Energy and Environment Sceince
L-T-P-C: 2-0-0-2

Syllabus:

Unit – 1 [4 Hours]: Present Energy resources in India and its sustainability:

Energy Demand Scenario in India, Different type of conventional Power Plant, Advantage and Disadvantage of conventional Power Plants, Conventional vs Non- conventional power generation.

Unit – 2 [4 Hours]: Basics of Solar Energy: Solar Thermal Energy; Solar Photovoltaic: Advantages and Disadvantages, Environmental impacts and safety.

Unit – 3 [4 Hours]: Wind Energy: Power and energy from wind turbines, India's wind energy potential, Types of wind turbines, Offshore Wind energy, Environmental benefits and impacts.

Unit – 4 [4 Hours]: Biomass Resources: Biomass conversion Technologies, Feedstock pre-processing and treatment methods, Bioenergy program in India, Environmental benefits and impacts; Other energy sources: Geothermal Energy resources, Ocean Thermal Energy Conversion, Tidal Energy.

Unit – 5 [4 Hours]: Air pollution: Sources, effects, control, air quality standards,

air pollution act, air pollution measurement; Water Pollution: Sources and impacts; Soil Pollution: Sources and impacts, disposal of solid waste. Noise pollution

Unit – 6 [4 Hours]: Greenhouse gases effect, acid rain; **Pollution aspects of various power plants; Fossil fuels and impacts,** Industrial and transport emissions impacts.

Pollution aspects of various power plants; Fossil fuels and impacts, Industrial and transport emissions impacts

Thermal Power Plant

Combustion and Pollution

Introduction to Fuels

What are the Types of fuel used in all combustion equipment?

Solid, Liquid, and gaseous fuels are being used in Industrial boilers/furnaces for combustion

Type of Fuels	Categories
Solid	Coal & Lignite
Liquid	HSD, LDO, F.Oil, LSHS
Gaseous	N.Gas, Bio- gas
Agro- Waste	Bagasse, Pith, Rice Husk, coconut shell

A good knowledge of fuel properties will be helpful for selecting right type of fuel for right application and also efficient of fuel

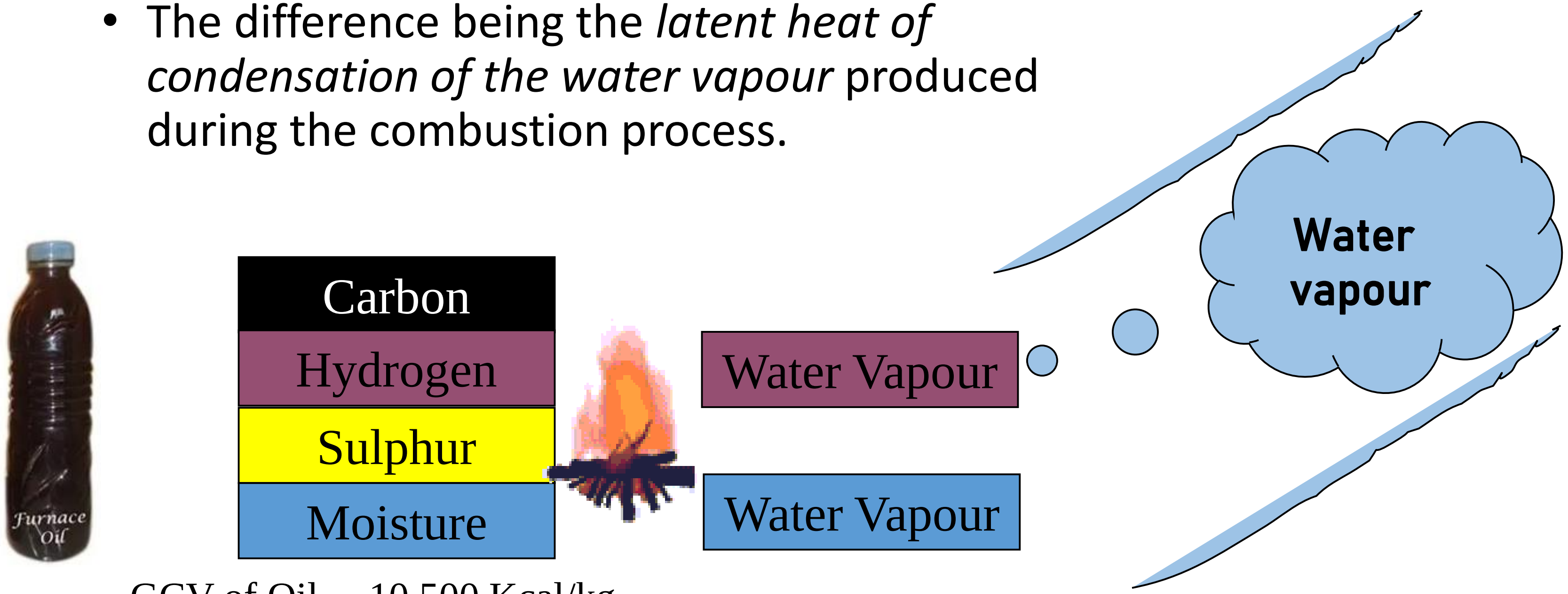
Calorific Value

- The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value.

$C + O_2 \rightarrow CO_2$ + <u>8084</u> Kcals/kg of Carbon

$2C + O_2 \rightarrow 2\,CO$ + 2430 Kcals/kg of Carbon

- The difference being the *latent heat of condensation of the water vapour* produced during the combustion process.



GCV of Oil – 10,500 Kcal/kg

NCV – 9800 Kcal/kg

Properties of Coal

Coal Classification

ANTHRACITE

Oldest & hard coal
High carbon with little volatile content & practically no moisture

BITUMINOUS COAL Sum-bituminous

Commonly used in India

LIGNITE

Youngest & soft coal
Mainly high volatile matter and moisture with Low fixed carbon

Table 1.4 GCV for Various Coals				
Parameter	Lignite (Dry Basis)	Indian Coal	Indonesian Coal	South African Coal
GCV, (kcal/kg)	4,500*	4,000	5,500	6,000

Properties of Gaseous Fuels

LPG, N.gas, producer gas, blast furnace gas, coke oven gas etc. The GCV is expressed kcal/Nm3 i.e. at

Typical Physical and Chemical Properties of Various Gaseous Fuels				
Fuel Gas	Relative	Higher Heating	Air/Fuel ratio,	Flame

- Methane is the main constituent (> 95%)
- No Sulphur content.
- Lighter than air (0.668 KG/M3)

Sulphur	3	0.41	-
Oxygen	1	9.89	Trace
Nitrogen	Trace	1.22	0.75
Ash	Trace	38.63	-
Water	Trace	5.98	-

Combustion of Gas

Natural gas is pure methane, CH_4. Its combustion equation is

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

for every 16 kgs of methane consumed, 64 kg O2 = 44 kgs of carbon dioxide & 36 Kg of water vapour produced. Stoichiometric air fuel ratio by volume 10:1

Liquefied Petroleum Gases (LPG) C3H8

Low-And High-Pressure Gas Burners.

Low-pressure burners using gas at a pressure less than 0.15 kg/cm^2 (2 psi)

Excess air levels in natural gas burner are in the order of 5%.

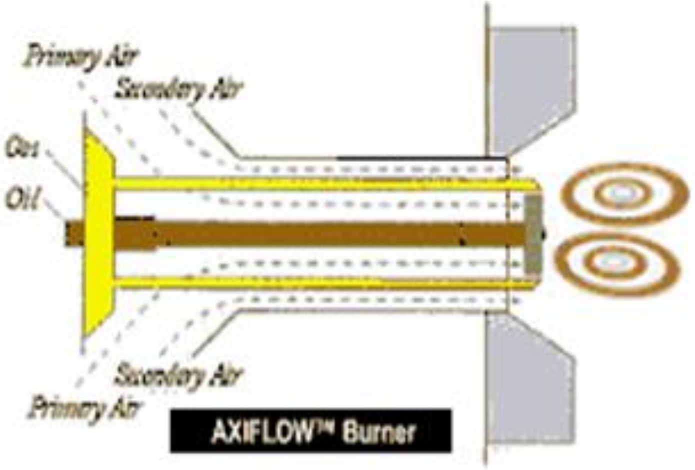


Figure 1.8 High Pressure Gas Mixer

Properties of Agro Residues

Table 1.15 Ultimate Analysis of Typical Agro Residues				
	Deoiled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Mineral Matter	19.77	16.73	1.63	3.52
Carbon	36.59	33.95	48.55	44.95
Hydrogen	4.15	5.01	6.99	4.99
Nitrogen	0.82	0.91	0.80	0.56
Sulphur	0.54	0.09	0.10	0.08
Oxygen	31.02	32.52	41.93	31.94
GCV (Kcal/kg)	3151	3568	4801	4565

What is bulk density?
Transport cost is high




Which among the above Agro residue has higher and lowest GCV?

Combustion of Biomass

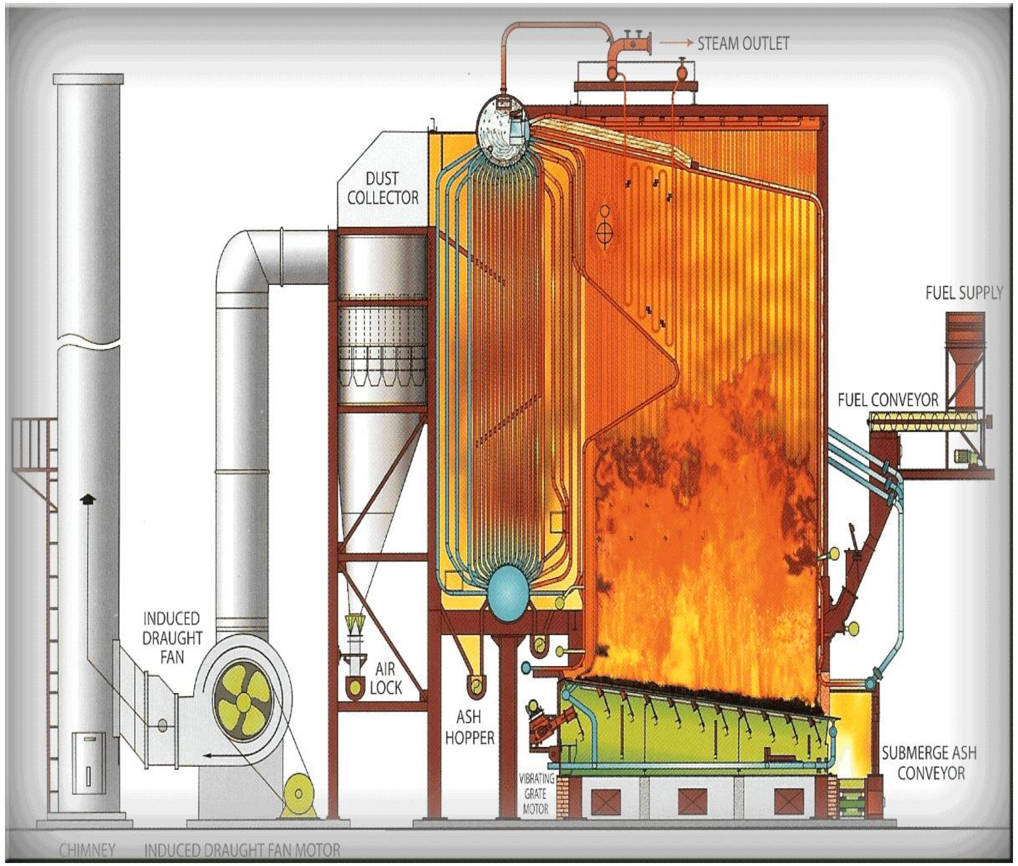
Biomass can be converted into energy (heat/Power)

During combustion,

1. First looses moisture at up to 100°C on heating
2. Then dried particle heats up, volatile gases (HCs, CO, CH4) are released & contributing >70% of the heating value
3. Finally, char oxidises and ash remains.

