Air Pollution

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The presence in the outdoor atmosphere of one or more contamination such as dust, fumes, gas, smoke, mist, odour or vapour in quantities or characteristics and of duration such as to be injurious to human, plant , animal life or to property or which unreasonably interferes with the comfortable enjoyment of life or property is known as **Air Pollution**.

Particulate Matter

a) Interference of inert particles with the clearing mechanisms of the respiratory tract: The effects includes a slowing of ciliary beat and mucus flow in the bronchial tree.

b) Particles act as carriers of adsorbed toxic gases such as SO_2 and produce synergistic effects

c) Particles may be intrinsically toxic because of their physical or chemical characteristics: such particles belong to metals which are usually found in the atmosphere in trace quantities, but may constitute a great health hazard because of the possibility of their concentrations increasing beyond normal levels (0.01 to 3.0 percent of all particulate air pollution).

Major toxic metals and their effects

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Element	Sources	Health effects
Lead	Auto exhaust (from gasoline), paints, storage batteries, pipes	Neurotoxin, affects blood system, behavioural disorders, death
Cadmium	Coal, zinc mining incineration of plastic containers, refining of metals, tobacco smoke	Cardiovascular disease and hypertension, interference with zinc and copper metabolism, kidney damage
Nickel	Combustion of coal, diesel and residual oils, tobacco smoke, chemicals and catalysts, steel and non-ferrous alloys manufacture	Respiratory symptoms, lung cancer (as nickel carbonyl)
Mercury	Combustion of fossil fuels, evaporation from ore mining, exhausts from metal smelters, chloralkali cells, paints, pharmaceuticals	Nerve and brain damage, kidney damage

Gaseous Pollutants

Sulphor Oxides

Most Common – SO_2
Colorless sharp pungent odour gas
Moderately soluble in water 11.3 g/100 ml

Oxidized slowly in clean air

SO_2 can react with polluted atmosphere under then presence of sun light and catalyst – salts of Sulphuric acid

SO_3 – H_2SO_4

SO_2 & SO_3 easily washed out due to rain

Effects of sulphur dioxides on humans

Concentration (ppm)	Effects
0.2	Lowest concentration causing a human response
0.3	Threshold for taste recognition
0.5	Threshold for odour recognition
1.6	Threshold for inducing reversible broncho-constriction in healthy individuals
8-12	Immediate throat irritation
10	Eye irritation
20	Immediate coughing

Nitrogen Oxides NO, N_20, $N0_2$, N_2O_3, N_2O_5

Major Pollutant – NO_2

Brown Pungent Gas – Irritating Odour

Can be detected at 0.12 ppm

Adsorbs sunlight and initiates series of photochemical reaction.

Small Concentration – Lower Stratosphere

Effects of atmospheric NO_2

Effect	NO_2 conc. (ppm)	Exposure
Increase in acute respiratory disease	0.06-0.1	2-3 years
Increase in acute bronchitis in school children	Up to 0.1	6 months
Human olfactory threshold	0.12	<24 hrs
Increase in airway resistance	5	10 min
Pulmonary edema	90	30 min

Carbon monoxide Single Largest Pollutant in urban Atmosphere

colourless, odourless, non-irritating but very poisonous gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

CO – CO_2 Very slow oxidation

Resident time – 6 months
Exposed to sun light several years no change

Effects of COHb blood levels

COHb blood level	Effects on healthy individuals	Effects on heart patient
1-5	Blood flow to certain vital organs increases to compensate for reduction in oxygen carrying capacity of blood	Heart patients may lack sufficient cardiac reserve to compensate
5-9	Visual light threshold increased	Patients with angina pectoris require less exertion to induce chest pain
16-20	Laboured respiration during exertion, visual evoked response abnormal	May be lethal for patients with severe cardiovascular disease
20-30	Headache, nausea	
30-40	Severe headache, nausea and vomiting, dizziness	
40-50	Slurring of speech; tendency to collapse	
50-60	Convulsions; coma	
60-70	Fatal coma if not treated	

CO levels cities are usually between 10 to 40 ppm on an annual 8hr average basis and occasional short term concentration may exceed 100 ppm.

