Parivesh

A News Letter from ENVIS Centre - Central Pollution Control Board

Editorial

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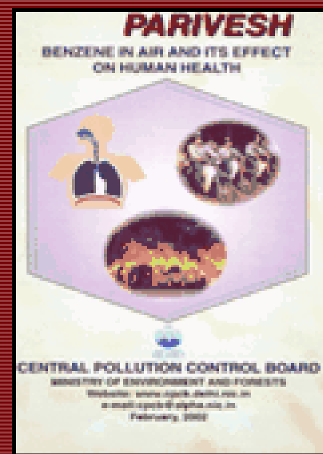

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The human activities whether for industrial activities, transportation use fuels of various kinds. Burning of fuels leads to a plethora of combustion products ,which contribute towards air pollution including trace organics.

Trace organic are to be monitored to ascertain their characteristics and concentration in the ambient air. These trace organics include Benzene , Toluene , Xylenes (BTX), Volitile Organic Compounds (VOCs),Polycyclic Aromatic Hydrocarbons (PAHs) etc. Monitoring Helps us to take necessary preventive and control measures. With this in view , the Central Pollution Control Board has set up infrastructure and facilities for Benzene monitoring in Delhi, which include active sampling and passive sampling devices, ATD-GC for analysis in its laboratory , online BTX analysers and mobile van for monitoring at selected locations and traffic intersections. Based on monitoring data, it has been possible to identify the polluted area, polluters and also prepare action plans to abate the Pollution. Action Plan for Benzene reduction in the gasoline and the environment for the capital city of the Delhi and the whole country. Because of initiatives taken for controlling the air pollution from different sources, particularly automobiles, fuel quality, the increasing trend of Benzene pollution in the city has been arrested. Benzene content in gasoline has been reduced from 5% to 3% in Metropolitan Cities & 1% in National Capital Territory (NCT) & Mumbai during year 2000. The results of initiatives and emissions from petrol pumps are being felt through findings of CPCB monitoring.

I am grateful to my colleagues Dr. B. Sengupta, Member Secretaray, Dr. S.K. Tyagi, Scientist 'C' and their whole team for collecting and collating relevant information relating to Benzene pollution and health effects for this Newsletter.

We hope, it will be useful to all concerned with protection and improvement of air quality.

(Dilip Biswas)
Chairman, CPCB

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BENZENE IN AIR AND IT'S EFFECT ON HUMAN HEALTH

PHYSICO- CHEMICAL PROPERTIES OF BENZENE, TOLUENE & XYLENE :

Benzene is a naturally occurring colourless liquid at room temperature (25 ^{o}C) and pressure (760 mm Hg). It has a characteristic aromatic odour, a relatively low boiling point (80.1^{o}C) and high vapour pressure, which causes it to evaporate rapidly at room temperature. Benzene is released into the environment from both natural and man-made sources, although the later is the most significant source. Benzene in air exists predominantly in the vapour phase, with residence time varying between few hours to a few days depending on the environment and climate. Degradation of benzene in air occurs mainly by reaction with hydroxyl, alkoxy and peroxy radicals. Toluene and Xylene are also present in most of the sources along with Benzene. Physico-chemical properties of Benzene, Toluene & Xylene are given in Table : 1.

	Benzene	Toluene	o-Xylene	m-Xylene	p-Xylene
Physical form (20^{o}C)	Clear colourless liquid	Clear colourless liquid	Colourless liquid	Colourless liquid	Colourless liquid
Flash Point (o ^{o}C)	-11.1 ^{o}C	4.4 ^{o}C	30 ^{o}C	25 ^{o}C	25 ^{o}C
Flammable limits	1.3-7.1%	1.17-7.1%			
Melting/Freezing point	5.5 ^{o}C	-95 ^{o}C	-25.2 ^{o}C	-47.9 ^{o}C	13.3 ^{o}C
Boiling point (760 mmHg)	80.1 ^{o}C	110.6 ^{o}C	144.4 ^{o}C	139.1 ^{o}C	138.3 ^{o}C
Density (20 ^{o}C)g/ml.	0.878	0.8669	0.876	0.860	0.857
Vapour pressure (26 ^{o}C)	13.3 kPa	28.7 mmHg	0.66	0.79	0.86
Solubilities	Water: 1800mg/lt at 25 ^{o}C Non aq. Solvents miscible with most	Fresh water : 535mg/lt at 25^{o}C Sea Water 380mg/lt at 25 ^{o}C	Water: 142mg/lt	146mg/lt	185mg/lt

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SOURCES OF BENZENE IN THE ENVIRONMENT

Sources of BTX Emission

Transport :	(I). Vehicular Pollutio
	a) Vehicular exhaust
	b) Fuel filling station
	c) Fuel adulteration
	(II). Railways
	(III). Airways
Industries :	(I). Major industrial units (Refinery, Petrochemical etc) :
	(II). Industrial estates :
	(III). Medium scale chemical industries
Domestic Emissions :	(I). Domestic combustion units
	(II). Commercial combustion units

- **Developed Country Scenario :**

The proportion of benzene currently in both leaded and unleaded petrol is about 1% by volume in the United Kingdom. There has been no increase in the amount of benzene in leaded petrol over the last decade, in spite of a threefold reduction in its lead content.