Moisture in feed may vary from 25 - 55%
Temperatures of biofuels -800 to 1200°C

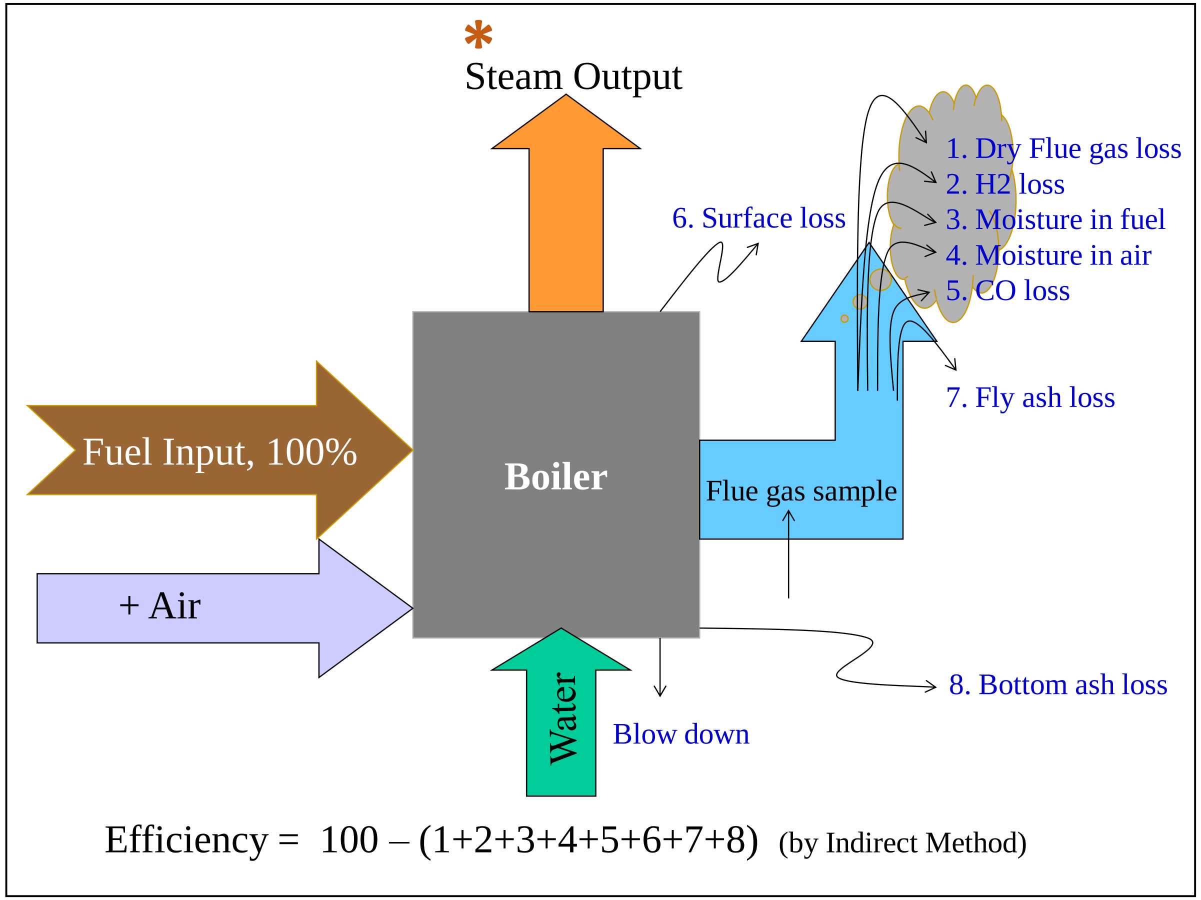
Fixed bed combustion: Grate furnaces are appropriate for high moisture, different particle sizes, and high ash content fuels. *For smaller plants, fixed bed systems are usually more cost-effective.*
Fluid bed combustion plants are used for largescale applications (30 MWth).



Biomass Combustion in a Boiler Biomass Cogen Video

1.7 Indirect Method Testing- Concept Diagram

***Measure**
All Input & all Output **except** steam output



1. which method is most accurate one?

In direct method, If boiler efficiency is 90%, an error of 1% will result in significant change in efficiency.

i.e.90 $\pm$ 0.9 = 89.1 to 90.9.

In indirect method, 1% error in measurement of losses will result in

Efficiency = 100 – (10 $\pm$ 0.1)

= 90 $\pm$ 0.1 = 89.9 to 90.1 ***most accurate***

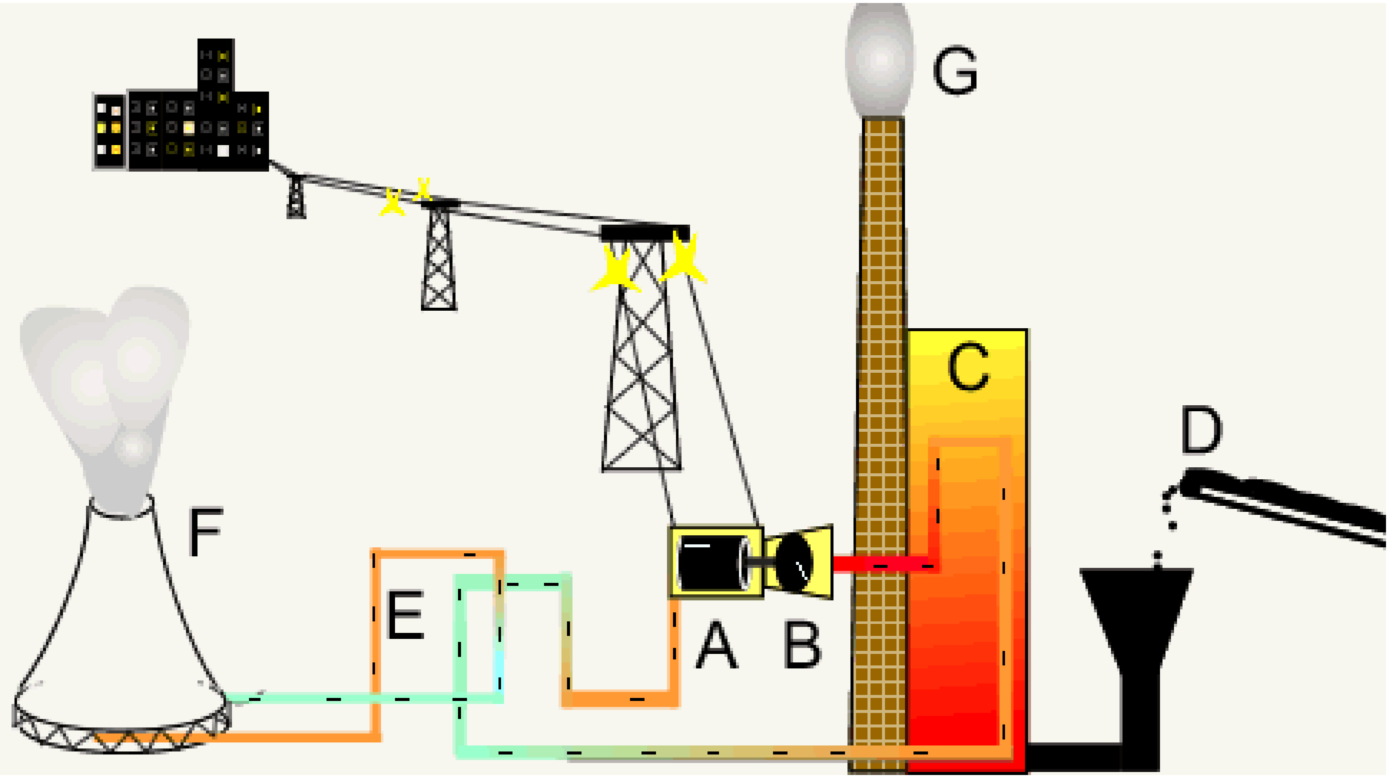
2. State two causes for rise in exit flue gas temperature in a boiler

3. Why boiler efficiency by indirect method is more useful than direct method?

Thermal Power Station

Contents

Fundamental Concepts



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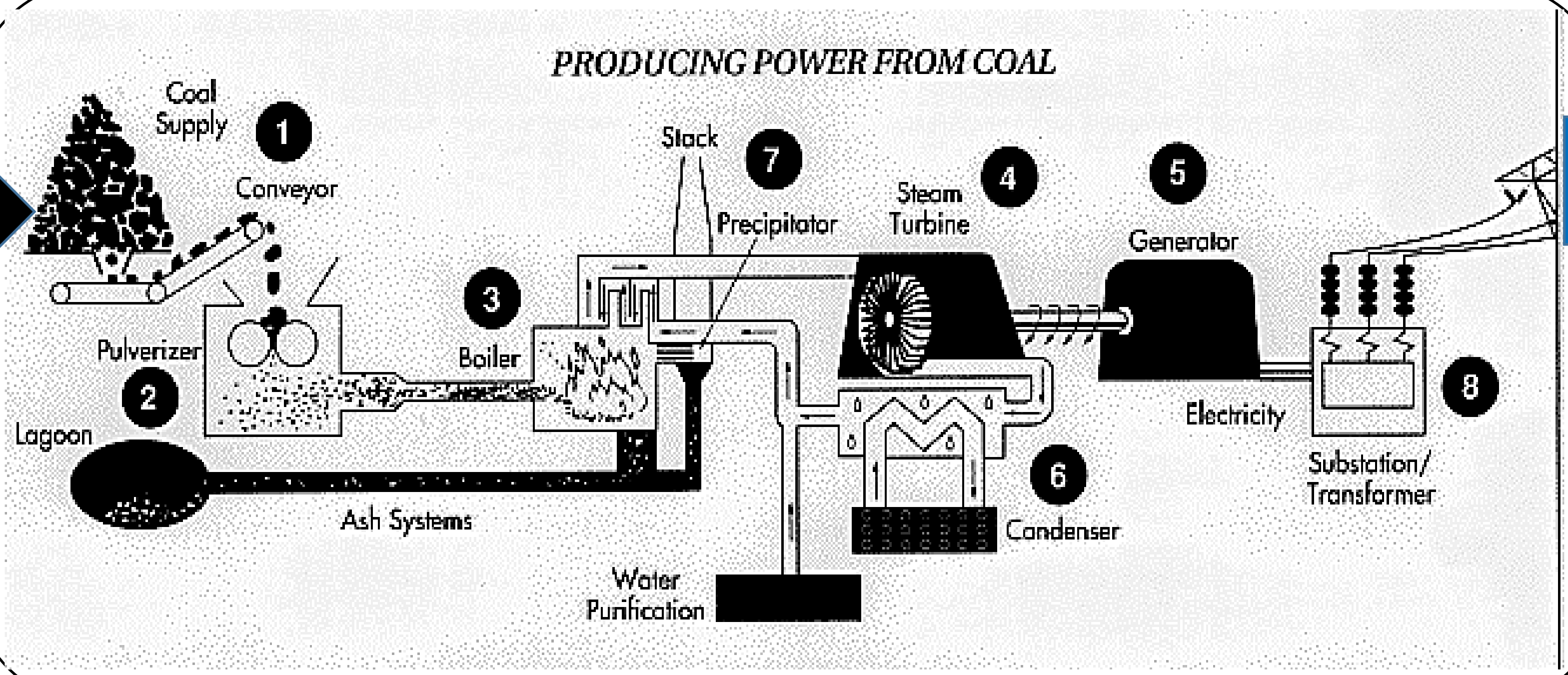
Thermal Power Generation Plant

Coal Input



Power Output

What is the power plant efficiency ?

$$\frac{\text{Output power in kcals}}{\text{Input coal in kcals}} \times 100$$

What is the power plant heat rate?

