Indian Institute of Technology, Kharagpur. Spring 2018

EV 20001: Environmental Science

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What does the syllabus say on the topics I am supposed to speak on?

AIR POLLUTION

Air Pollutants – sources, characterization and effects
Dispersion of pollutants - Meteorology; Control of particulate matters and gaseous pollutants
Global atmospheric change; Green House effect
Acid rains, Ozone layer depletion

WASTE MINIMIZATION

Benefits of Waste Minimization
Life Cycle Assessment
Waste Reduction Techniques
Cleaner production

There are many standard text books that discuss this topic. Parts of the materials given in the study materials and PPT slides are taken from various sources. You may consult the following books for some of the topics.

Introduction to Environmental Engg and Science, Gilbert Masters, Prentice Hall, 2008

Environmental Pollution and Control, Jeffreys Peirce, Butterworth, 1998.

Definition of ENVIRONMENT

The definition varies from one country to another, but the sense remains the same

As per the UNEP Judicial Handbook on Environmental Law :
"ENVIRONMENT is a complex of natural and anthropogenic factors and elements that are mutually interrelated and affect the ecological equilibrium and the quality of life, human health, the cultural and human heritage and the landscape."

A one-liner from the Environment Protection Act of Bulgaria
"ENVIRONMENT is that part of nature which is or could be influenced by human activity"

Love for the environment and the urge to keep the environment clean have been pronounced since the early days of human civilization.

Environment and Human Civilization

- **The human civilization in some parts of the World was characterized by exploitation, destruction and non-caring of the Environment**
- **The first chapter of Genesis: People are commanded by God to subdue Nature, procreate and to have dominion over all living things. Perhaps people were advised so for their survival.**
- **There are many counter-examples of love for Nature, considering Nature as God.**
- **On the whole, the problems aggravated over centuries**

"If seven maids with seven mops
Swept it for half a year,
Do you suppose," the Walrus said,
"That they could get it clear?"
"I doubt it," said the Carpenter,
And shed a bitter tear.

—Lewis Carroll

Was the Walrus positive and hopeful?

A Vedic Shloka

द्यौः शान्तिरन्तरिक्षं शान्ति पृथिवी शान्तिरापः शान्तिरोषधयः शान्तिः। वनस्पतयः शान्तिर्विश्वेदेवाः शान्तिर्ब्रह्म शान्तिः सर्व शान्तिः शान्तिरेव शान्तिः सा मा शान्तिरेधि।
Yajurveda 36.1; Atharvaveda 19.9.94; A.C.Bose, *The Call of the Vedas*, Bhartiya Vidya Bhavan, Mumbai,1999, p.281

Here Shanti does not mean Peace only, it means fulfilment, wholesomeness, purity.

1: Om, May there be Peace in Heaven, May there be Peace in the Sky,
2: May there be Peace in the Earth, May there be Peace in the Water, May there be Peace in the Plants,
3: May there be Peace in the Trees, May there be Peace in the Gods in the various Worlds, May there be Peace in Brahman,

4: May there be Peace in All, May there be Peace Indeed within Peace, Giving Me the Peace which Grows within Me,

Historical References

Environmental Pollution is as old as the human civilization

Hippocrates (ca460 – ca370 B.C.), known as the Father of Western Medicine, wrote a book **AIRS, WATERS AND PLACES** dealing with the effect of food and weather on human health.

61 B.C.: The Roman philosopher and statesman Seneca says – "I left the heavy air of Rome behind."

1558 A.D: Queen Elizabeth forbade people to burn coal, severe penalty for violation

1760 on: Beginning of INDUSTRIAL REVOLUTION – quantum jump in coal burning; manufacture of iron and steel accelerated; other industrial activities; locomotives and steam ships followed. Air quality affected

1905: Bengal Smoke Nuisance Act to regulate burning and to install chimneys in Calcutta and Howrah

1925: Air pollution problems recognized in California; the **Technical Foundation of Air Pollution Meteorology** established

Air Pollution

Meuse Valley Fluoride Fog, 1930; Donora Fog, 1948, London Killer Fog, 1952

Meuse Valley Fog: First scientific proof of the potential of air pollution, December 1-5, 1930

- Emissions from steel works, zinc smelters, glass manufacturing in the city of Liege on the river Meuse in Belgium and surrounded by small hills on all sides
- Emissions contained SO2, fluoride, CO, particulates
- Sixty people killed, Hundreds hospitalized

Donora Fog, 1948

- The worst air pollution disaster in USA
- Started on the Halloween night, October 25, 1948, continued for seven days
- The town of Donora was on the river Monongahela in Pittsburgh, PA
- Sources of emission were steel works, zinc smelters as in Meuse valley
  - twenty people killed and hundreds hospitalized.

London Smog, 1952

- Occurred between Dec 5-9, 1952
- Anticyclonic and windless condition, a large part of London covered with dense fog
- Public life, transport (both road and rail) at standstill, flighjts cancelled
- An estimated 4000 people killed (more recent estimate puts the figure at 12,000)and 100,000 ill
- The fog disappeared quickly after Dec 9.