These levels can easily lead to COHb concentration in blood approximately 2-8 %.

CO levels in urban areas

City	Maximum 1 hr CO values, ppm
London	58
Chicago	46
Los angles	43
New York	27
Kolkata	35

Effect on health of ozone and total photochemical oxidants

Effects	Concentration (ppm)	Exposure
Ozone		
Increased airway resistance	0.1-1.0	1hr
Extreme fatigue, lack of coordination	1.0-3.0	2hr
Severe cough	2.0	2hr
Pulmonary edema	9.0	unkonwn
Total Oxidants		
Eye irritation	0.1	Instantaneo us
Aggravation of asthma	0.050-0.06	1hr
Impaired performance of athletes	0.03-0.3	1hr

Hydrocarbons

At the concentration usually found in urban air, the hydrocarbons cause no adverse effects on human health.

Aliphatic hydrocarbons produce undesirable effects only at concentrations 10^2 to 10^3 times higher than those usually found in the atmosphere. No effects have been observed for levels below 500ppm.

Aromatic hydrocarbons are more reactive than aliphatic ones .

Outdoor air may contain low levels of benzene from automobile service stations, wood smoke, tobacco smoke, the transfer of gasoline, exhaust from motor vehicles, and industrial emissions. About 50% of the entire nationwide (United States) exposure to benzene results from smoking tobacco or from exposure to tobacco smoke.

Benzene increases the risk of cancer and other illnesses. Benzene is a notorious cause of bone marrow failure.

Substantial quantities of epidemiologic, clinical, and laboratory data link benzene to aplastic anemia, acute leukemia, and bone marrow abnormalities.

The specific hematologic malignancies that benzene is associated with include: acute myeloid leukemia (AML), aplastic anemia, myelodysplastic syndrome (MDS), acute lymphoblastic leukemia (ALL), and chronic myeloid leukemia (CML).

Benzene targets liver, kidney, lung, heart and the brain and can cause DNA strand breaks, chromosomal damage, etc. Benzene causes cancer in animals including humans. Benzene has been shown to cause cancer in both sexes of multiple species of laboratory animals exposed via various routes.

Some women who inhaled high levels of benzene for many months had irregular menstrual periods and a decrease in the size of their ovaries.

Benzene exposure has been linked directly to the neural birth defects spina bifida and anencephaly.

Men exposed to high levels of benzene are more likely to have an abnormal amount of chromosomes in their sperm, which impacts fertility and fetal development.

benzo[*a*]pyrene

A vast number of studies over the previous three decades have documented links between benzo[*a*]pyrene and cancers.

It has been more difficult to link cancers to specific benzo[*a*]pyrene sources, especially in humans, and difficult to quantify risks posed by various methods of exposure (inhalation or ingestion). Researchers at Kansas State University recently discovered a link between vitamin A deficiency and emphysema in smokers. Benzo[*a*]pyrene was found to be behind the link, since it induces vitamin A deficiency in rats.

In 1996, a study was published that provided the clear molecular evidence conclusively linking components in tobacco smoke to lung cancer. Benzo[*a*]pyrene, found in tobacco smoke (including cigarette smoke), was shown to cause genetic damage in lung cells that was identical to the damage observed in the DNA of most malignant lung tumours.

Table 2.18 Effects of specific air pollutants on vegetation

Pollutant	Level (ppm) and exposure	Effects
SO_2	0.3 to 0.5 for several days	Bleached spots, chlorosis, chronic injury to spinach, and other leafy vegetables
NO_2	0.25 for 8 month	Increased abscission and reduced yield in citrus plants
	0.5 for 10–12 days	Suppressed growth of tomatoes
	3.5 for 21 hours	Spots of mild necrosis on cotton and bean plants
	25 for 1 hour	Acute leaf injury
Ozone	0.03 for 8 hours, time effect reduced if low level SO_2 is also present	Fleck on upper surface; Necrosis and bleaching; damage to tobacco leaves at O_3=0.027 ppm and SO_3=0.24 ppm after 2 hours of exposure
Peroxyacetyl nitrate (PAN)	0.01 to 0.05 for a few hours	Glazing or bronzing of underside of leaf; damage to sensitive plants; young leaves more susceptible to damage
HF	0.001 for 7–21 days can be significant; cumulative effect	Necrosis of leaf tip, grapes are particularly susceptible
Ethylene	0.1 for several hours or 0.05 for several weeks	Epinasty; leaf abscission, flower dropping