While people working with petrol, in its manufacture and distribution, might be expected to derive their main exposure from this source, a major source of exposure for the general population is from vehicle exhausts, and here benzene is mostly produced by chemical reactions occurring during combustion of petrol in the engine. The importance of this source is illustrated in Table 2, which shows that no less than 78% of atmospheric benzene in the United Kingdom is emitted from petrol engine exhausts. From this it is clear that to achieve air quality standards for benzene , control from this source is essential. While petrol exhaust is the major source of benzene in the air we breathe outdoors especially in urban areas, it is important to realize that there are other sources of human exposure, some of which contribute a significant proportion of an individual's total intake. Cigarette smoke contains benzene, and may be the main source of exposure for a heavy smoker; passive smoking may make a small contribution to benzene intake. Benzene may also be present in low concentrations in some foods and in drinking water, and diet may be the main source of benzene for non-smokers living in unpolluted, rural areas.

Table 2 gives some estimated figures for the different amounts of benzene (measured by weight in microgram i.e. µg) to which we may be exposed daily from these sources.

Table 2 : Sources of Benzene emissions in the UK in 1991.

	Tonnes/Year*	**%**
Petrol engine exhausts	39,250	78
Diesel engine exhausts	4,550	9
Petrol evaporation from vehicles	3,350	7
Petrol refining and distribution	1,350	3
Combustion of oil, wood, etc	950	2
Gas leakage	400	<1
Other Industrial processes	16-350	<1

Figures rounded to the nearest 50 tonnes

Source : Department of Environment, U.K.. Expert Panel on Air Quality Standards : Benzene (1994)

Table 3 : World Production of benzene in thousands of tones for 1981

	Capacity	**Production**
North and South America (Total)	9350	6150
Asia (total)	3550	2460
Western Europe (total)	6950	3800
Eastern Europe (total)	5840	2340
Japan	2880	2060
USA	8030	5190
USSR	3250	1700
Other Countries	100	50
World	25800	14800

Note : Benzene in Petrol is not included.

Source : WHO, Environmental Health Criteria Document-150, Benzene (IPCS, 1993)

- ## Gasoline (Petrol) and Mobile sources :

Benzene is present in both exhaust and evaporative emissions. Motor vehicles account for approximately 85% of the total benzene emissions. The remaining is attributed to stationary sources (15%). Benzene is a component of gasoline.

Another important source of benzene in air is active smoking of tobacco. As per EPA's estimate active smoking accounts for roughly half of the total population exposure to benzene, which is over and above that from motor vehicles.

Benzene is quite stable in atmosphere and the only important reaction in the lower atmosphere in the reaction with OH radical. This reaction too is very slow. Benzene is one of the ingredients of petroleum product.

Benzene hydrocarbons can be condensed and washed out to the coke-oven gas. Crude oil contains benzene and its homologues account for 3.9%-4.8%. In USA Benzene is also produced from olefines. Benzene in the motor fuel is infact burnt in the combustion process, but at the same time there is an additional amount of benzene produced througl dealkylation which is emitted. Benzene is mainly used as raw material for the production of substituted aromatic hydrocarbons. The major source is emission from motor vehicles and evaporation losses during the

handling distribution and storage of petrol.

As the CPCB survey during 1988-89 five Metro cities account for 35% of total vehicular population in India. 2 Wheelers in 5 Metros only account for 23% of all 2 Wheelers in India. Two-wheelers have grown in number accounting for 68.8% of all vehicles in 1995 against 8.8% in 1951 in India.

Delhi alone accounts $1/8^{th}$ of Total Vehicle Population (TVP) in India. The total number of vehicles in Delhi (27.0 lacs) was more than number of vehicles in cities of Mumbai (7.24 lacs), Calcutta (5.61 lacs) and Chennai (8.12 lacs) pu together during 1995. The total no. of 2 Wheelers in Delhi (14.03 lacs) was about one and half times of other three Metros i.e. Mumbai (2.46), Calcutta (2.22) & Chennai (4.61) put together during 1993.