Daily Mirror

Smog shock—the worst for 10 years

HOSPITALS ALERT AS 40 DIE

MASKED MEN—ON THE BEAT

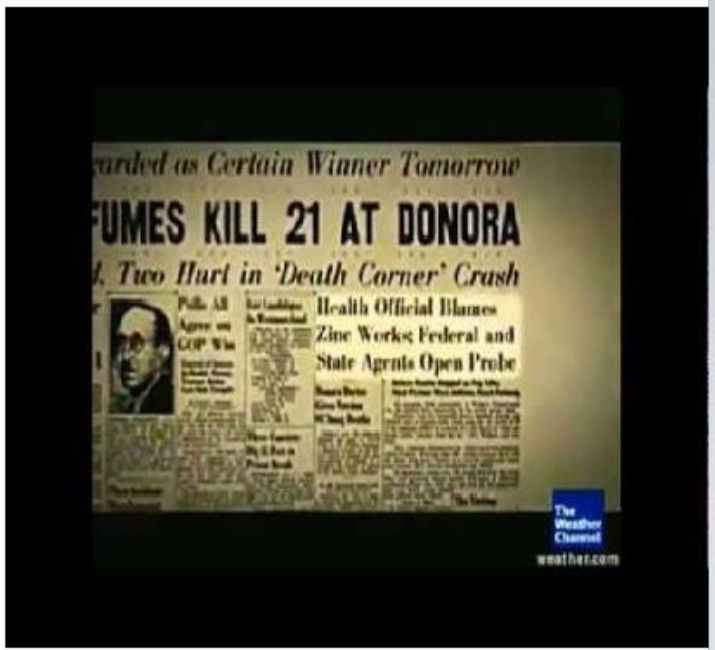
Baby off to join his Dad

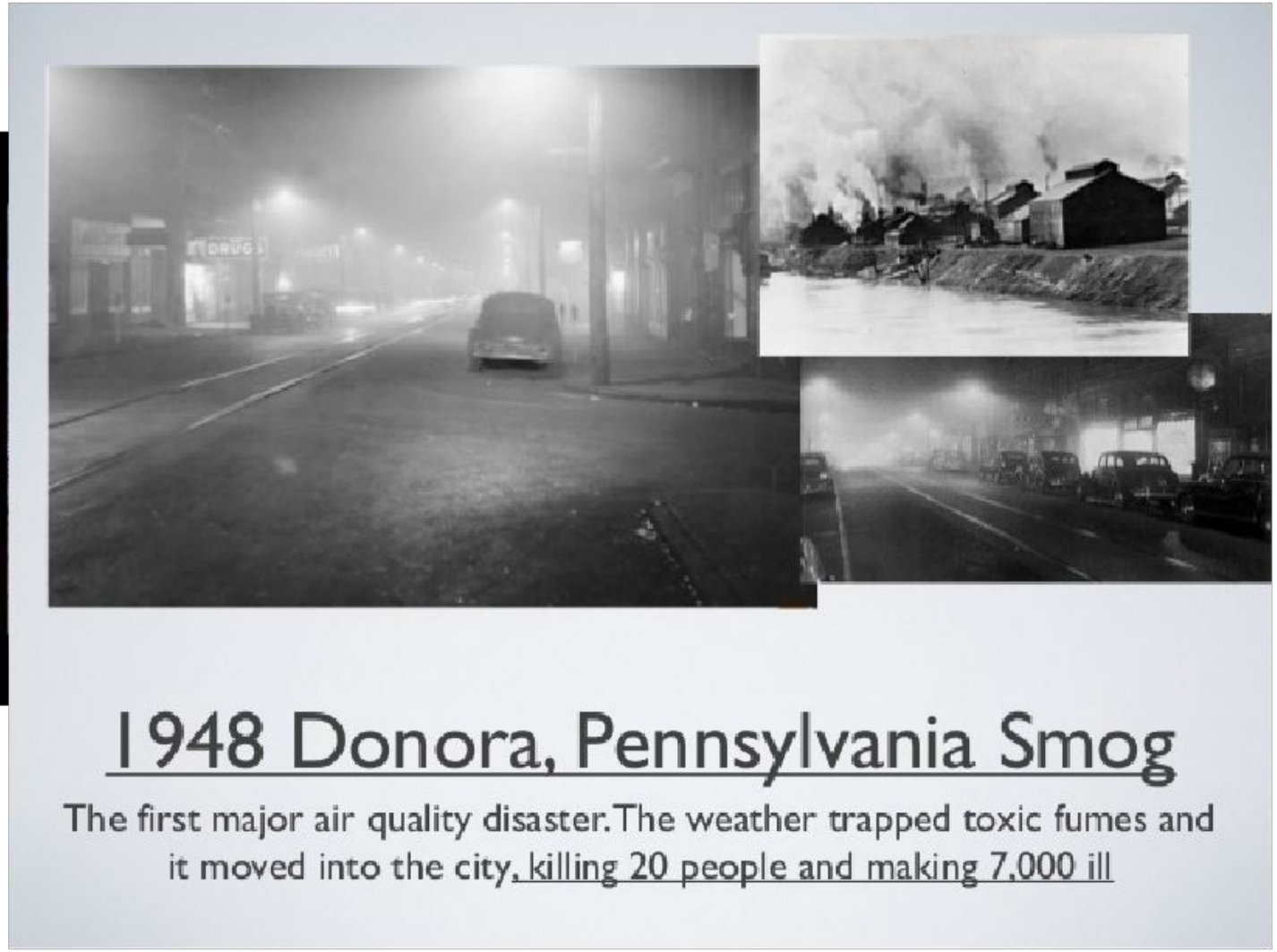
AND THIS IS WHAT CAUSES IT ALL . .

"Stay inside" warning

SENSATIONAL ½ PRICE 21-JEWEL BARGAINS

Pictures of London smog



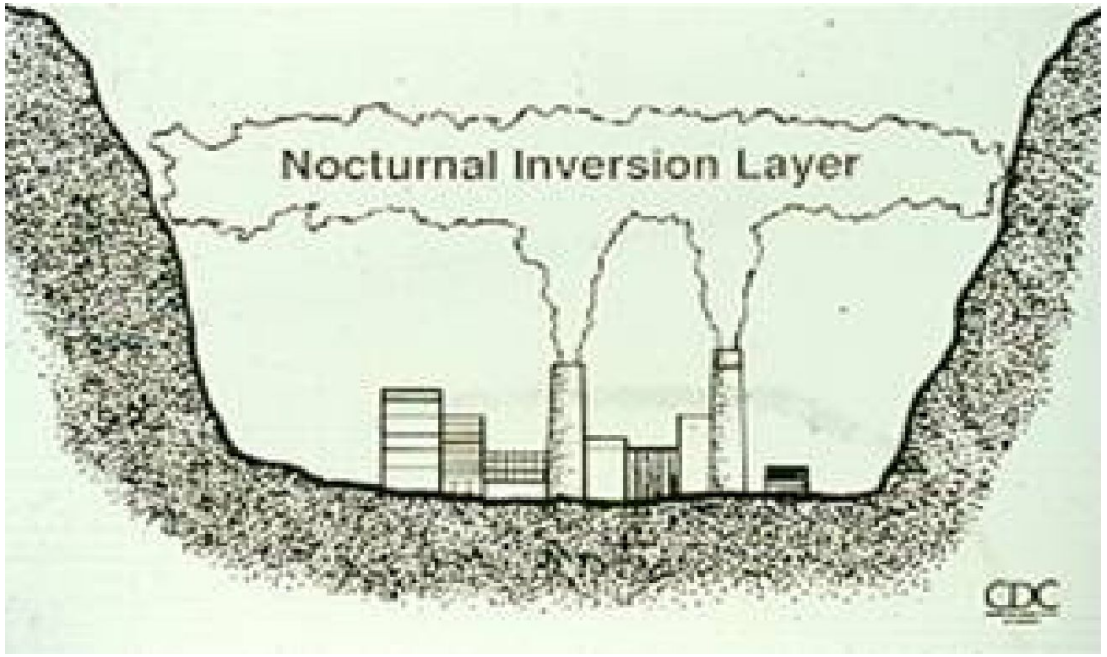


Donora smog, 1948

Temperature Inversion

The fog and disaster at all the above three places occurred because of temperature inversion

This means lower temperature near the ground and the reverse above the ground, preventing convective air movement. The phenomenon becomes more acute in valleys surrounded by hills.



Schematic of Temperature Inversion

THE BHOPAL DISASTER

Also known as Bhopal Gas Tragedy , caused by leakage of Methyl Isocyanate from the Union Carbide's pesticide plant in the night of Dec 2-3, 1984. Effects – 4000-8000 deaths (some say that the figure is much higher), 4000 permanent disabilities, above 500,000 people affected. Cleanup of the site is still pending.

- ✓ **Common Air Pollutants:**
- ✓ **Particulates, SO2, Nox, Volatile Organic Compounds including chlorinated hydrocarbons (VOC's), O3, CO, some organics formed by photochemical reactions in the atmosphere,**

Less common – H2S, HF (from industrial emission), Hg (from power plants)

Green House gases: CH4, N2O, sulfur hexafluoride (SF6)

- ✓ **Major Sources: _Combustion of fossil fuels (Domestic heating, Power generation, Motor vehicles); Industrial processes, Agricultural processes, Waste incineration**