Effect on Air Pollution on Materials

The damage caused by atmospheric pollutants to materials is a well-known phenomenon. Particulates such as soot, dust and fumes soil painted surfaces, fabrics and buildings, and because of their abrasive nature, particulates can cause damage to exposed surfaces when they are driven by wind at high velocities.

Through their own corrosiveness or in the presence of S02 and moisture. They can accelerate the corrosion of steel, copper, zinc and other metals.

The most notorious pollutant responsible for metallic corrosion is sulphur oxide. It has been reported that corrosion of hard metals such as steel begins at annual mean concentrations of 0.02 ppm (52 µg/m^3). At levels of 0.09-1 ppm, SO_2 affects fabrics, leather and paint. SO_2 is readily absorbed by leather and causes its disintegration. Paper is also disc coloured by SO_2 and becomes brittle and fragile. Sulphuric acid and mist in the atmosphere causes deterioration of structural materials such as marble and limestone. Many priceless marble sculptures and buildings have suffered damage in the last 30 years as a result of increased SO_2 content in the atmosphere.

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Ozone is a very reactive substance. Much of the degradation of materials, such as fabrics and rubber, now attributed to weathering is caused primarily by ozone.
Ozone causes the cracking of synthetic rubbers at atmospheric levels of 0.01-0.02 ppm (20-40 µg.m3).

It also attacks fabric fibres and the adverse effects increase in the order: fibres made of cotton, acetate, nylon and polyester. The fading of fibres and the cracking of rubber are attributed to ozone's oxidising ability.

Nitrogen oxides, although less widely publicised than ozone, are known to cause fading in acetate, cotton and rayon fibres at levels of 0.6-2 ppm over 2-3 month period.

It has been observed that particulate nitrates attack and damage nickel-brass alloys in the presence of moisture

Table 2.7 Major air pollution disasters (refs. 18, 19, 20)

Location	Conditions and causes	Symptoms and effects
Meuse Valley, Belgium, Dec. 1930	Inversion, smoke, SO_2 (9.6-38.4 ppm.) H_2SO_4 mist	60 excess deaths, thousands ill, eye and nasal irritation, cough
Donora, U.S.A. Oct. 1948	Inversion and fog, SO_2 (0.5-2 ppm.) smoke, zinc particles, H_2SO_4 mist	20 excess deaths, 6000 of town's 14000 population became ill, irritation of eyes, nose and respiratory tract, breathlessness, nausea
Poza Rica, Mexico, Nov. 1952	Shallow inversion, fog and calm conditions, H_2S release due to burner failure	22 excess deaths, 320 hospitalised, irritation of the respiratory tract
London, England Dec., 1952	Low temperature inversion, thick fog, stagnant air, smoke (4500 $\mu g/m^3$) and SO_2 (1.4 ppm) accumulation.	Estimated 4000 deaths, thousands hospitalised for respiratory and heart disease, chronic bronchitis, broncopneumonia
London, England Jan. 1956	Extended fog conditions similar to 1952 episode, particulates (3250 $\mu g/m^3$), SO_2 (0.57 ppm)	1000 excess deaths
London, England Dec. 1962	Shallow inversion, thick fog smoke (2000 $\mu g/m^3$), SO_2 (1.26 ppm)	700 excess deaths, increased illness.
New York, U.S.A. Nov 1966	SO_2, particles	168 excess deaths
Seveso, Italy July, 1976	Reactor explosion releasing dioxin plume and cloud settled over an area of 1430 hectares	No excess deaths, 187 cases of skin chloracne, 32 official abortions, 15 cases of deformed births and 6 premature offspring, dizziness, diarrhea.
Bhopal, India Dec. 1984	Release of 30 tonnes of deadly methyl isocynate gas from storage tanks due to alleged failure of vent scrubber system	Estimated deaths more than 2500; 1,00,000 people severely affected, vomiting, violent coughing, chemical conjunctivitis, suffocation, cardiac failure.