$$\frac{\text{Input coal in K.Cal}}{\text{Output power in KWH}}$$

11.1 Introduction

Purpose of the Performance Test

The purpose of the performance test is to find the efficiency parameters for **the power plant as a whole** and also the **various components of the power plant.**

Performance Terms and Definitions

1 Gross Heat Rate or 'GHR' means the heat energy input in kCal required to generate one kWh of electrical energy at generator terminals;

$$\text{Gross heat rate } (Q_e)\text{, kcal/kWh}$$

$$= \frac{\text{Fuel consumption, kg} \times \text{GCV of fuel, kcal/kg}}{\text{Generator output, kWh}}$$

Net heat rate refers to the heat rate after deducting the auxiliary power consumption

2 Net Heat Rate or NHR – The heat energy in kCal, input to a Generating Station to deliver one kWh **at the switchyard**.

$$\text{Net heat rate } (Q_e)\text{, kcal/kWh}$$

$$= \frac{Gross\ heat\ rate, kcal/kWh}{1-(\%\ auxiliary\ power\ consumption/100)}$$

3 Plant Load Factor or 'PLF' =

$$\frac{\text{Energy generated during the period (MWh)}}{\text{Total capacity (MW) x total hours in the period}} 100$$

4 Overall efficiency

The term "overall efficiency" as defined **solely for power generation only**

$$\text{Overall efficiency}, \eta\ \% = \frac{\text{Generator output, kW}}{\text{Mass flow rate of fuel, kg/s} \times \text{Gross calorific value, kJ/kg}} \times 100$$

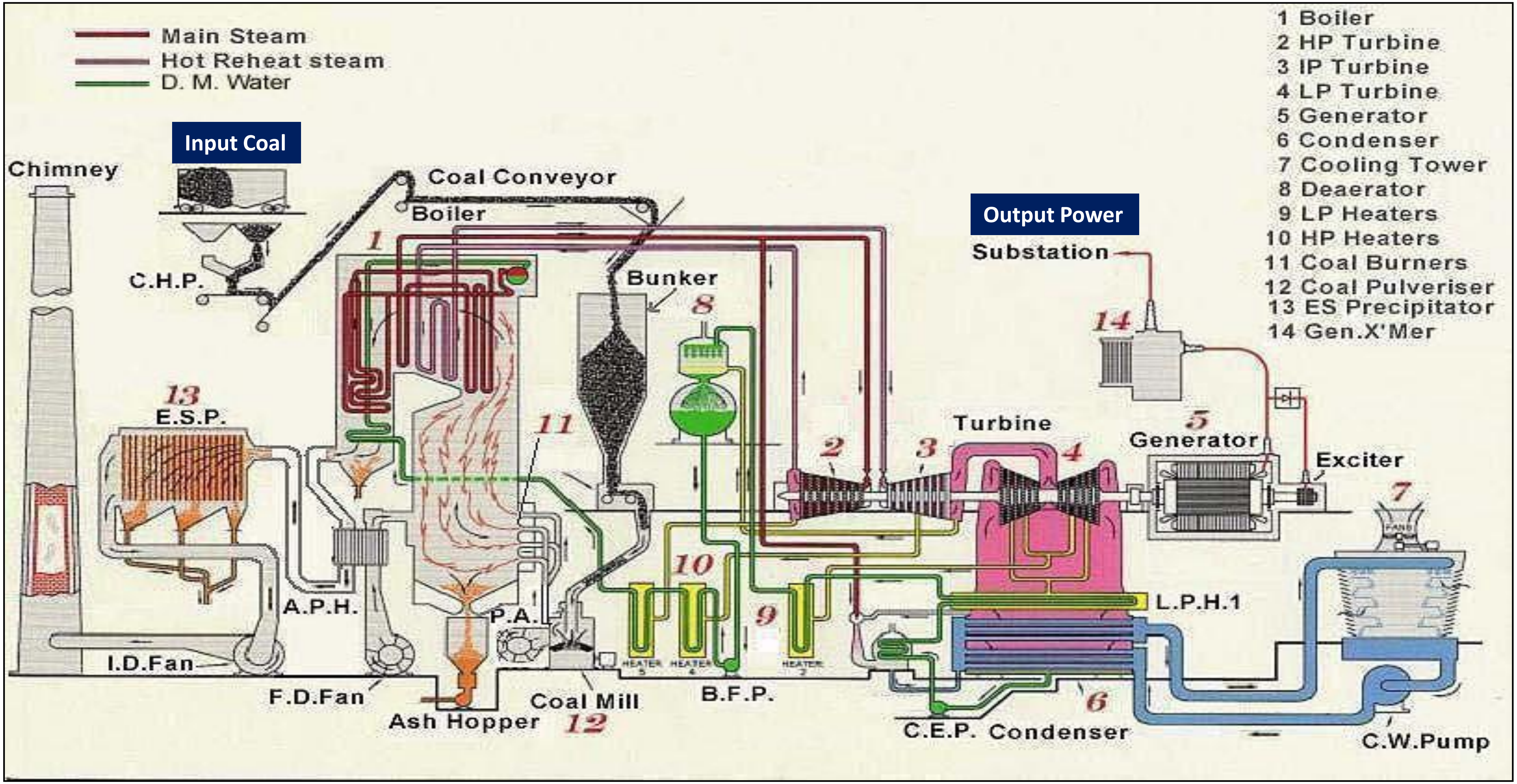
$$\text{Overall efficiency, \%} = \frac{860}{\text{Gross heat rate, kcal/kWh}} \times 100$$

5 Specific fuel consumption

$$\text{Specific fuel consumption, kg/kWh} = \frac{\text{Total fuel consumption, kg}}{\text{Gross generation, kWh}}$$

Auxiliary Energy Consumption energy consumed by auxiliary equipment of the generating station and transformer losses within the generating station, and shall be expressed as a % of the sum of gross energy generated **at the generator terminals;**

Components of a Typical Power Plant



Major Area/Equipments in Thermal Power Plant are

1. **Fuel handling system and preparation** *(Coal handling system and coal mills)*
2. **Boilers and its associated parts**
3. **Steam Turbines and its associated parts**
4. **Condensers**
5. **Draft system and Fans** *(ID fans, FD fans, PA fans)*
6. **Water pumping systems** *(Boiler feed water , Condensate extraction pump, DM water pump, Make up water pump, Raw water pump, etc).*

Typical auxiliary power consumption in power plant

Equipment Ref.	500 MW		210 MW		110 MW	
	% Gen	% APC	% Gen	% APC	% Gen	% APC
BFP	0.00*	0.00*	2.70	33.60	2.94	24.50
CEP	0.40	5.70	0.27	3.34	0.36	3.00
CWP	1.00	14.20	0.66	8.31	1.26	10.50
IDF	1.30	18.70	1.26	15.80	1.71	14.23
PAF	0.60	8.50	0.68	6.50	1.78	14.46
FDF	0.30	4.10	0.40	5.00	0.26	2.13
Mills	0.60	8.20	0.58	7.23	0.83	6.92
CT fans	0.23	3.20	0.32	3.54	0.48	4.00
Air Comp.	0.08	1.20	0.12	1.56	0.24	2.00
A/C Plant	0.04	0.50	0.08	0.94	0.11	0.92
CHP	0.12	1.70	0.14	1.70	0.29	2.41
AHP	0.09	1.20	0.13	1.66	0.31	2.54
Lighting	0.06	0.80	0.08	1.00	0.08	0.68
others	2.23	31.90	0.60	7.44	1.36	11.32
APC	**7.00**	**100.00**	**8.00**	**100.00**	**12.00**	**100.00**

1- Coal Handling Plant

Coal handling plant is one of the important energy consumers in thermal power plants and contains the following energy consuming equipments. Crushers, Conveyors, Feeders Tipplers

The major objectives of coal handling plant energy audit are

- To evaluate specific energy consumption of the CHP equipments (kWh/ton of coal)
- To evaluate percentage power consumption of CHP with respect to total auxiliary power consumption
- To analyse the crushed coal size and rejects

Coal Mills

The major objectives of coal mill energy audit are

- To evaluate specific energy consumption of the mills. **(kWh/ton of coal)**
- To establish air to coal ratio of the mills **(ton of air per ton of coal)**
- To perform heat balance of the mills
- To analyse the coal fineness and mill rejects

Example 11.1. Determine the air fuel ratio and specific energy consumption of mill from the following data

Coal flow rate	= 48.64 TPH
Air flow rate	= 112.6 TPH
Energy consumption	= 351 kW

$$\text{Air to coal ratio of the mill} = \frac{\text{Air flowrate, kg/hr}}{\text{Coal flowrate, kg/hr}}$$

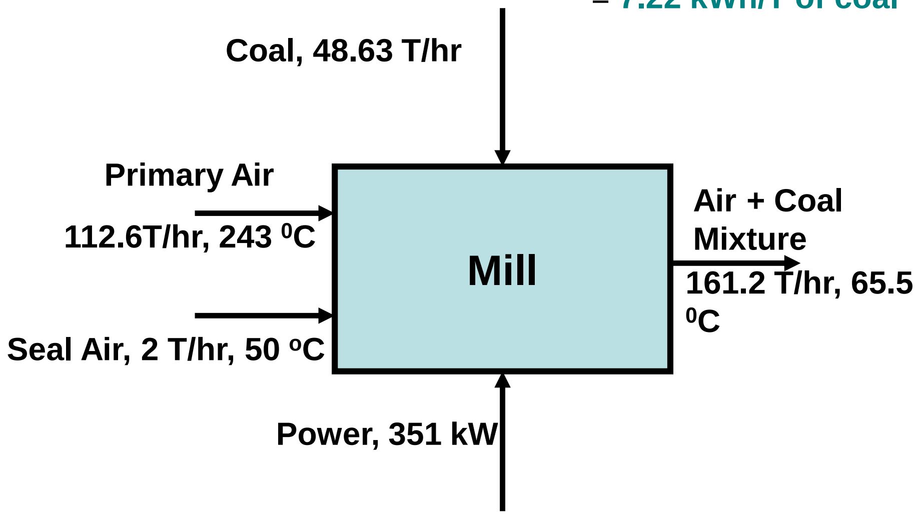
= 112.6 / 48.64

= 2.31 kg of air/kg of coal

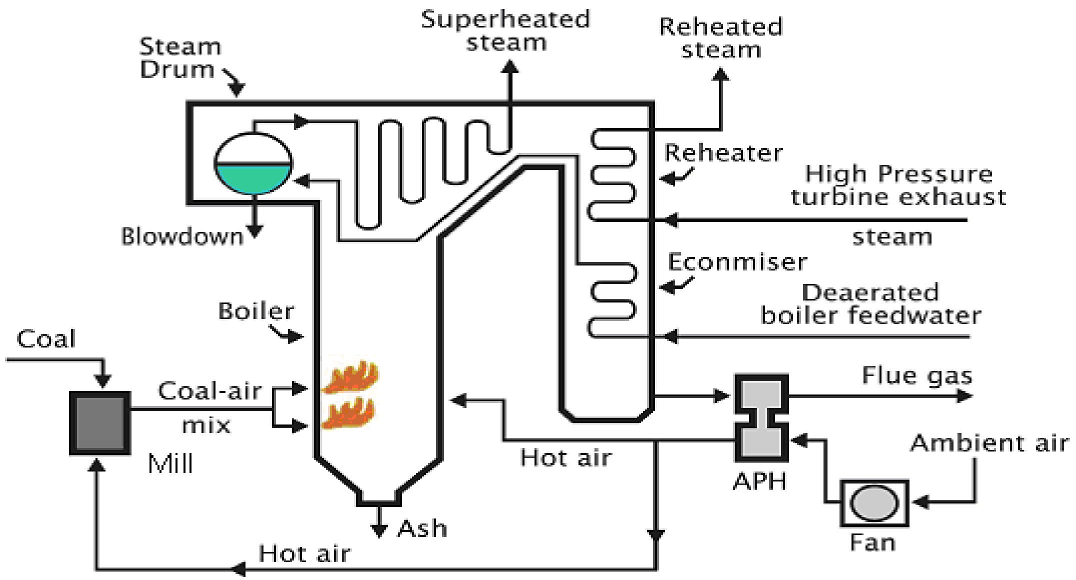
$$\text{Specific energy consumption the mill, kWh/T} = \frac{\text{Electricity consumption, kW}}{\text{Coal flowrate, TPH}}$$

= 351 / 48.64

= 7.22 kWh/T of coal



2. Boiler



Schematic diagram of a utility boiler

For performance evaluation of boiler, refer to Chapter – 1 of this book.