Natural processes: Thunderstorms, Volcanoes

- ✓ **Particulate Matters**

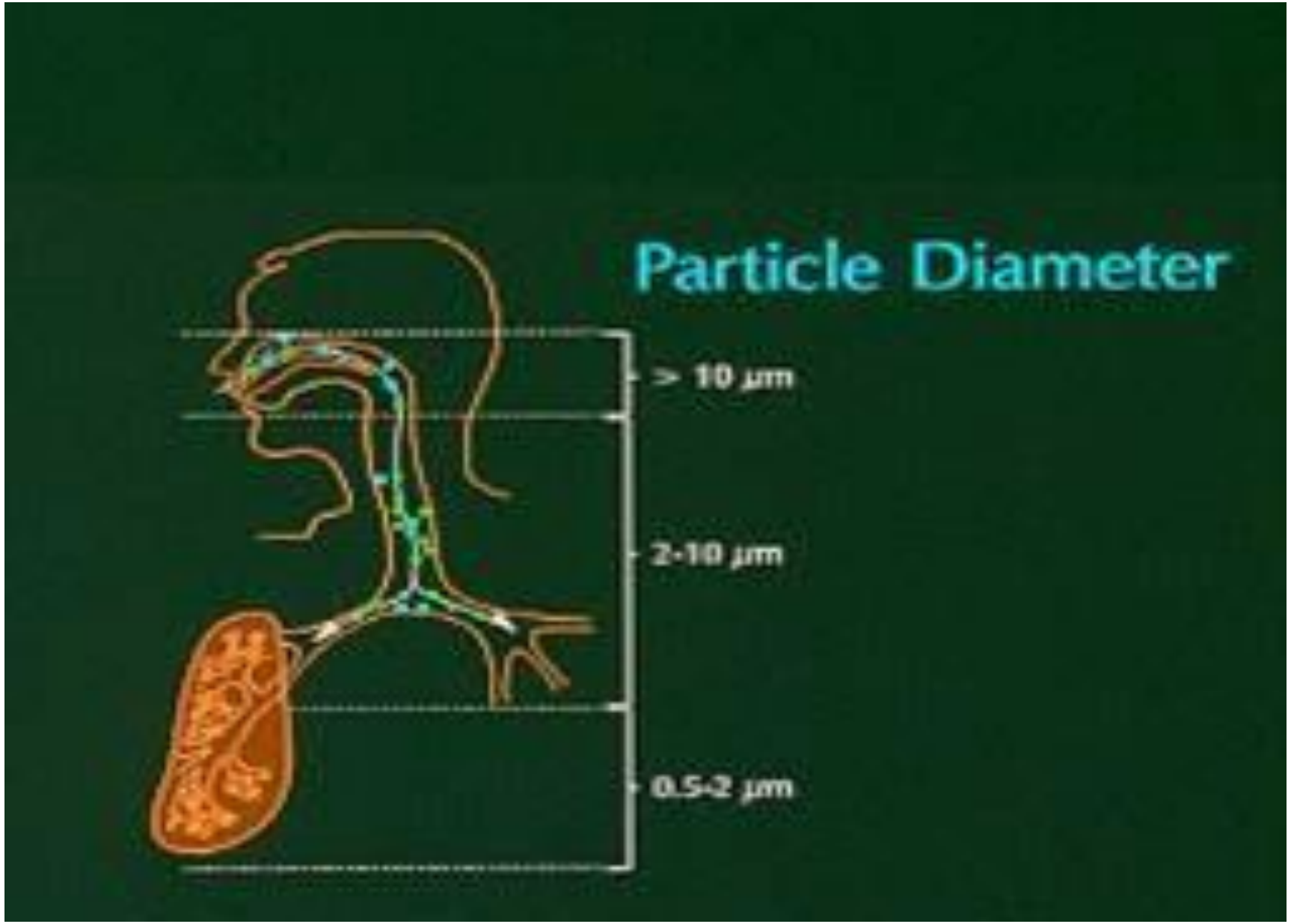
Course particles, much of this is arrested before the air duct

- ✓ **Fine Particulates**

PM10 particles with a diameter less than 10 micrometre

PM2.5 particles with a diameter less than 2.5 micometre

Passage of particulates during inhalation



Health Effects

Pollutant	Sources	Health Effects
Particulate Matter	Automobile, bus and truck exhaust, fuel burning (wood stoves, fireplaces), industry, construction.	infant respiratory mortality lung function
Ozone	Produced when nitrogen oxides (vehicle emissions) and volatile organic compounds (VOC) chemically react under sunlight.	lung growth asthma exacerbations all respiratory hospitalization
Nitrogen dioxide	Results from high temperature fuel combustion and atmospheric reactions.	symptoms in asthmatics
Carbon monoxide	Formed when carbon-containing fuel is not burned completely, emitted by motor vehicles more than any other source.	asthma hospitalization clinic visits for lower respiratory tract disease, headache
Sulfur dioxide	Industrial sites such as smelters, paper mills, power plants and steel manufacturing plants are the main sources.	asthma hospitalization clinic visits for lower respiratory tract

Effects are there on Animals, Plant Life, Non-living Objects

Global Meets on Environment

Deterioration of the environment in general got the attention of environmentalists as well as world leaders in 1960's.

It was strengthened after publication of the book **Silent Spring by Rachel Carson**, a marine biologist, in 1962.

She passionately examined and described the effect of chlorinated pesticides on the living world.

The United Nations General Assembly decided to convene the **United Nations Conference on the Human Environment** in 1972.

The Swedish Government hosted the conference in Stockholm. Leaders from 113 countries (that included the then Prime Minister of India) participated in the 12-day long conference (June 5-12, 1972), discussed the issues at length and converged on a 26 point action program to regulate and control environmental pollution.

The Stockholm Conference was the driver of change.

Some of the principles of the Stockholm Declaration are: Human rights must be asserted, apartheid and colonialism condemned, Natural resources must be safeguarded, The Earth's capacity to produce renewable resources must be maintained, Wildlife must be safeguarded, etc

The Preamble of the Stockholm Declaration said: "To achieve this environmental goal will demand the acceptance of responsibility by citizens and communities, and by enterprises and institutions at every level, all sharing equitably in common efforts".

As a follow-up action in India

- **The Central Pollution Control Board (CPCB)** was established in 1974 and a number of State Pollution Control Boards (SPCB's) were also created.
- The first environmental law was enacted by the Indian Parliament in 1974 called the **Water (Prevention and Control of Pollution) Act, 1974**.
- **Air (Prevention and Control of Pollution) Act, 1981** (often called **the Air Act**), and an umbrella act called **Environment (Protection Act) 1986**.
- **A series of rules under the act followed, the major ones being**
- **Municipal Solid Waste Rule, 2000 revised recently as Solid Waste Management Rules, 2016**
- **Plastic Waste (Management and Handling) Rules, 2011, recently revised as Plastic Waste Management Rules, 2016**
- **Electronic Waste (Management and Handling) Rules, 2011, recently revised as Electronic Waste Management Rules, 2016, etc.**
- **Standards of water quality and air quality were prescribed in the acts and the rules, Updated from time to time to make them more stringent.**
- **The CPCB and SPCB's are responsible for monitoring and for enforcement of the Acts and the Rules.**

Constitutional Provisions about Environment in INDIA

The 42nd Amendment of the Constitution , 1976

✓**Responsibilities of the Sate**

Article- 48 A: The state shall endeavor to protect and improve the environment and safeguard the forests and wild life of the country.

✓**Responsibilities of the Citizens**

Article 51 –A: It is the duty of every citizen to protect and improve the natural environment including forests, lakes, rivers and wild life.

Legislations in a few other countries:

- ✓ **Clean Air Act, 1955 in USA.**
- ✓ **The Act has since been modified from time to time to cope with the growing need on more strict monitoring and regulation - 1963 Clean Air Act, The Clean Air Quality Act of 1967, 1970 Clean Air Act Amendments, 1977 Clean Air Act Amendments, 1990 Clean Air Act Amendments.**
- ✓ **The US National Environmental Policy Act 1970 was signed on Jan 1, 1970 and the US Environmental Protection Agency (US EPA) was formed on December 2 of the same year.**
- ✓ **US EPA has the overall responsibility of environmental monitoring and regulation. There are State Level agencies as well in the US.**
- ✓ **Japan enacted the first comprehensive environmental law in 1967.**

A number of major global conferences were held as continuation to the Stockholm Conference.