NATIONAL AMBIENT AIR QUALITY STANDARDS (2009)

Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)	
Sulphur Dioxide (SO_2), µg/m³	Annual * 24 Hours **	50 80	20 80	-Improved West and Gaeke Method -Ultraviolet Fluorescence
Nitrogen Dioxide (NO_2), µg/m³	Annual * 24 Hours **	40 80	30 80	-Jacob & Hochheiser modified ($NaOH-NaAsO_2$) Method -Gas Phase Chemiluminescence
Particulate Matter (Size less than 10µm) or PM_{10}, µg/m³	Annual * 24 Hours **	60 100	60 100	-Gravimetric -TEOM -Beta attenuation
Particulate Matter (Size less than 2.5µm) or $PM_{2.5}$, µg/m³	Annual * 24 Hours **	40 60	40 60	-Gravimetric -TEOM -Beta attenuation
Ozone (O_3) µg/m³	8 Hours * 1 Hour **	100 180	100 180	-UV Photometric -Chemiluminescence -Chemical Method
Lead (Pb) µg/m³	Annual * 24 Hours **	0.50 1.0	0.50 1.0	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper -ED-XRF using Teflon filter

* Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Carbon Monoxide(CO), mg/m^3	8 Hours ** 1 Hour **	02 04	02 04	-Non dispersive Infrared (NDIR) Spectroscopy
Ammonia (NH_3), µg/m^3	Annual * 24 Hours **	100 400	100 400	-Chemiluminescence -Indophenol blue method
Benzene (C_6H_6), µg/m^3	Annual *	05	05	-Gas Chromatography (GC) based continuous analyzer -Adsorption and desorption followed by GC analysis
Benzo(a)Pyrene (BaP) Particulate phase only, ng/m^3	Annual *	01	01	-Solvent extraction followed by HPLC/GC analysis
Arsenic (As), ng/m^3	Annual *	06	06	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper
Nickel (Ni), ng/m^3	Annual *	20	20	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper

* Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

NOTE: Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigations.

AIR QUALITY INDICES:

Air quality indices are tools devised to simplify the interpretation of data with minimum loss of scientific information so as to provide a scale for measuring the air pollution status.

1. US EPA Air quality Index
2. The Mitre Air quality Index (MAQI)
3. Extreme value Index (EVI)
4. Oak Ridge Air Quality index)QRAQI)
5. Air Quality Index (NAAQS Dependent)
6. Air Quality Depreciation Index (NAAQS Independent)
7. National Ambient Air Quality Index 2015

7. **AIR Quality Index 2015**

The project aims to achieve the following:

(i) Inform public regarding overall status of air quality through a summation parameter that is easy to understand;

(ii) Inform citizens about associated health impacts of air pollution exposure; and

(iii) Rank cities/towns for prioritizing actions based on measure of AQI.

The overall objective of the project can be stated as under:

"To adopt/develop an Air Quality Index (AQI) based on national air quality standards, health impacts and monitoring programme which represents perceivable air quality for general public in easy to understand terms and assist in data interpretation and decision making processes related to pollution mitigation measures."

Eight parameters (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) having short-term standards have been considered for near real-time dissemination of AQI.

It is recognized that air concentrations of Pb are not known in real-time and cannot contribute to AQI.

However, its consideration in AQI calculation of past days will help in scrutinizing the status of this important toxic.