Air leakage estimation:

$$APH\ leakage\% = \frac{(O_2\%\ in\ the\ gas\ leaving\ the\ APH\ - O_2\%\ in\ the\ gas\ entering\ APH)}{(21 - O_2\%\ in\ the\ gas\ leaving\ APH)} \times 100$$

APH Effectiveness

= (Air temp APH out – Air Temp APH in)/(Flue Gas temp. APH in – Air temp. APH in)
= (354 – 35) / (379 – 35)
= 92.7 %

Economiser Effectiveness

= (F. W temp out – FW temp in) / (F. Gas temp ECO in – F. Water temp in)
= (274 – 244) / (473 – 244)
= 13.1 %

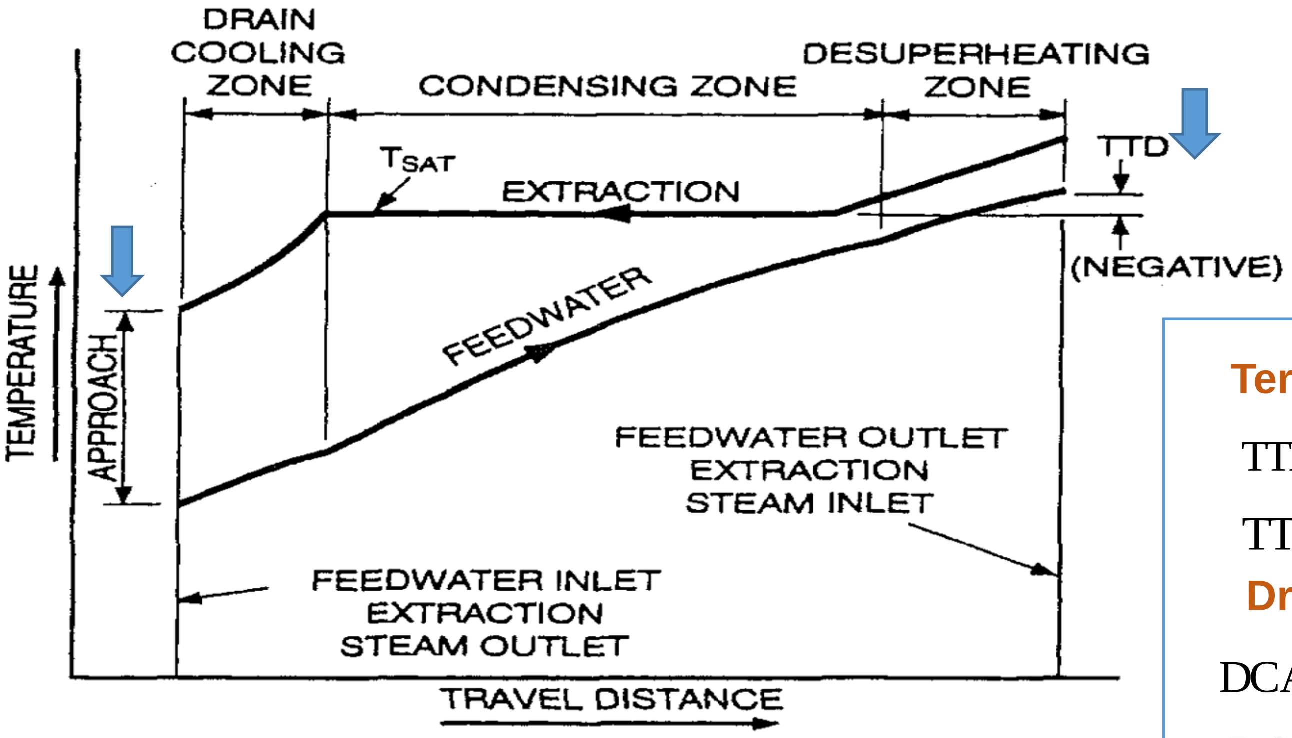
Typical boiler specifications for a 210 MW unit

Particulars	Unit	Details at Continuous Rating (NCR)
Type		Water tube single drum
Capacity	TPH	627.32
Main Steam pressure	kg/cm^2	155
Main Steam temperature	^{0}C	540
Boiler efficiency	**%**	**87.16**
Super heater outlet flow	TPH	627.32
Reheater outlet flow	TPH	565.6
GCV of coal	kCal/kg	4350
Coal consumption	TPH	106.2
Total combustion air	TPH	822
Re-heater outlet temperature	^{0}C	540
Water-economizer inlet temperature	^{0}C	241
Water-economizer outlet temperature	^{0}C	280
Oxygen content at economizer outlet	%	4.23

LP and HP Heaters Performance

❑ Performance of the feed water heaters

Terminal Temperature Difference (TTD)
Drain Cooler Approach (DCA)



Temperature profile for a feed water heater

Parameter Reference	UNIT	LP Heater
Extraction steam pressure	kg/cm^2 (a)	0.614
Extraction steam temperature	^oC	86.5
Shell steam pressure	kg/cm^2 (a)	0.488
Shell steam temperature	^oC	86.5
Saturated temperature of steam @ shell pressure	^oC	86.5
Inlet feedwater temperature	^oC	47
Outlet feedwater temperature	^oC	77.5
Drain outlet temperature	^oC	61.8

Terminal Temperature Difference (TTD)

$$TTD = \text{Saturation temp. of extraction steam}, {}^oC - \text{Feed water outlet temp.}, {}^oC$$

$$TTD = 86.5\ {}^oC - 77.5\ {}^oC \qquad TTD = 9\ {}^oC$$

Drain Cooler Approach (DCA)

$$DCA = \text{Drain outlet temp.}, {}^oC - \text{Inlet feed water temp.}, {}^oC$$

$$DCA = 61.8\ {}^oC - 47\ {}^oC \qquad DCA = 14.8\ {}^oC$$

Increased values of TTD and DCA with respect to the design values indicate extent of drop in heat transfer mainly due to fouling.

6. Condenser

Purpose of the Condenser Performance Test

Condenser is designed for certain **cooling water inlet temperature, thermal load and condenser back pressure.**

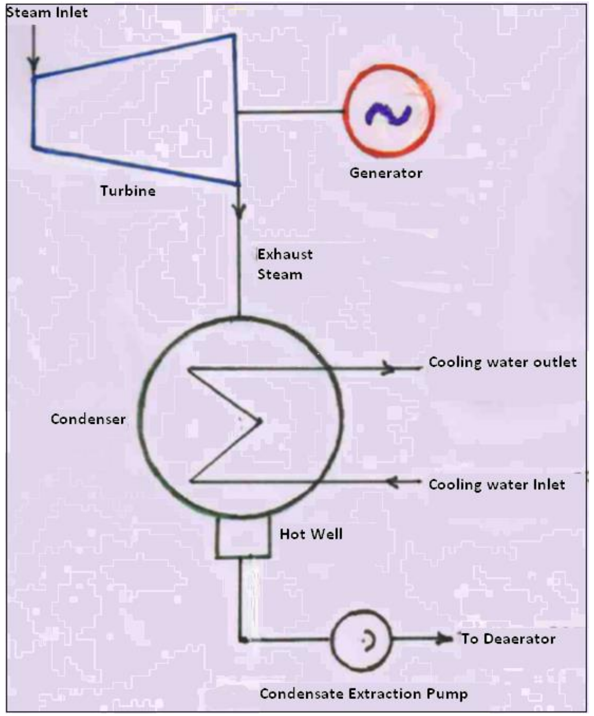
1. The performance of the condenser is expected to deteriorate over a period of time due to bad chemistry of cooling water maintained in it resulting in **scale formation and tube fouling affecting the heat tran**sfer badly.
2. **Low cooling water flow** through the condenser tubes raises the exhaust steam **temperature and thus the condenser back pressure**.
3. **Air ingress** into the condenser through leaky valves, pipe fittings and instrument tapings and improper functioning of Steam Jet Air Ejector will also contribute to **increased condenser back pressure.**

As the condenser back pressure increases, the Turbine output decreases because each unit mass of steam does less work on the turbine.

Hence performance assessment of the condenser is periodically required to determine:

- **i. Condenser effectiveness**
- **ii. Condenser heat load**
- **iii. The terminal temperature difference (TTD)**

The values achieved during performance assessment are compared with the design values or performance guaranteed values or the values recorded during first time commissioning of the plant and the reasons for deviations are analysed and actions are taken to improve the performance of the condenser to its rated value and there by maintaining the efficiency of the Turbine cycle.