- ✓ **1992 Rio Conference on Environment and Development l Agenda 21, chapter 30: "Strengthening the Role of Business and Industry", including "Promoting responsible entrepreneurship" l**

- ✓ **2002 World Summit on Sustainable Development l Political Declaration: "duty of the private sector to contribute to the evolution of equitable and sustainable communities and societies" and (para. 27) and "need for the private sector to enforce corporate accountability, …within a transparent and stable regulatory environment" (para 29) l**

- ✓ **2012 "Rio+20" Conference held at Johannesburg: "green growth"?**

Table 1: National Ambient Air Quality Standards

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (notified by Central Government)
Sulphur Dioxide (SO_2), $\mu g/m^3$	Annual*	50 80	20 80
	24 hours**		
Nitrogen Dioxide (NO_2), $\mu g/m^3$	Annual*	40 80	30 80
	24 hours**		
Particulate Matter (size less than 10 µm) or PM_{10} $\mu g/m^3$	Annual*	60 100	60 100
	24 hours**		
Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ $\mu g/m^3$	Annual*	40 60	40 60
	24 hours**		
Ozone (O_3) $\mu g/m^3$	8 hours*	100 180	100 180
	1 hour**		

Lead (Pb) $\mu g/m^3$	Annual* 24 hours**	0.50 1.0	0.50 1.0
Carbon Monoxide (CO) mg/m^3	8 hours* 1 hour**	02 04	02 04
Ammonia (NH_3) $\mu g/m^3$	Annual* 24 hours**	100 400	100 400
Benzene (C_6H_6) $\mu g/m^3$	Annual*	5	5
Benzo(a)Pyrene (BaP)-particulate phase only, ng/m^3	Annual*	1	1
Arsenic(As), ng/m^3	Annual*	6	60
Nickel (Ni), ng/m^3	Annual*	20	20

Only **eight parameters (see the section on Air Quality Index)** to calculate the Air Quality Index (AQI) are now measured

An Air Quality Index (AQI) has been defined to indicate the health effect of air pollution

AQI Category	AQI	Concentration range*							
		PM_{10}	$PM_{2.5}$	NO_2	O_3	CO	SO_2	NH_3	Pb
Good	0 - 50	0 - 50	0 - 30	0 - 40	0 - 50	0 - 1.0	0 - 40	0 - 200	0 - 0.5
Satisfactory	51 - 100	51 - 100	31 - 60	41 - 80	51 - 100	1.1 - 2.0	41 - 80	201 - 400	0.5 - 1.0
Moderately polluted	101 - 200	101 - 250	61 - 90	81 - 180	101 - 168	2.1 - 10	81 - 380	401 - 800	1.1 - 2.0
Poor	201 - 300	251 - 350	91 - 120	181 - 280	169 - 208	10 - 17	381 - 800	801 - 1200	2.1 - 3.0
Very poor	301 – 400	351 - 430	121 - 250	281 - 400	209 - 748*	17 - 34	801 - 1600	1200 -1800	3.1 - 3.5
Severe	401 - 500	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

*** CO in mg/m_3 and other pollutants in $\mu g/m_3$; 2h-hourly average values for PM_{10}, $PM_{2.5}$, NO_2, SO_2, NH_3, and Pb, and 8-hourly values for CO and O_3.**

Emission Standards for Industries

The emission standards are industry specific.

The pollutants likely to be emitted by industries are identified and the permissible limits are specified in the standards. Thus there are emission standards for power plants, refineries, cement plants, sugar industries, pharmaceutical industries, hazardous waste incinerators etc.

Also, the standards may differ for industries installed long ago from those built recently. **For example, for thermal power plants built after Jan 2003, the emission standards are:**

SO2- 200 mg/m3, NOx- 300 mg/m3, Hg- 0.03 mg/m3, Particulate Matters (PM)- 50 mg/m3.

Every industry is required to keep their record of emission monitoring. The SPCB's are required to monitor the emissions from time to time and to take regulatory actions (such as closure of an industry) if necessary. On-line monitoring is now being implemented to collect more reliable data and to prevent manipulations.

Environmental Performance Index (EPI)

The Center for Environmental Law and Policy, Yale University and The Center for International Earth Science and Information Network of Cornell University developed the concept of Environmental Performance Index (EPI)

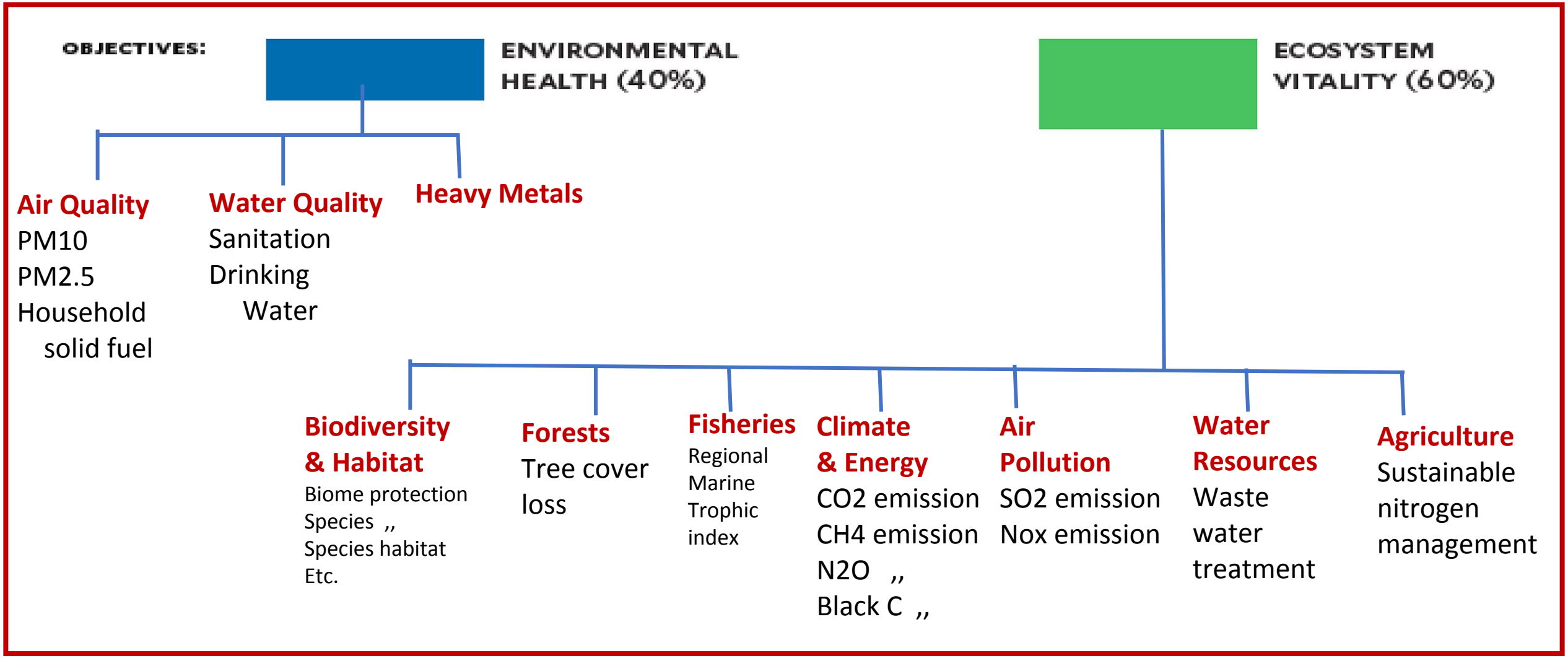
It is based on a number of criteria and factors.

There are 24 performance indicators across ten issue categories covering environmental health and ecosystem vitality.

These metrices provide a gauge at a national scale of how close countries are to established environmental policy goals. **The EPI thus offers a scorecard that highlights leaders and laggards in environmental performance, gives insight on best practices, and provides guidance for countries that aspire to be leaders in sustainability.**

According to the 2016 listing of 180 countries, Finland was on the top and India's position was 141. This year's ranking places India at 177 followed by Democratic Republic of Congo, Bangladesh and Burundi. Switzerland tops the 2018 list.

Environmental Performance Index (EPI) – Center for Environmental Law and Policy, Yale Univ and Center for International Earth Science Information, Cornell Univ



Air Pollution from Electronic and Electrical Industries

Generation of wastes from the above industries are rapidly increasing

Typically for the **electronics industry**, there are large waste gas streams (up to 400,000 Nm^3/h) with relatively low concentrations of different solvents.

