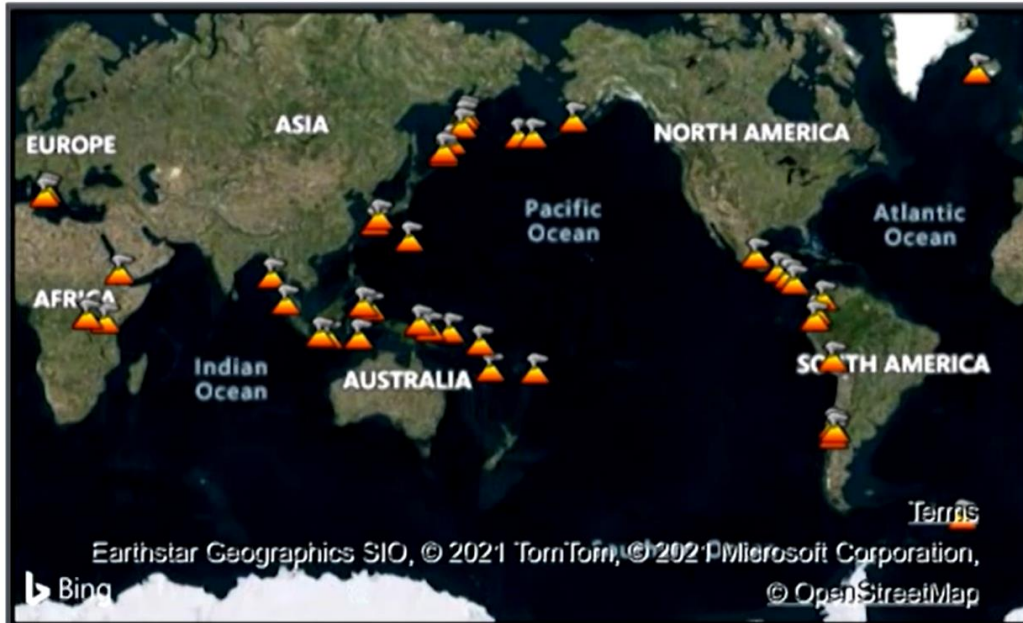
- Emits gases SO₂, H₂S, HF, CO₂, CH₄ and Ash (PM).
- Eruptions may harm the environment at a considerable distance and time.

Volcanic eruption at Mount St. Helen

- The concentration of SO₂ in tones per day releases from Mount St. Helen eruption from 1980 to 2005.
- Up to 3750 tons per day of SO₂ was released into the atmosphere.
- Particulate (smoke) levels reached an average over the four days of about 1,600 µg/m³ (about five times usual normal levels).
- The prevailing winds moved 520 million tons of ash eastward across the United States.



Active Volcanoes around the World



- Overall, **50 volcanoes** were in **continuing eruption status** as of 19 August 2021 in the entire world.

Natural sources of air pollution;

Forest Fire

- Uncontrolled forest fire emits CO, CO₂, hydrocarbons, ash and oxides of nitrogen.
- Around 37,059 fires were detected in the year 2018 using MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor data:
 - 54.40 % - of forest area exposed to occasional fires
 - 7.49 % - to moderately frequent fires
 - 2.4 % - to high incidence levels while
 - 35.71 % - of forests not yet been exposed to fires



Australian bush fires

- The extreme bush fires that blazed across southeastern Australia in late 2019 and early 2020 released 715 million tonnes of CO₂ into the air.
- The unprecedented fires burnt across as much as 74,000 km² of mostly eucalyptus, or gum, forest in southeast Australia — an area larger than Sri Lanka.



Huge bush fires on 21 December 2019, at Sydney, Australia



Natural sources of air pollution; Dust storm

- Entrain large amount of Particulate Matter in air.
- Visibility reduction during major dust storms is frequently the cause of severe highway accidents. It also affects the air travel.



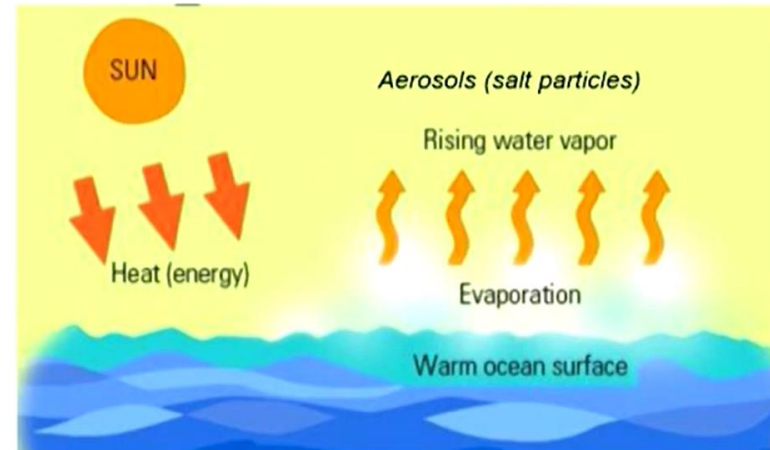
Sand and dust storm event

- Dust storm at New South Wales and over parts of Victoria to arrive in Melbourne, Australia on January, 2020.
- The air became orange, and visibility dropped significantly. It became almost impossible to drive.