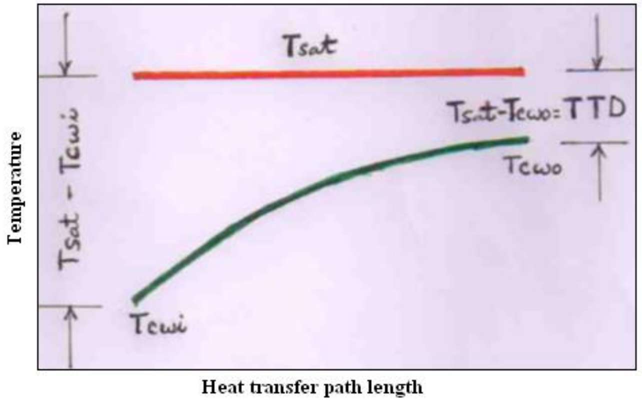
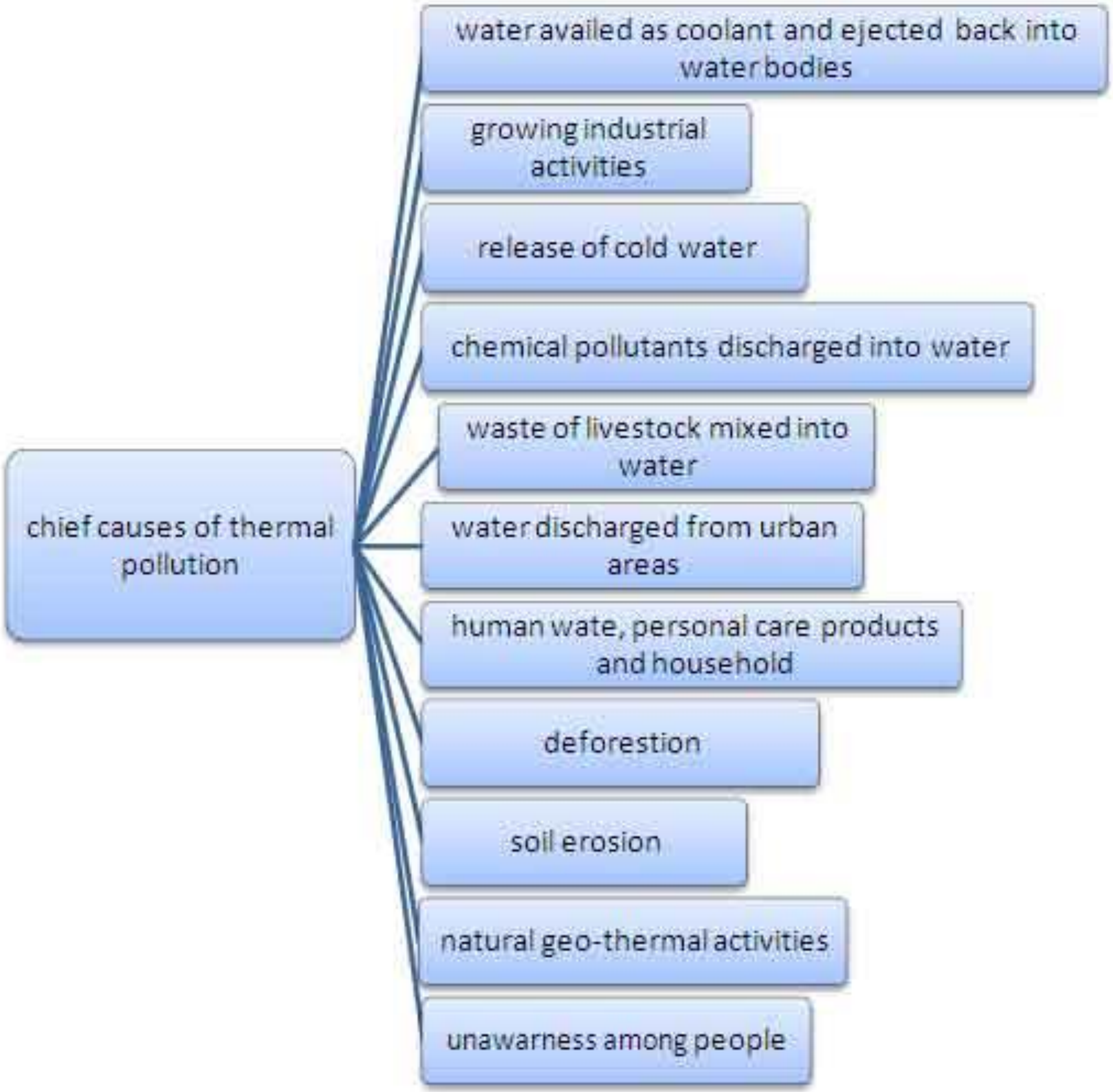
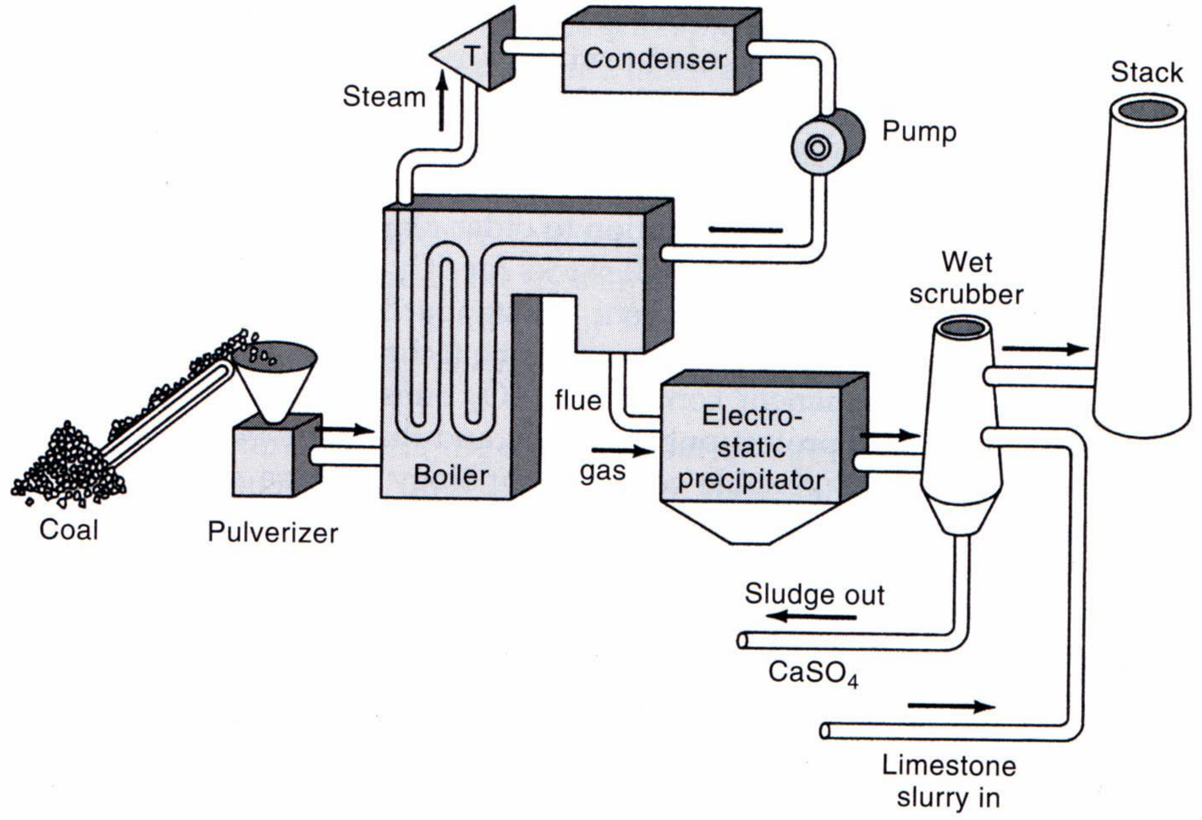


Figure 11.8 Temperature profile across condenser


chief causes of thermal pollution
water availed as coolant and ejected back into water bodies
growing industrial activities
release of cold water
chemical pollutants discharged into water
waste of livestock mixed into water
water discharged from urban areas
human wate, personal care products and household
deforestion
soil erosion
natural geo-thermal activities
unawarness among people

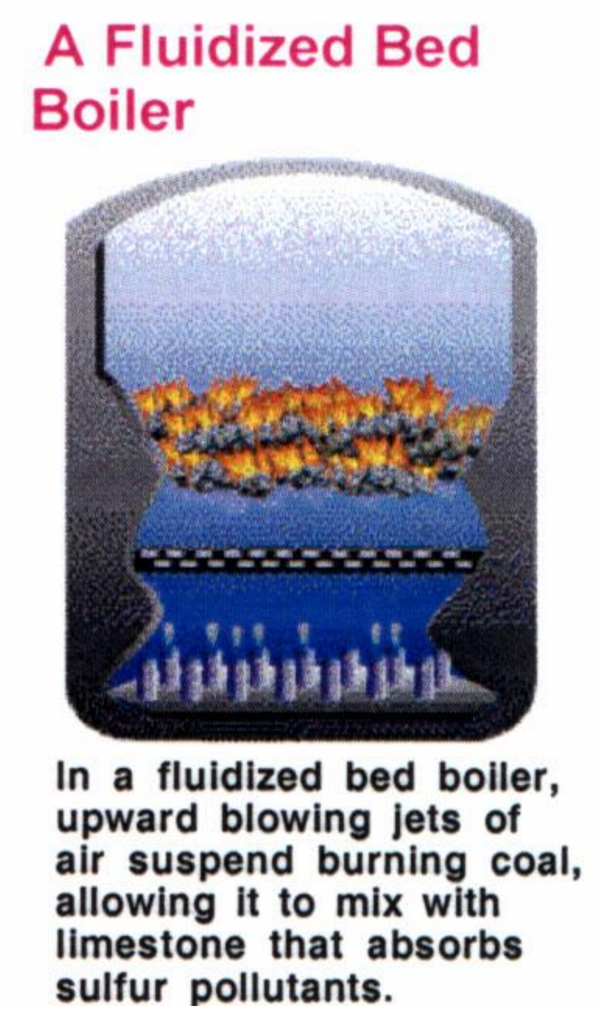
Power Plant Pollution Control



What is being
Removed by
The electrostatic
Precipitator?

By the wet
Scrubber?

Fluidized Bed Combustion



Key Reaction:

CaO (lime) + $1/2O_2$ +SO_2
= $CaSO_4$ (calcium sulfate)

Limestone = $CaCO_3$

What else besides calcium sulfate
Is emitted by Fluidized Bed
Combustion (FBC)?

FBC reduces NOx by lowering
Temperature of burning

Fossil fuel, biomass, and waste burning power plants

- In the United States, about 65% of total electricity generation in 2018 was produced from fossil fuels (coal, natural gas, and petroleum), materials that come from plants (biomass), and municipal and industrial wastes.
- In India , 75 % electricity is generated from thermal plant
- The substances that occur in combustion gases when these fuels are burned include
- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Sulfur dioxide (SO_2)
- Nitrogen oxides (NO_x)
- Particulate matter (PM)
- Heavy metals such as mercury

Negative effects

- Nearly all combustion byproducts have negative effects on the environment and human health:
- CO_2 is a greenhouse gas, which contributes to the greenhouse effect.
- SO_2 causes acid rain, which is harmful to plants and to animals that live in water. SO_2 also worsens respiratory illnesses and heart diseases, particularly in children and the elderly.
- NO_x contribute to ground-level ozone, which irritates and damages the lungs.
- PM results in hazy conditions in cites and scenic areas and coupled with ozone, contributes to asthma and chronic bronchitis, especially in children and the elderly. Very small, or *fine PM*, is also believed to cause emphysema and lung cancer.
- Heavy metals such as mercury are hazardous to human and animal health.

Coal power plants release particulate matter

Soot contains particles anywhere from 2.5 to 10 micrometers in diameter.

These have irregular surfaces that allow sulfur dioxide and nitrogen oxides to bind to them.

If it doesn't have a control system, a typical plant can emit as much as **500 tons of particles into the air each year**.

The particles can cause health problems such as asthma, chronic bronchitis, and even premature death.

Mercury is released during coal combustion:

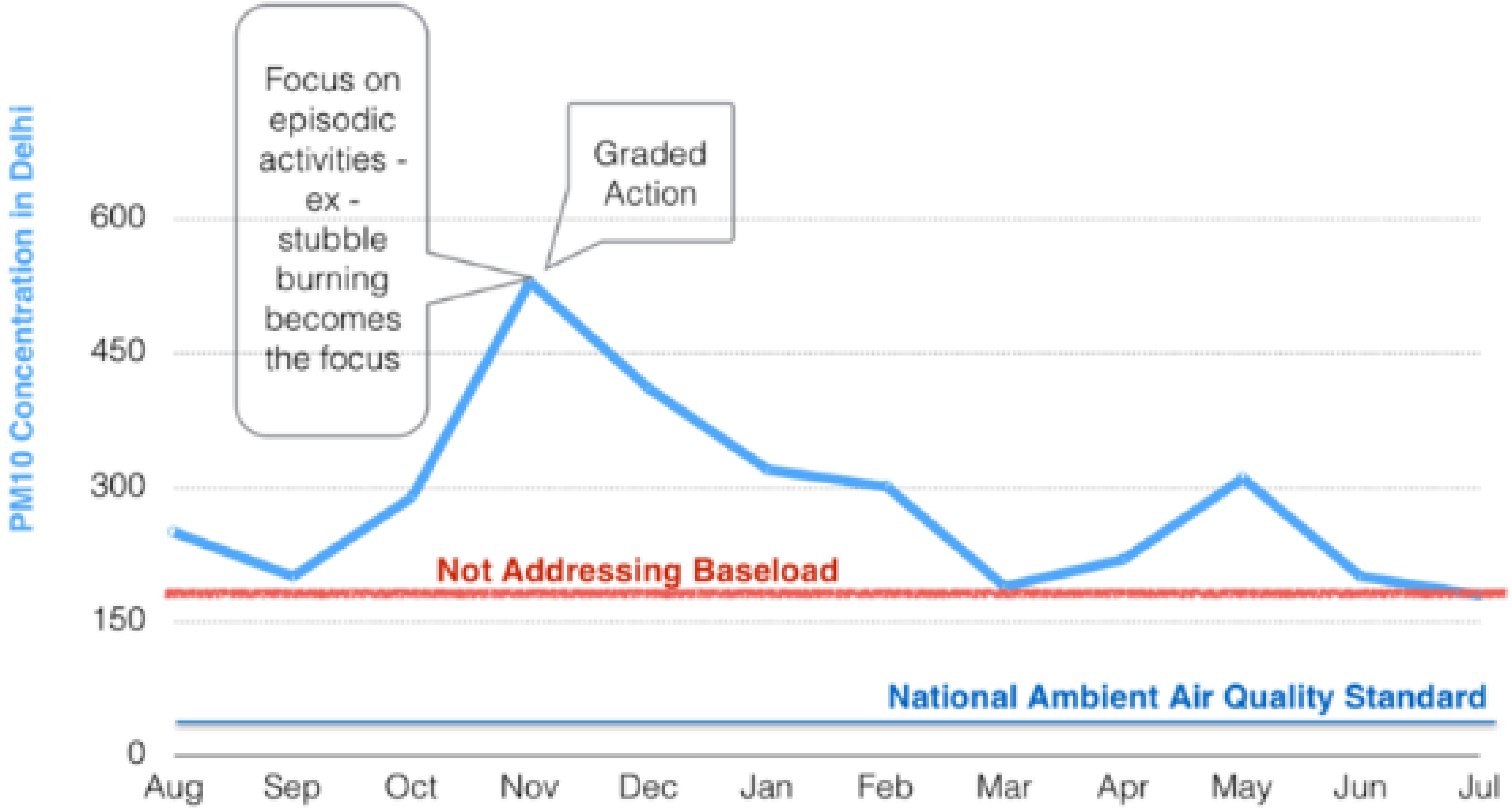
- In general, power plants emit 50 percent of the mercury released into the air, and 75 percent of the acid gases released.