The waste gases mainly occur in coating, cleaning and etching processes during the production of semiconductors, CDs/DVDs, Blue-ray discs, DVTs, TFT-LCD and plasma displays. The electronics industry has important standards to meet the need of environmental protection.

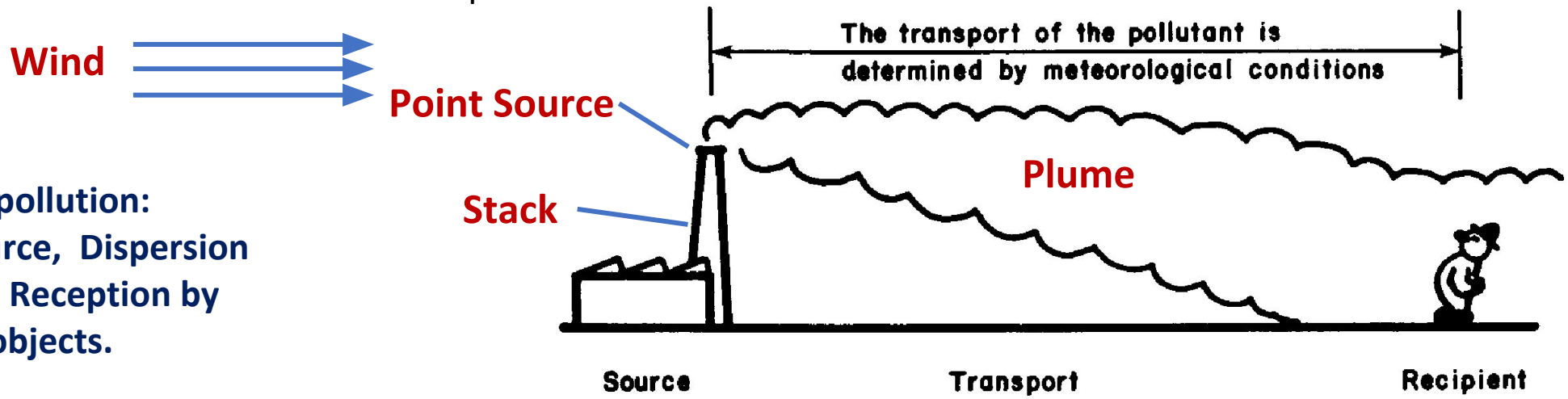
The **electrical industry** produces waste gases from dryers, kilns, and coating machines that occur in the production of basic elements such as motherboards, or end products such as motors or neon tubes.

VOC abatement techniques include absorption, adsorption or outright burning of the pollutants. For example, **Regenerative Thermal Oxidation (RTO)** is a technique for the optimal abatement of all organic pollutants such as VOC. The waste gas is directed through ceramic heat exchangers into the regenerative thermal oxidizer where harmful compounds are oxidized without residue. The hot clean gas releases thermal energy as it passes through the ceramic heat exchanger beds. This energy is recovered and used further in the process resulting in reduced auxiliary fuel requirements and lower operating costs.

In addition, these industries generate huge quantities of solid wastes much of which are toxic. There are rules [**E-Waste (Management) Rules, 2016 that do not explicitly say anything about VOC emission during production of electrical and electronic goods**] , standards and treatment technologies for these wastes which are beyond the scope of this class.

Atmospheric Dispersion of Pollutants from a Point Source

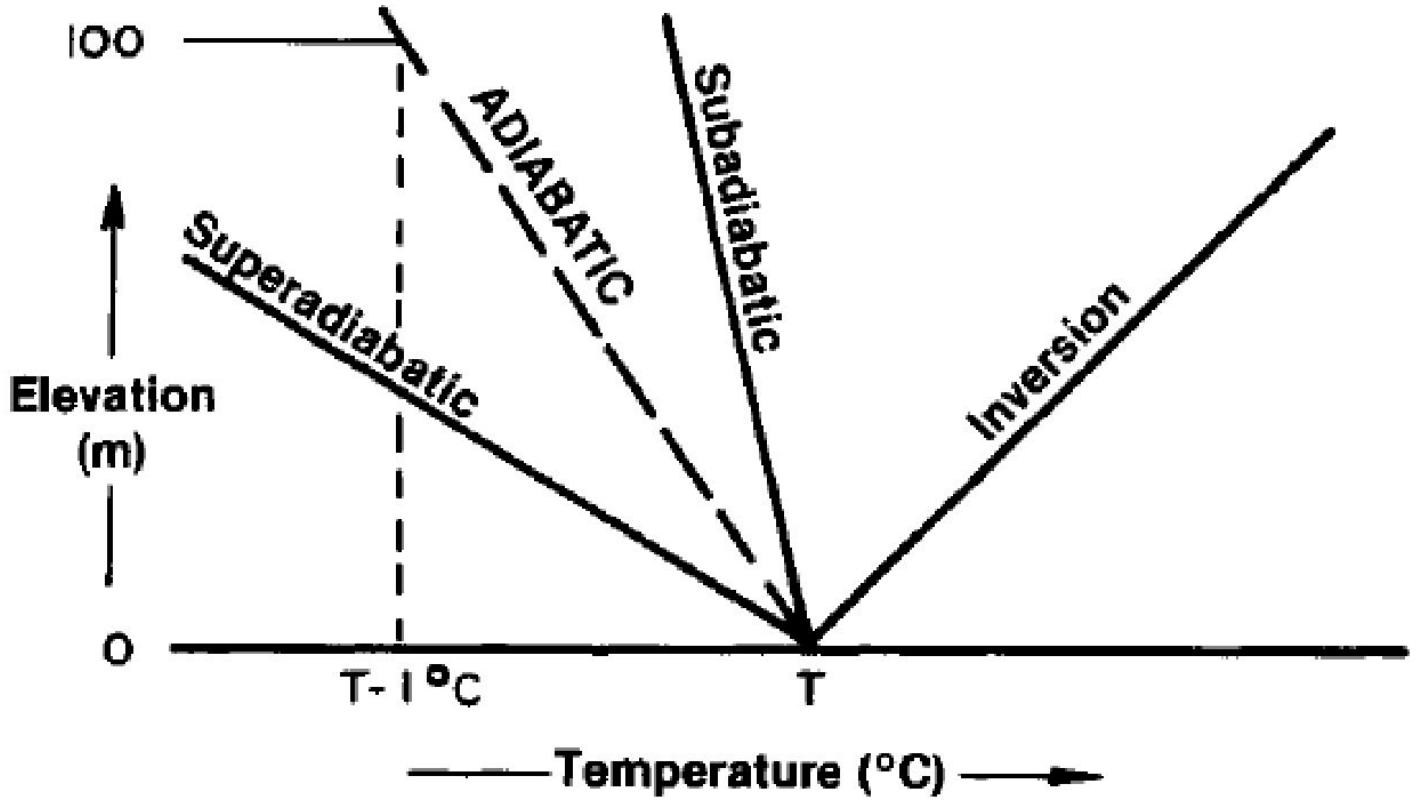
- In many practical situations, emission of air pollutants (also water pollutants) occurs from a highly localized source such as a chimney or 'stack' called a *Point Source*.
- In reality, a Point Source is a source of small cross sectional area such as the opening of a stack at the top.
- The stream of gases (such as combustion products from the coal burning furnace or boiler in a power plant) containing particulates, acid gases (such as SOx, NOx) etc rise up a distance in the air because of its velocity at the opening and its lower density than surrounding air (because of higher temperature). Thereafter it gets bent and dispersed because of the velocity of atmospheric air.
- The concentrations of the pollutants decrease downstream because of dilution and dispersion. A part of it also reached the ground level.
- It is very important to have an estimate of the ground level concentration since that greatly affects humans, animals and vegetation.
- The gas stream containing the pollutants with a gradually increasing cross-section is called a 'plume'.
- If the wind is low, the plume shows a somewhat regular shape. But in high wind, it gets twisted in an irregular fashion because of turbulent motion of atmospheric air.