Natural sources of air pollution; Oceans

- Emits aerosols to atmosphere, in the form of salt particles.
- The corrosive properties of these aerosols are harmful at coastal locations.



Natural sources of air pollution;

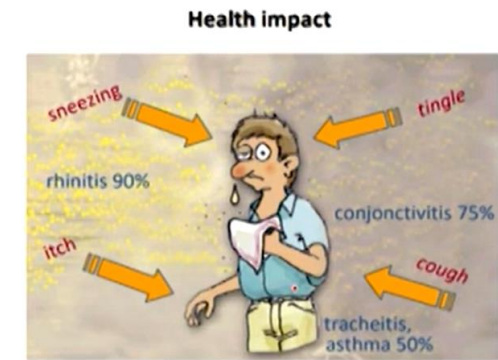
Pollen grain

- The pollens which cause respiratory distress and allergic reactions in humans.



Pollen Allergy in Europe

- Over 150 million European citizens suffered from chronic allergies during the year 2016.
- By 2025 more than 50% of all Europeans will suffer from allergy, with no age, social or geographical distinction.



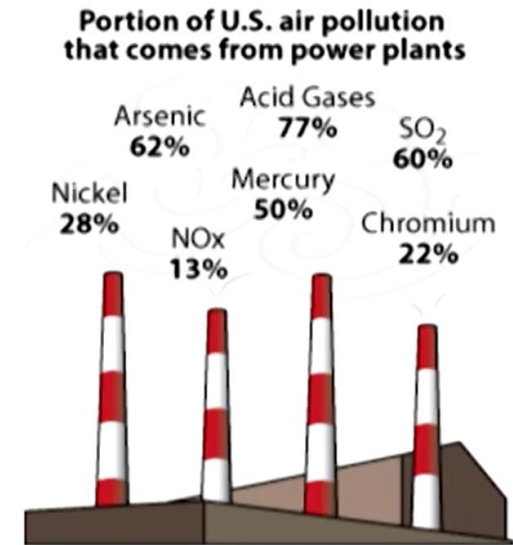
Anthropogenic point sources of air pollution: **Industrial Stack Emissions**

- Industrial units are associated with manufacturing products, which involves combustion of different kind of fuel such as diesel, LPG, kerosene, wood, coal, natural gas etc.
- The major air pollutant released from stacks/chimneys (i.e. point sources) of the industrial units is particulate matter followed by gaseous pollutants like SO_2 , CO , NO_x etc.



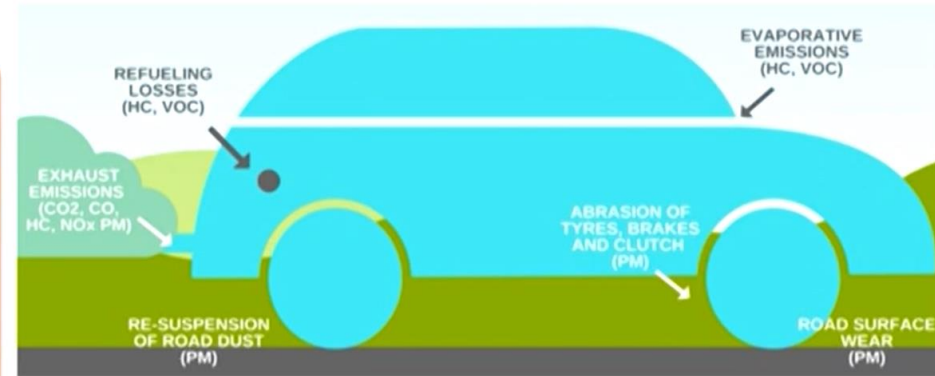
Anthropogenic point sources of air pollution: **Power Plant Chimneys**

- In India approximately 70% of power generation is obtained via coal based thermal power plants.
- Large amount of SO_x , NO_x , CO_2 , CFCs & Suspended Particulate Matter are released into air, which is also responsible for deterioration of the environment



Anthropogenic line sources of air pollution: **Automobiles**

- Automotive vehicles emit several pollutants depending upon the type of quality of the fuel consumed by them.
- Various pollutants are released from vehicular sources include:
 - Exhaust emissions- CO_2 , CO, HC, NO_x , PM.
 - Non-exhaust emissions- PM, heavy metals
 - Evaporative emissions- HC, VOCs



Anthropogenic sources of air pollution: Waste Burning

- Open burning of any type of wastes viz. Agricultural wastes, Garden wastes, Municipal Wastes or Residential wastes releases harmful pollutants due to incomplete combustion.
- Pollutants includes PM, CO, PAH (Polycyclic Aromatic Hydrocarbons), SO_x, NO_x, VOC.