- Mercury vapor is highly toxic, and can easily enter water and be converted by bacteria into a neurotoxin known as methyl mercury, which can cause seizures, cerebral palsy, and even death.

Power plants reduce air pollution emissions in various ways

- Burning low-sulfur-content coal to reduce SO_2 emissions.
- Some coal-fired power plants *cofire* wood chips with coal to reduce SO_2 emissions. Pretreating and processing coal can also reduce the level of undesirable compounds in combustion gases.
- Different kinds of particulate emission control devices treat combustion gases before they exit the power plant:
  - *Bag-houses* are large filters that trap particulates.
  - Electrostatic precipitators use electrically charged plates that attract and pull particulates out of the combustion gas.
  - Wet scrubbers use a liquid solution to remove PM from combustion gas.
- Wet and dry scrubbers mix lime in the fuel (coal) or spray a lime solution into combustion gases to reduce SO_2 emissions. Fluidized bed combustion also results in lower SO_2 emissions.
- NO_x emissions controls include low NO_x burners during the combustion phase or selective catalytic and non-catalytic converters during the post combustion phase.

Changing the focus from ‘Peak’ to ‘Baseload’

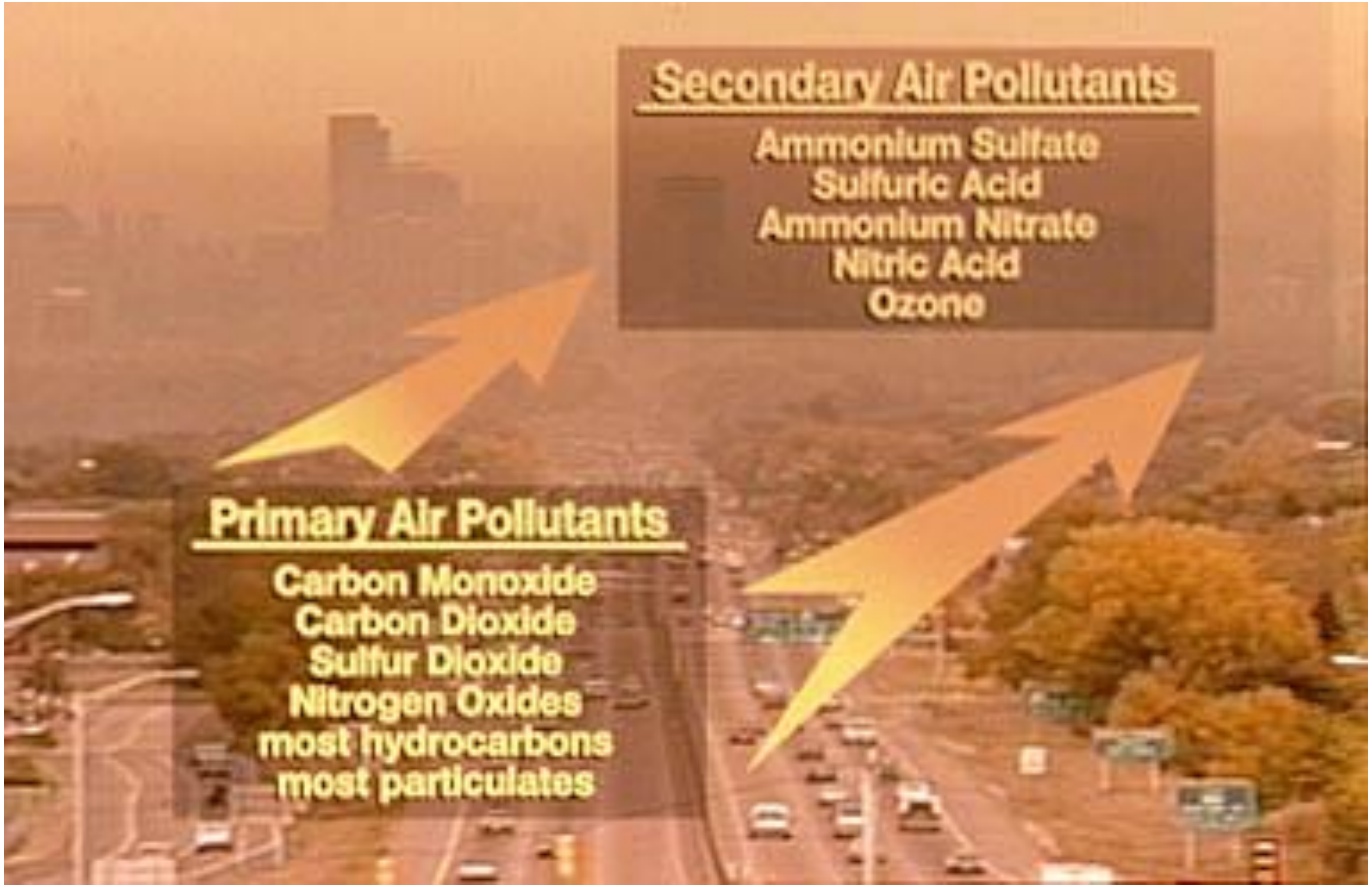


Air Pollution From Fossil Fuels

Stationary Point Source

Mobile Point Source

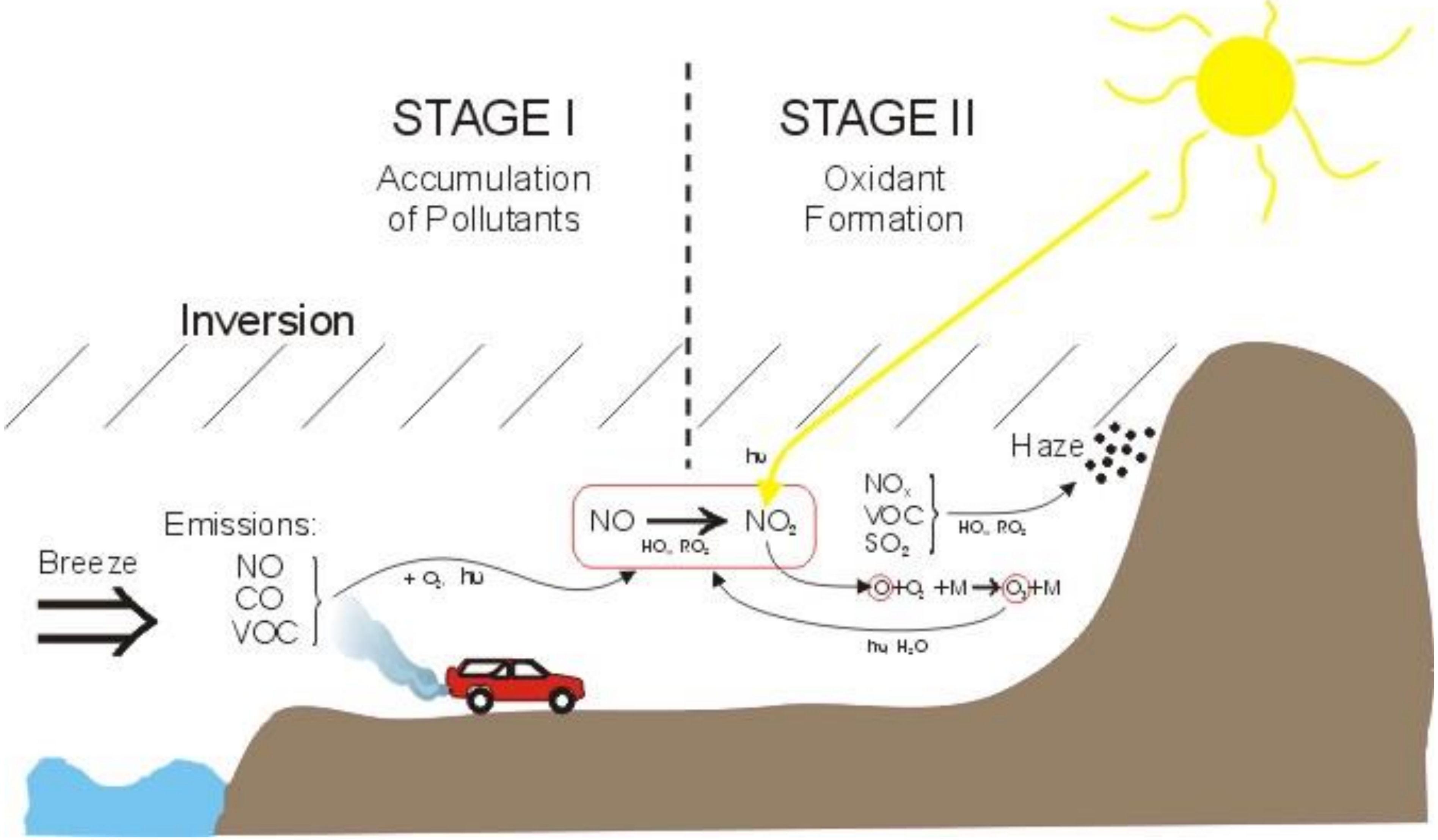
Primary & Secondary Pollutants



Photochemical Smog (Brown Smog)

- Photochemical smog is a mixture of primary and secondary pollutants formed under the influence of sunlight.
- Primary Pollutants involved are mostly NOx and volatile hydrocarbons + sunlight to produce ozone (O_3), aldehydes (CH2O), PANS (peroxyacyl nitrates), and nitric acid (HNO_3).

PHOTOCHEMICAL SMOG



Industrial Smog (gray smog)

- Industrial smog consists mostly of sulfur dioxide, suspended droplets of sulfuric acid, and a variety of suspended solid particles and droplets that emanate from coal and heavy oil burning power plants and factories.

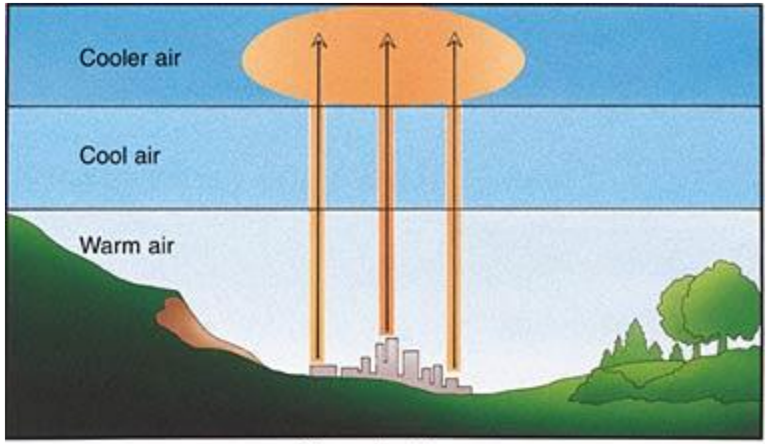
Factors That Influence The Formation of Smog

- Local climate
- Topography
- Amount of industry
- Fuels used in industry, heating & transportation
- Amount of precipitation (rain and snow cleanse atmosphere of pollutants)
- Wind patterns (winds sweep pollutants away)
- Hills and mountains reduce flow of air in valleys and allow pollutants to accumulate at ground level.
- Diurnal temperature fluctuations allow pollutants to move upward and downward in atmosphere (density differences) to prevent pollutants from accumulating at ground level.