Three phases of air pollution: Emission from a source, Dispersion through the air and Reception by living or non-living objects.

Basic Meteorology and Atmospheric Dispersion

- About 95% of the air mass of about 100 miles deep atmosphere remain within 12 miles of the earth's surface. This 12 mile region is called the Troposphere. Weather and air pollution issues are confined to the troposphere.
- Pollutants move and circulate in the troposphere much in the same way tropospheric air does.
- Absorption of solar radiation at the earth's surface warms up the air at the ground level. The hot air goes up and cools down because at a lower pressure at a higher level.
- The rate at which dry air cools as it rises is called the Adiabatic Lapse Rate. It can be calculated from the basic principles and is about $1^{o}C/100m$.
- The relationship between the ambient temperature and the dry adiabatic lapse rate essentially determines the atmospheric stability. Atmospheric Stability refers to the vertical motion of air under given ground temperature, density and lapse rate.
- Three types of lapse rates have been defined depending upon the atmospheric condition – Adiabatic ($1^{o}C/100m$), Superadiabatic (lapse rate > $1^{o}C/100m$) and Subadiabatic (lapse rate < $1^{o}C/100m$).
- If the ambient lapse rate is the same as the dry adiabatic lapse rate, the atmosphere is said to have Neutral Stability. Sub-adiabatic condition makes the atmosphere more stable with less vertical air motion. A special case of Sub-adiabatic conditions is called Temperature Inversion when the air temperature actually increases with altitude and a layer of warm air exists over a layer of cold air preventing vertical air motion.
- Temperature Inversion is what caused the air pollution catastrophies at Meuse valley, Donora, London and elsewhere.



Ambient Lapse Rate and Dry Adiabatic Lapse Rate

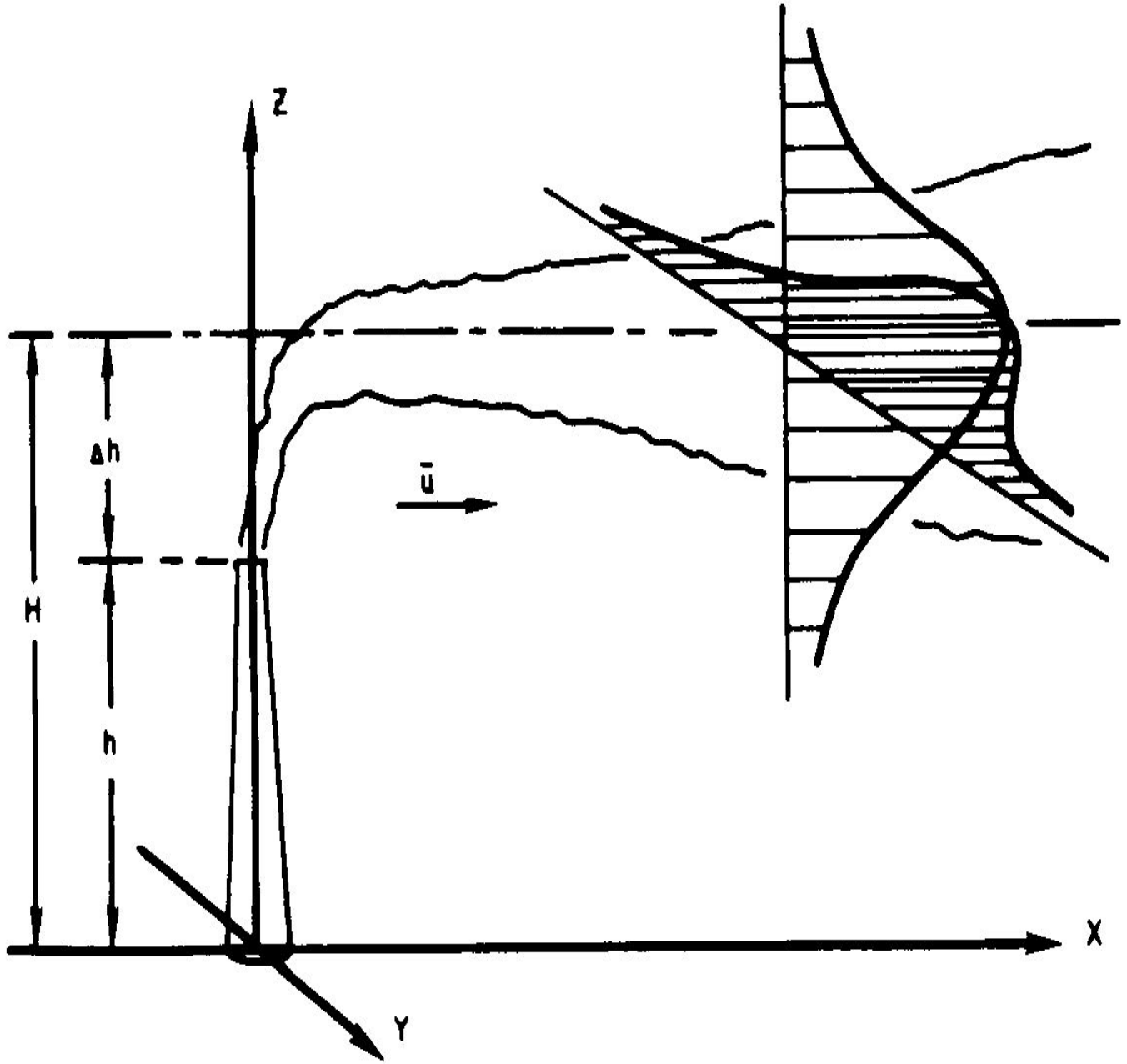
Importance of the Atmospheric Stability classes or categories

Dispersion of a pollutant occurs faster if the atmospheric condition is less stable. Atmospheric stability condition has been classified in a few categories (A, B, C, D, E and F) depending upon the intensity of solar radiation and surface wind speed. The spread of pollutants in the 'plume' depends upon the stability conditions. Spread parameters used in the procedure of dispersion calculation described in the next a few slides are obtained from charts which have been prepared for different categories of atmospheric stability.

The Gaussian Dispersion Model (developed by Pasquill)

- **This is simplified model and technique of calculation of downstream concentration of the pollutant as a function of position (*x, y, z*)**
- **The pollutant moves downwind because of the wind velocity (assumed to be uniform along the x-direction) and simultaneously disperses in the transverse directions (*y*- and *z*-direction) displaying a Gaussian dome-shaped spread. The pollutant concentration is maximum at the plume center-line. The spread in the transverse directions may be expressed in terms of dispersion coefficients.**
- **The pollutant is emitted continuously at a constant rate**

h = Height of the stack
$\triangle h$ = height of the 'straight part of the plume
$h + \triangle h$ = " effective stack height"
Thus the point source is located at $H = h + \triangle h$



Dispersion Equation and its Solution

Concentration of the pollutant can be described by a partial differential equation which may be obtained by mass balance over a small volume of air involving the rate of input and output terms. The equation is

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = D_{Ex}\frac{\partial^2 C}{\partial x^2} + D_{Ey}\frac{\partial^2 C}{\partial y^2} + D_{Ez}\frac{\partial^2 C}{\partial z^2} \quad \textbf{(Eq 1)}$$

U = wind velocity in the x-direction

The rate of emission at the source located at (0, 0, *H*) is Q (say gm/sec)

$$C(x,y,z) = \frac{Q}{2\pi U\sigma_y\sigma_z}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right)\right] \quad \textbf{(Eq 2)}$$

Here σ_y and σ_z are the spreading parameters in the *y*- and *z*-directions. These quantities can be estimated from available charts. The ground level concentrations at any x and y can be calculated by putting *z* = 0. Charts for the spreading parameters (*their dimension is length*) are given on the next two slides.