Indoor air pollution

- In contrast to outdoor air pollution, the indoor air pollution is source dominated.
- Pollutants generated in the home are not rapidly dispersed by the wind.
- Allergens and irritants can pose significant residential problems, especially for sensitive people.





A scenario of major sources of air pollutants in Europe

1 / Around 90 % of ammonia emissions and 80 % of methane emissions come from **agricultural activities**.

4 / **Waste (landfills), coal mining and long-distance gas transmission** are sources of methane.

2 / Some 60 % of sulphur oxides come from **energy production and distribution**.

5 / More than 40 % of emissions of nitrogen oxides come from **road transport**.

Almost 40 % of primary $PM_{2.5}$ emissions come from transport.

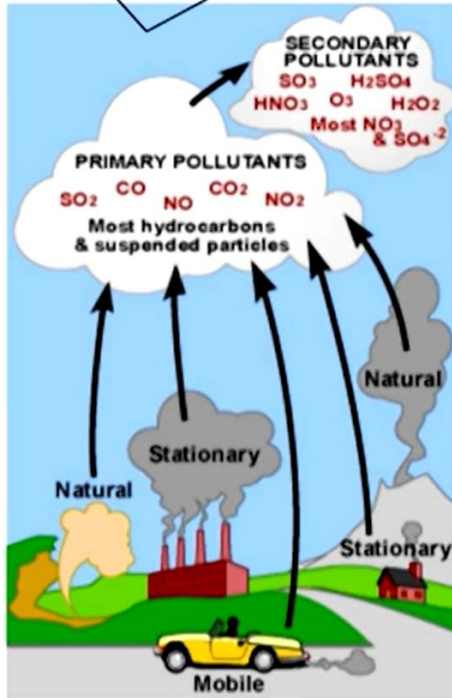
3 / Many **natural phenomena**, including volcanic eruptions and sand storms, release air pollutants into the atmosphere.

6 / **Fuel combustion** is a key contributor to air pollution – from road transport, households to energy use and production.

Businesses, public buildings and households contribute to around half of the $PM_{2.5}$ and carbon monoxide emissions.

Types of air pollutants

- Primary air pollutants
- Secondary air pollutants



- Criteria air pollutants

- Ground-level Ozone (O₃)
- Particulate Matter (PM)
- Carbon Monoxide (CO)
- Lead (Pb)
- Sulphur Dioxide (SO₂)
- Nitrogen Dioxide (NO₂)

- Hazardous air pollutants

187 hazardous air pollutants

Primary air pollutant: Carbon Monoxide (CO)

- It is formed as a by-product of incomplete combustion processes such as the burning of petrol, coal or wood.
- During the process, if there is not enough oxygen available to create carbon dioxide as a by-product, then carbon monoxide is created instead.
- The biggest sources of carbon monoxide comes from vehicles, especially when they are moving slowly or when the engine is idle.



Primary air pollutant: Sulphur Dioxide (SO₂)

- The most common Sulphur oxide is Sulphur dioxide (SO₂), which is a colourless gas with a burnt matchstick type smell.
- They are formed during the burning of fuels containing Sulphur, such as coal and oil, and metal-containing ores (including aluminium, copper, zinc, lead and iron)
- It is also produced from natural sources such as active volcanoes and hot springs



Primary air pollutant: Nitrogen Oxides (NO_x)

- Nitrogen dioxide (NO₂) which is a reddish, brown gas that has an unpleasant smell and is poisonous in high concentrations.
- They are formed when fossil fuels are burned at high temperatures, but can also be formed naturally by lightning strikes.
- Most of the nitrogen dioxide in urban areas comes from exhaust emissions.
- These can contribute to environmental problems such as acidification. It also forms secondary pollutants such as Ozone.



Primary air pollutant: Ammonia

- Ammonia (NH₃) is a very soluble colourless gas with a strong pungent smell.
- It is primarily released from animal waste and fertilizer use, vehicle exhaust and other processes.
- The biggest source of ammonia release is from agriculture including the intensive rearing of animals and crops.