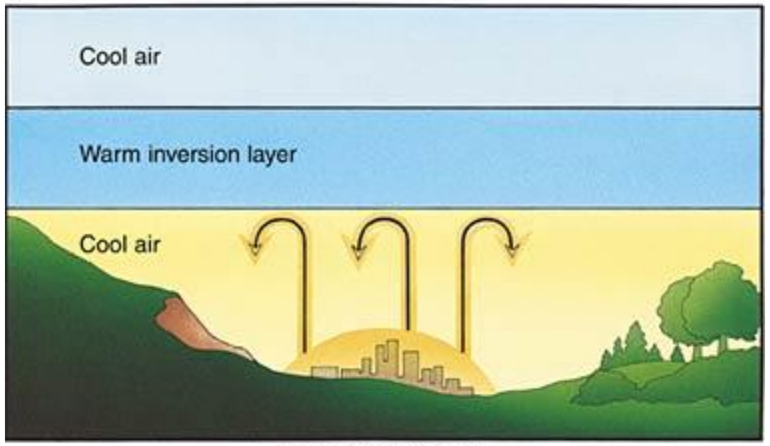
Thermal Inversions

- Warm air normally rises in the atmosphere. In a valley, a layer of dense, cool air, can become trapped below a layer of warm air capped by a denser cool air layer. This prevents air from ascending keeping air pollutants trapped in the lowest cool air layer. These events typically only occur for a few hours. When high pressure air masses stall over valley areas, thermal inversions can last for several days.

- Las Angeles California is surrounded by mountains on three sides with over 15 million people, over 24 million motor vehicles and is subject to thermal inversions 50% of the year!
- LA = has the worst air pollution in the USA



Normal pattern



Thermal inversion

Other Highly Polluted Cities in the World

- Denver, Colorado
- Mexico City, Mexico
- Rio de Janeiro and Sao Paulo, Brazil
- Beijing and Shenyang, China
- Bangkok, Thailand

Human Respiratory System

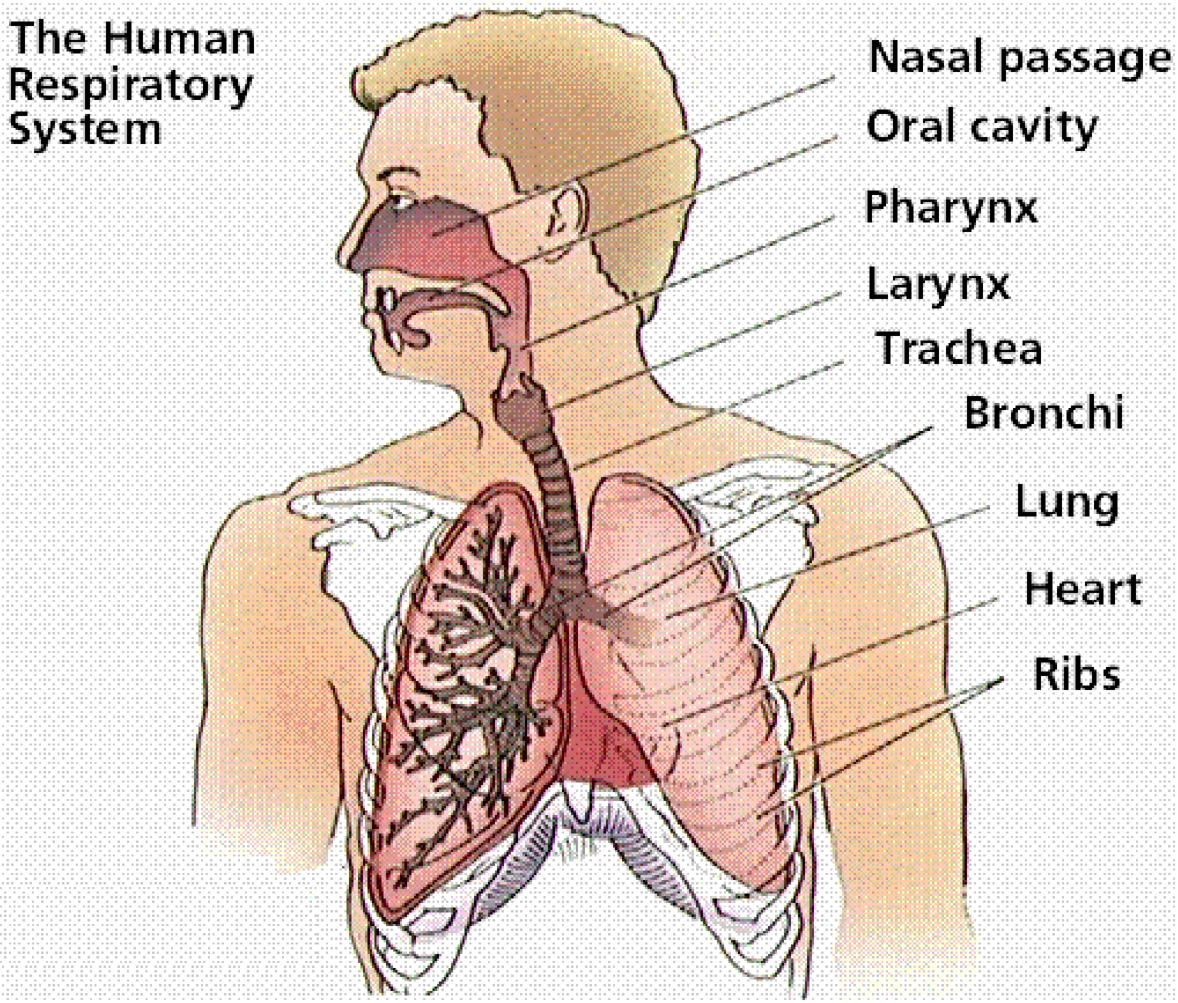
Nasal Passage – hairs to filter out pollutants

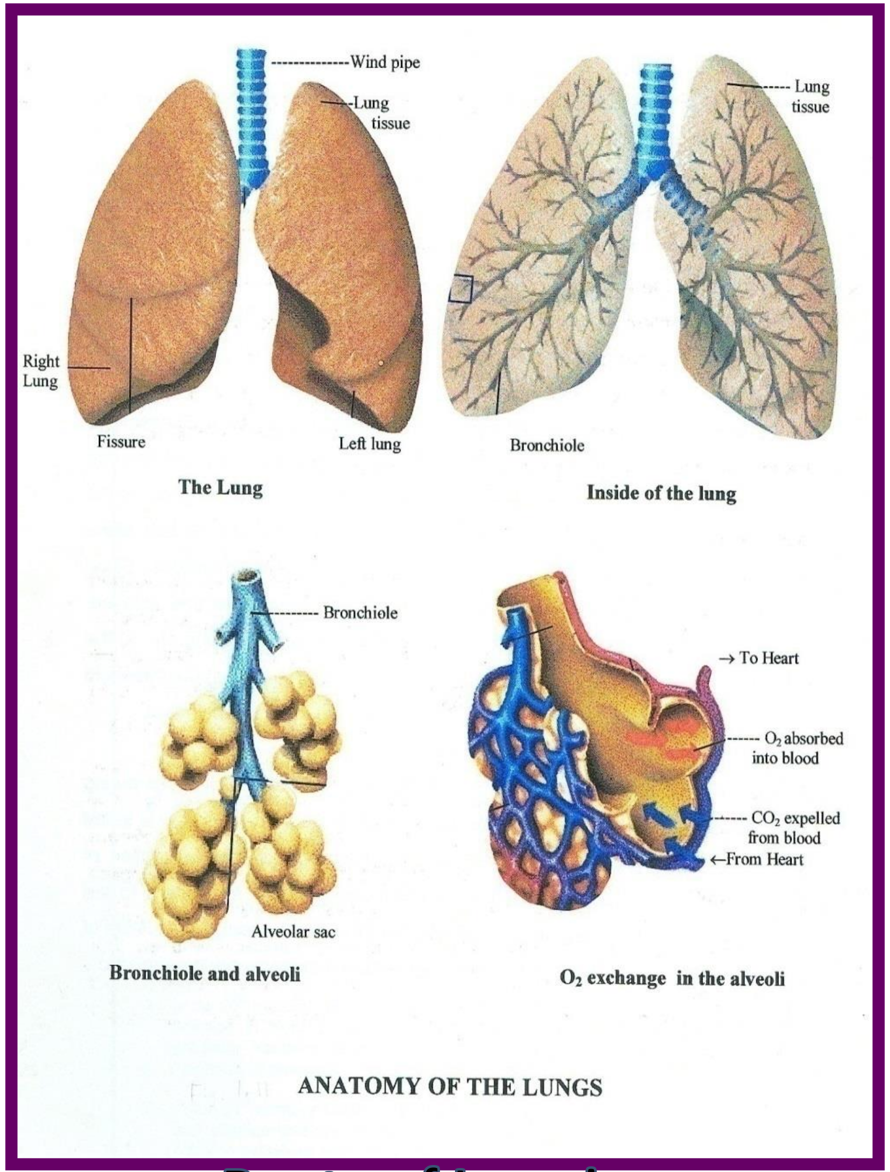
Sneezing and coughing expel contaminated air.

Sticky mucus in upper respiratory track capture small particles and filter some gaseous pollutants.

Cells of upper respiratory tract are lines with cilia that move back and forth, transporting mucous and the pollutants they trap to your throat where they can be expelled.

Alveoli in bronchioles allow for proper gas exchange.