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

AQI calculation and description as per CPCB 2014 guideline is presented at different monitoring locations during monitoring. The sub-index (I_p) for a given pollutant concentration (C_p), as based on 'linear segmented principle' is calculated as:

$$I_p = [\{(I_{HI} - I_{LO})/ (B_{HI}-B_{LO})\} * (C_p-B_{LO})] + I_{LO} \quad (1)$$

B_{HI}= Breakpoint concentration greater or equal to given conc.

B_{LO}= Breakpoint concentration smaller or equal to given conc.

I_{HI} = AQI value corresponding to B_{HI}

I_{LO}= AQI value corresponding to B_{LO}

Finally;

AQI = Max (I_p) (where; p= 1, 2,...., n; denotes n pollutants)

Proposed Breakpoints for AQI Scale 0-500, (units: µg/m³ unless mentioned otherwise)

AQI Category (Range)	PM_{10} 24-hr	$PM_{2.5}$ 24-hr	NO_2 24-hr	O_3 8-hr	CO 8-hr (mg/m³)	SO_2 24-hr	NH_3 24-hr	Pb 24-hr
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+

<u>Example for PM10 calculation</u>

Site	AQI	Breakpoint=PM10	I_{HI}	I_{LO}	B_{HI}	B_{LO}	C_P	**I_p(=AQI)***
1	0-50	0-50	200	101	250	101	249.9	**200.0**
2	51-100	51-100	200	101	250	101	114.1	**109.7**
3	101-200	101-250	200	101	250	101	238.3	**192.2**
5	201-300	251-350	200	101	250	101	194.9	**163.4**
6	301-400	351-430	200	101	250	101	104.8	**103.5**
7	401-500	430+	300	201	350	251	262.4	**212.4**

IND-AQI Category and Range

AQI Category	**AQI Range**	**Color Code**
Good	0 – 50	
Satisfactory	51 – 100	
Moderately-polluted	101 – 200	
Poor	201 – 300	
Very Poor	301 – 400	
Severe	>401	

During ambient air monitoring following observations were recorded at two locations. Classify the quality of air of these station as per CPCB 2014.

	24 hourly average (μg/m^3)						O_3, 8 hr (μg/m^3)	CO, 8 hr (mg/m^3)
Locations	PM_{10}	$PM_{2.5}$	NO_2	SO_2	NH_3	Pb		
ONE	250	90	30	90	200	0.9	90	04
TWO	150	40	20	30	80	1.0	50	02

Use breakpoint concentration from following table.

AQI Category (Range)	**PM_{10} 24-hr**	**$PM_{2.5}$ 24-hr**	**NO_2 24-hr**	**O_3 8-hr**	**CO 8-hr (mg/m^3)**	**SO_2 24-hr**	**NH_3 24-hr**	**Pb 24-hr**
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
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Severe (401-500)	430 +	250+	400+	748+	34+	1600+	1800+	3.5+

Reasons for High Air Pollution in India

The reasons for high air pollution in India are as follows:

(i) Poor Quality of Fuel

Fuel of poor quality such as coal, diesel, petrol, fuel oil is used in India. Although during the past few years, various measures have been taken to improve the quality of fuel such as reduction of sulphur in diesel, unleaded petrol etc.

(ii) Old Process Technology

Old process technology is employed in many industries especially in small scale industries resulting in high emission of air pollutants

(iii) Wrong Siting of Industries

Wrong siting of industries especially close to residential areas results in people getting affected due to air pollution.

(iv) No Pollution Preventive Step in Early Stage of Industrialization

No pollution preventive steps were taken in early stage of industrialization which has resulted in high levels of air pollutants in many areas.

(v) Poor Vehicle Design

Poor vehicle design especially 2-stroke two wheelers result in high emission of air pollutants.

(vi) Uncontrolled Growth of Vehicle Population

Uncontrolled growth of vehicle population in all major cities/towns has resulted in high levels of air pollution.

(vii) No Pollution Prevention and Control System in Small/ Medium Scale Industry

No pollution prevention and control system in small/medium scale industry exists resulting in high levels of air pollution.

(viii) Poor Compliance of Standard in Small/Medium Scale Industries

Poor compliance of standard in small/medium scale industries also result in high levels of air pollution.