Note that the concentration distribution does not depend upon the properties of the gas (such as its diffusivity or molecular weight. This is because convection as well as atmospheric stability predominantly controls the phenomenon of dispersion and molecular properties have hardly any role to play.

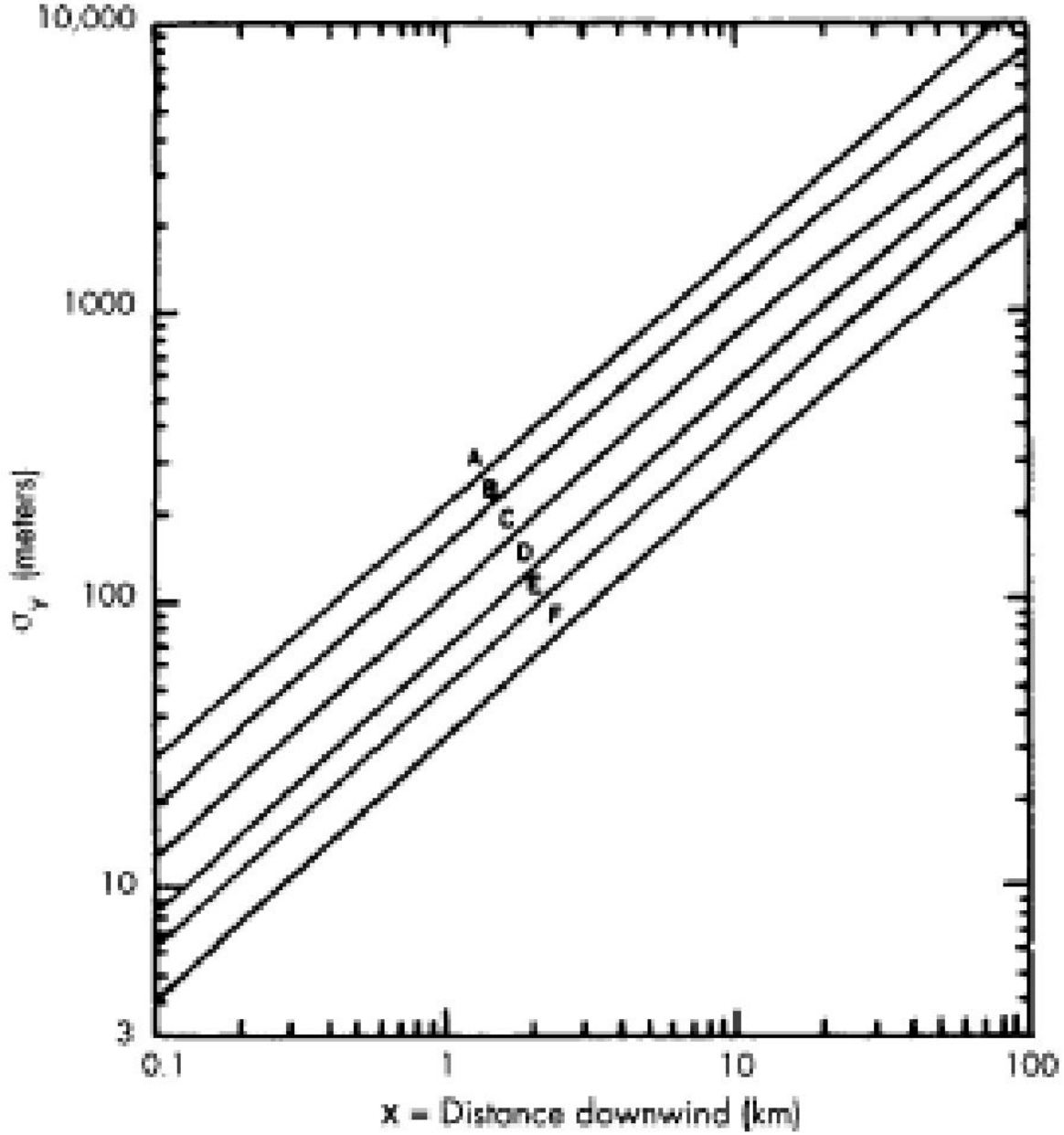


Chart for calculation of the spreading parameter σ_y

The parameters A, B C, D, E and F are atmospheric stability parameters and may be determined from separate charts.

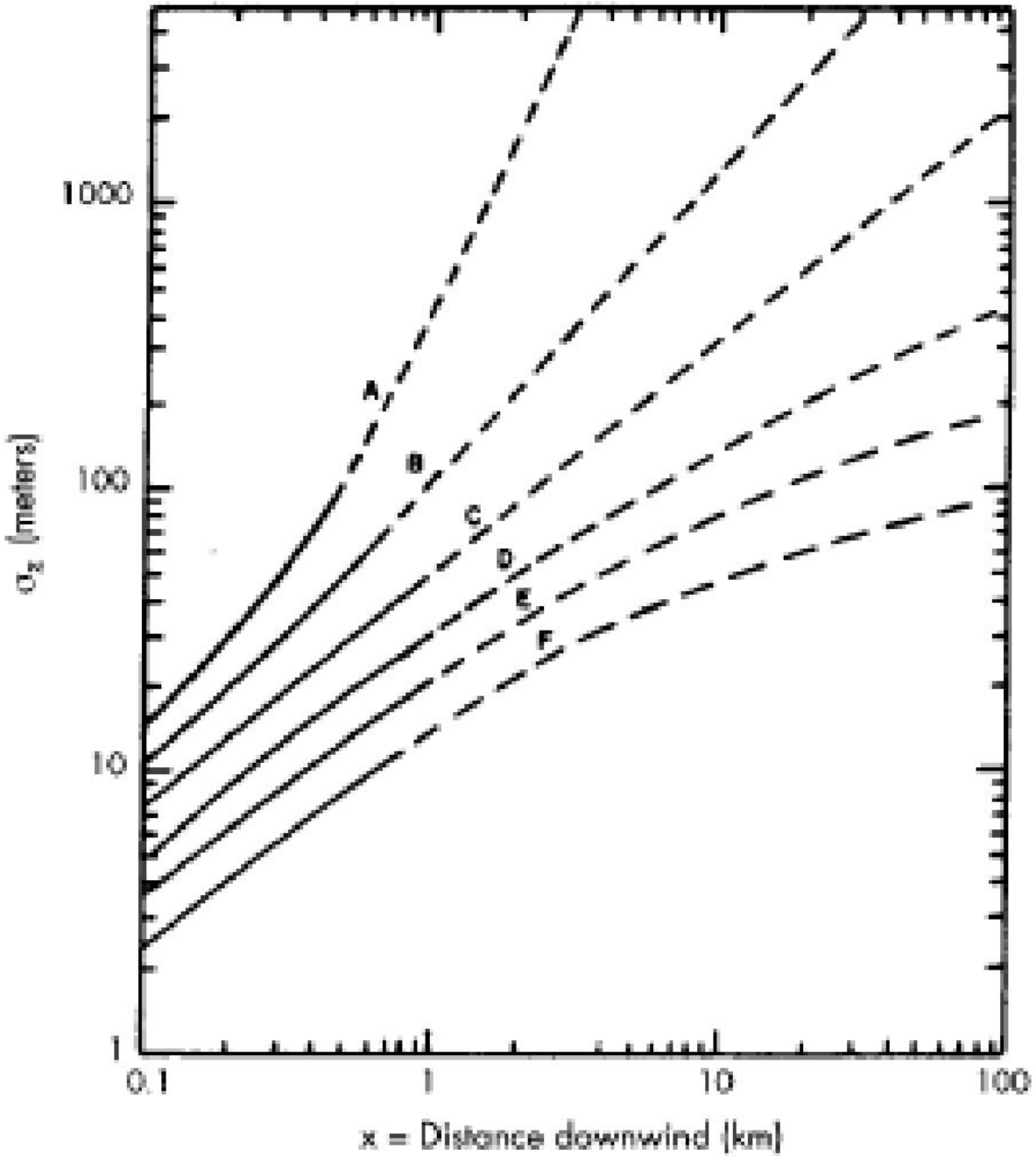


Chart for calculation of the spreading parameter σ_z

Chart for finding out the atmospheric stability parameters, A, B, C, D, E and F.