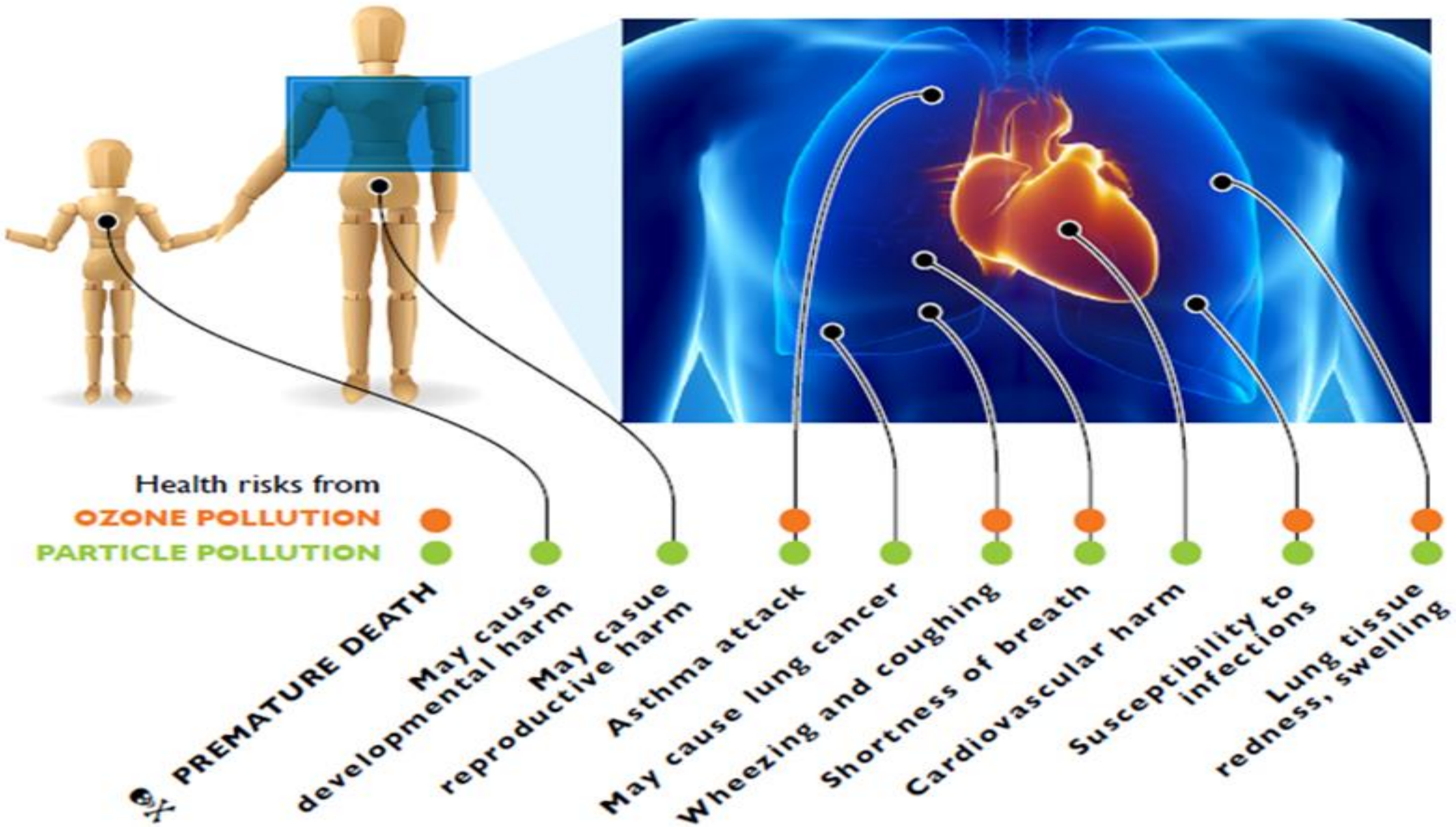




- **Route of Invasion**

- **Lung - the main entry point of air pollutants, and the target organ is the alveolus. (There are 300 million alveoli in human lungs)**
- **10,000 – 15,000 litres air enters every day in an adult lung.**
- **Increase in the concentration of pollutants cause parallel increase in the toxic insult to the lungs**
- **From the alveolus, pollutants travel via lymph or blood to different organs.**

Air pollution remains a major danger to the health of children and adults.



Effects of Air Pollution on Human Health

- Elderly, infants, pregnant woman, and people with heart disease, asthma, or other respiratory diseases are most vulnerable to air pollution (indoor and outdoor).
- lung cancer [+]
    - asthma: acute inflammation of alveoli and/or bronchi/ bronchioles (typically an allergic reaction caused by muscle spasms in the bronchiole walls).
    - chronic bronchitis - persistent inflammation and damage to the cells lining the bronchi and bronchioles causing mucus buildup, painful coughing, and shortness of breath.
    - emphysema: irreversible damage to alveoli leading to abnormal dilation of air spaces, loss of lung elasticity, and shortness of breath.
    - Carbon monoxide (CO) - reacts with hemoglobin in red blood cells to reduce ability of blood to carry oxygen. This occurs mostly as an indoor air pollutant from smoking, kerosene heaters, woodstoves, fireplaces, and faulty heating systems.
    - Suspended Particulate Matter – Small enough to penetrate the lungs and lodge in cellular tissue, mostly carcinogenic. They can cause cancer, trigger asthma attacks, aggravate other lung diseases such as bronchitis, and interfere with the blood's ability to take in oxygen and release carbon dioxide.

Effects of Air Pollutants on Health

- Sulfur dioxide – causes constriction of the airways and causes severe constriction for people with asthma. (WHO estimates 625 million people exposed from burning fossil fuels).
- Nitrogen Oxides – especially NO_2 can irritate the lungs, aggravate asthma and chronic bronchitis, cause emphysema-like conditions, and increase susceptibility to respiratory infections. NO_2 has recently been attributed to the cause of malignant melanoma.
- VOC's – (benzenes and formaldehyde) and toxic particulates such as lead, cadmium, PCB's and dioxins (agent orange) can cause mutations, reproductive problems, and cancer.
- Ozone – causes coughing, chest pain, shortness of breath, and eye, nose, and throat irritation. "Ozone alert days" - Has nothing to do with UV index!

How Many People Die Prematurely?

- No one really knows.
- Estimated annual deaths in USA related to outdoor air pollution = 65,000 – 200,000 mostly due to exposure to fine or ultra-fine particulate matter (after 9-11 will now start to see tremendous increases in those numbers in from NYC metropolitan region)
- According to the American Lung Association air pollution in the USA costs a minimum of 150 billion dollars/year in health care costs and losses in work productivity.
- WHO and World Bank estimated in 1997 that in China 2.7 million people die prematurely each year from the effects of outdoor air pollution.

Harmful Effects of Air Pollutants on Materials

- Fallout of soot and grit on buildings, cars, and clothing.
- Air pollutants break down exterior paint on cars, buildings and deteriorate roofing materials.
- Irreplaceable marble statues, historic buildings, and stained glass windows have been pitted, gauged, and discolored by air pollutants.

Solutions: Preventing and Reducing Air Pollutants

- Clean Air Acts of 1970, 1977, and 1990 – These laws require the EPA to establish national ambient air quality standards (NAAQS) for seven outdoor pollutants:

1. Suspended particulate matter
2. Sulfur oxides (SOx)
3. Carbon monoxide (CO)
4. Nitrogen oxides (NOx)
5. Ozone (O_3)
6. Volatile Organic Compounds (VOC's)
7. Lead (Pb)

Prevention of Significant Deterioration

- EPA under the Clean Air Act for regions in which air is cleaner than NAAQS, should not be allowed to deteriorate!
- National Emission Standards for Toxic Air Pollutants – includes 302 compounds and 20 categories of chemical compounds that are harmful to human health.
- Due to lack of money provided to EPA, standards have only been set for a few of these compounds.
- Car emissions tests – catalytic converters
- Automotive gasoline must have 10% additive of ethanol or MTB's in nine cities (Baltimore, Chicago, Hartford, Houston, LA, Milwaukee, NY, Philadelphia, and San Diego)
- Clean Air Act calls for overall reduction in these seven pollutants by motor vehicles and fossil fuel power plants and industry.

- Presently there have been decreases in atmospheric pollutants since the 1970's for ground ozone, CO, Sox, suspended particulate matter, NO_2 and lead levels have decreased.

How Can US Air Pollution Laws Be Improved?

- 1. Pollution prevention is best! Leaded gasoline outlawed, lead in air was reduced by 98%.
- 2. Increase fuel efficiency standards for cars and trucks, this will reduce oil imports.
- 3. Require stricter emission standards.
- 4. Fund research and development of alternative energy resources.
- Subsidize businesses and homeowners, vehicle owners for using energy conservation approaches such as hybrid vehicles, solar and wind energy for space heating, green buildings, etc..

Power plants discharge polluted water:

- Many power plants are placed along bodies of water, where they can draw it in for cooling.
- Billions of gallons may be used daily. The water is then delivered back to the river or sea, creating warm plumes, which can starve aquatic life of oxygen in summer and trap species in ice-free areas during the winter.
- Discharge waters may also contain chlorine and heavy metals.

AMBIENT AIR QUALITY STANDARDS 2009

S.No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement	Remarks
			Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Government)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Sulphur Dioxide (SO_2), µg/m^3	Annual* 24 hours**	50 80	20 80	a) Improved West and Gaeke b) Ultraviolet fluorescence	Facilities available
2.	Nitrogen Dioxide (NO_2), µg/m^3	Annual* 24 hours**	40 80	30 80	a) Modified Jacob & Hocheiser (Na-Arsenite) b) Chemiluminiscence	Facilities available

Contd..

3.	Particulate Matter (size less than 10 µm) or PM_{10} µg/m^3	Annual* 24 hours**	60 100	60 100	a) Gravimetric b) TOEM c) Beta attenuation	• Most of the NAMP Stations have Gravimetric measurement facility including CPCB • CAQMS is having BAM • TEOM has to be introduced gradually
4.	Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ µg/m^3	Annual* 24 hours**	40 60	40 60	a) Gravimetric b) TOEM c) Beta attenuation	• Gravimetric measurement facility may be developed countrywide • CAQMS is having BAM • TEOM is yet to be introduced gradually
5.	Ozone (O_3) µg/m^3	8 hours* 1 hour**	100 180	100 180	a) UV photometric b) Chemiluminiscence c) Chemical Method	• CAQMS equipped with UV based or Chemiluminescence Online Analysers and may be used for 1 hrly data • Chemical method may be adopted nationwide but monitoring hours is not specified, however 09 hrs to 17 hrs may be introduced

6.	Lead (Pb) µg/m^3	Annual* 24hours**	0.5 1.0	0.5 1.0	a) AAS/ICP method after sampling on EPM 2000 or equivalent filter paper b) ED-XRF using Teflon filter	• It appears that Pb is to be monitored in PM_{10}, this standard already exists but monitored in SPM only at few locations. • Once the sampling is done in Teflon the same may also be analyzed by other method ED-XRF
7.	Carbon Monoxide (CO) µg/m^3	8 hours* 1 hour**	02 04	02 04	Non Dispersiv Infra Red (NDIR) spectroscopy	• Only option is to go with online analyzer
8.	Ammonia (NH_3) µg/m^3	Annual* 24hours**	100 400	100 400	a)Chemiluminiscence b) Indophenol blue method	• Recently introduced at few locations in CAQMS • Chemical method may be adopted nationwide
9.	Benzene (C_6H_6) µg/m^3	Annual*	05	05	a)Gas chromatography based continuous analyzer b) Adsorption and Desorption followed by GC analysis	• BTX analysers are being used at CAQMS • Active 24 hourly sampling in diffusion tubes followed by desorption in CS_2 and finally GC Analysis may be adopted nationwide in NAMP

10.	**Benzo(a) Pyrene (BaP) – particulate phase only, ng/m^3**	**Annual***	**01**	**01**	**Solvent extraction followed by HPLC/GC analysis**	• **Facilities available with CPCB but BIS method using GC-FID may not attain the desired lowest concentration level below $1 ng/m^3$ alternatively GC-MS or HPLC-UV Fluorescence may be provided**
11.	**Arsenic (As), ng/m^3**	**Annual***	**06**	**06**	**AAS/ICP method after sampling on EPM 2000 or equivalent filter paper**	• **It appears that 'As' is to be monitored in PM_{10}.** • **Micro-wave digester is required for digestion alternatively acid digestion at 70^0 C for 12 hours is required.**
12.	**Nickel (Ni), ng/m^3**	**Annual***	**20**	**20**	**AAS/ICP method after sampling on EPM 2000 or equivalent filter paper**	• **It appears that 'Ni' is to be monitored in PM_{10}.** • **Micro-wave digester is required for digestion alternatively acid digestion at 70^0 C for 12 hours is required.**

National Ambient Air Quality Monitoring

- four air pollutants *viz* ., Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_2, and Respirable Suspended Particulate Matter (RSPM / PM10) are regularly monitored at all the locations along with meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality.

- monitoring is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week, to have one hundred and four (104) observations in a year.

Air Quality Index

- The AQI system is based on maximum operator of a function (i.e. selecting the maximum of subindices of individual pollutants as an overall AQI)
- Eight parameters (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb)
- quickly disseminate information and associated health risks to public
- For continuous air quality stations, AQI is reported in near real-time for as many parameters as possible. For manual stations,

Good (0-50)	Satisfactory (51-100)	Moderately polluted (101-200)	Poor (201-300)	Very poor (301-400)	Severe (> 401)


Think.
Act.
Save.