Surface Wind Speed (at 10 m) (m/sec)	Day[a] Incoming Solar Radiation (Sunshine)			Night[a]	
	Strong	Moderate	Slight	Thin Overcast or 1/2 Low Cloud	3/8 Cloud
< 2	A	A–B	B	—	—
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	—
> 6	C	D	D	D	D

More details of atmospheric dispersion are available in many standard books on air pollution. For example, Noel de Nevers: Air Pollution Control Engineering, McGraw Hill, 2000.

Example 1: A leakage in the H2S bearing pipeline of a natural gas processing plant causes release of 100 g/h of the gas. On a sunny summer day, with a wind speed of 3 m/s, what would be the ground level concentration of H2S 1.5 km directly downstream from the leak?

Solution: The required concentration can be obtained directly from Eq(2). There is no stack height; i.e., $H = 0$, $z = 0$. The concentration is to be calculated directly downstream; i.e., $y = 0$.

The weather condition corresponds to class B stability. Obtain the values of the spreading parameters from the charts for

x = 1.5 km = 1500 m, and curve B.

$$\sigma_y = 210\text{m}, \quad \sigma_z = 160\text{m}$$

Also, Q = 100 g/h = 0.0278 g/sec

Substitute in Eq (2)

$$C(1500,0,0) = \frac{0.0278\ \text{g/s}}{2\pi(3\text{m/s})(210m)(160m)} \exp\left(-\frac{0}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(0+0)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(0-0)^2}{2\sigma_z^2}\right)\right]$$

$$= \underline{8.77\times10^{-9}\ \text{g/m}^3} \quad \text{(What is the value in ppm, vol/vol?)}$$

As per WHO guidelines http://www.euro.who.int/__data/assets/pdf_file/0019/123076/AQG2ndEd_6_6Hydrogensulfide.PDF**), H2S concentration of 1.5 mg/m3 may be tolerable for intermittent exposure. Calculate the distance directly downstream where the H2S concentration attains this value. Since the spreading parameters depend upon the distance *x*, solution to the problem will need some trial-and-error. This left as a piece HOMEWORK to be submitted as hardcopy before the next class on 07/02/18.**

Example 2: A coal-based power plant emits 1.1 kg/min of SO2 from a stack with an effective height of 60 m. On a thinly overcast evening, with a wind speed of 5 m/s, what is the ground level concentration of SO2 500 m directly downwind from the stack?

Solution: The weather condition corresponds to class D stability.

For *x* = 0.5 km, the spreading parameters can be obtained from the charts.

$$\sigma_y = 35\ \text{m}, \quad \sigma_z = 19\ \text{m}$$

Also *Q* = 1.1 kg/min = 18 g/sec, *H* = 60 m, *z* = 0 (ground level).

Substitute the values in Eq(2) to get

$$C(500,0,0) = \underline{11.8\times10^{-6}\ \text{g/m}^3}$$

Air Quality Monitoring

- Sampling and analysis may be done intermittently (once or twice a week or any other appropriate frequency) or continuously (online).

- For measurement of particulates (PM10 and PM2.5), use of 'high volume samplers' is common. Measured volume of gas passes through a filter of appropriate pore size to collect particles followed by accurate weighing (gravimetric method)

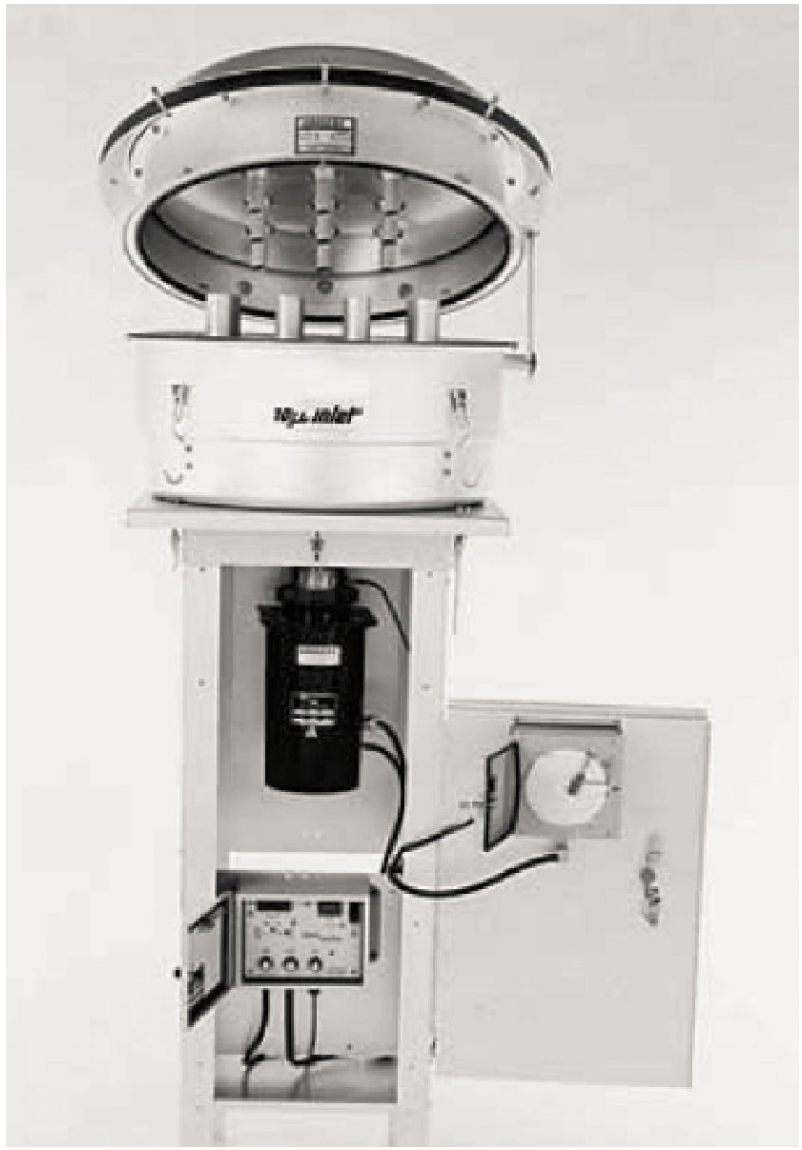
- A nephelometer is used for online monitoring. It is based on the principle of measuring the intensity of light scattered by particles and get the particle concentration therefrom. Calibration is required.

- Chemical or instrumental methods are used for other contaminants.

- Stack sampling is necessary for monitoring point source emissions from chemical industries or power plants.

- On-line monitoring is now preferred. CPCB and SPCB's are now issuing directives to industries to install on-line instruments for emission and even waste water monitoring.

- Remote monitors that use infra-red sensors are sometimes used for auto emission monitoring.



PM10

PM2.5

Anderson High Volume Samplers

Assignments

Assignments to be submitted before March 7, 2018. It is mandatory. Leave it in the office of the School of Env Sci and Engg

Assignment 1. Given in slide 35 of this file.

Assignment 2. Prepare a 2-page review (without pictures) of on-line monitoring instruments for PM10, PM2.5, SOx and NOX

Q?