The total number of vehicles in Delhi was 30 lacs as on March 31, 1998., which has grown up to **more than 34.25 lacs as on July 2001**. (Out of which CNG vehicle constitute 2450 Buses, 1178 Mini-Buses, 27,263 Three-Wheeler, 1993 Taxis). Diesel vehicles constitutes about 6% of total vehicles. Two wheelers owing to predominate category (i.e. about $2/3^{rd}$ of total vehicular population in Delhi need utmost attention. In the petrol driven two-wheeler the emission of benzene is significant because about 20-30% of fuel is coming out as unburnt hydrocarbon.

Table 4 : Percentage Contribution of Pollution Load From Gasoline And

Diesel Vehicles (Comparative Account).

Category of Vehicle	CO	HC	NOx	SO_2	Pb	PM
Petrol	67	84	5	4	100	-
Diesel	33	16	95	96	-	100

There are two sources of hydrocarbon emissions from the vehicles – evaporative emission and engine exhaust emission. The evaporative emission from vehicles comprises of running losses, diurnal losses, hot soak losses and fuel loading losses. The losses arise from the fuel tank and the carburetor. Similarly in gasoline handling systems from the refinery storage tank to gasoline dispensing stations evaporative losses take place.

Gasoline consumption in Delhi has shown a growth of 247% during 1997-98 against 1980-81 as compare to Diesel consumption growth of 150% only.

Table 5 : Estimate of Demand of Transport Fuels in India ('000 Tonnes)

Product	1987-88	1992-93	1995-96	2001-02
Gasoline	2800	3938	4779	6641
Diesel	17600	23261	29495	38492

- ## Benzene Emission from Passenger Car :

Benzene is a major constituent of evaporative emission due to its high volatility. In the gasoline engine exhaust against benzene is a significant component of hydrocarbon fraction due to its refractory nature in the combustion process.

Benzene emissions in European cars using modified ECE + EUDC test cycle are correlated by the following equations (ref 52).

For noncatalyst cars

BEE = 1.515 + 0.765.BF + 0.0414. NBAF (eq1)

For catalyst cars

BEE = 1.237 + 0.599.BF + 0.0602. NBAF (eq2)

Where BEE – wt% benzene in total hydrocarbons in engine exhaust,

BF - wt% benzene in feed and

NBAF - wt% nonbenzene aromatics in feed.

It may be noted that BEE is very sensitive to benzene content in gasoline and also depends on aromatic content in the fuel.

Sources of Benzene Emission :

- **Emissions from Benzene Production**

- Catalytic reforming/ separation process
  - Toluene dealkylation and toluene disprortionation process
  - Ethylene production
  - Coke oven and coke by product recovery plants

- **Emissions from Major Uses of Benzene**

- Ethylbenzene and Styrene production
- Cyclohexane production
- Cumene production
- Phenol production
- Nitrobenzene production
- Aniline production
- Chlorobenzene production
- Linear alkylbenzene production
- Other organic chemical production
- Benzene use as a solvent

- Emission from other Sources

- Oil and gas wellheads
- Glycol dehydration units
- Petroleum refinery processes
- Gasoline marketing
- Publicly owned treatment works
- Municipal solid waste landfills
- Pulp, paper and paperboard industry
- Synthetic graphite manufacturing
- Carbon black manufacture
- Rayon- based carbon fiber manufacture
- Aluminum casting
- Asphalt roofing manufacturing
- Consumer products/building supplies

-Emissions from combustion sources

- Medical waste incinerators
- Sewage sludge incinerators
- Hazardous waste incinerators
- External combustion solid, liquid and gaseous fuels in stationary sources heat and power generation
- Stationery internal combustion
- Secondary lead smelting
- Iron and Steel foundries
- Portland cement production
- Hot-mix ashalt production
- Open burning of biomass, scrap tires

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BENZENE EMISSION FACTOR FOR DIFFERENT SOURCES:

- **Emissions from Refuelling losses**

Refuelling losses – These depend on the ambient temperature at the time of refuelling, and are determined by the following equation

$$Bz_e = 0.23\ BZ_d + 0.21\ BZ_f$$

Where,

Bz_e Is the mass fraction of benzene in total hydrocarbons emitted

BZ_d Is the fraction of benzene in the petrol distributed

BZ_f Is the fraction of benzene in the petrol in the tank

- **Emissions from Evaporative losses from the carburettor and the fuel tank** :

These results from the dissipation of heat when the engine is turned off and from variations in temperature between day and night. The following equations have been established.

Engine stopped : % weight of benzene in vapour = 0.45 of the weight of benzene in petrol

Respiration : % weight of benzene in vapour = 0.89 of the weight of benzene in petrol

- **Emissions from exhaust :**

$$BZ_{exh} = 0.50 + 0.44\ BZ_{gas} + 0.04\ Ar$$

Where

BZ_{exh} Is the percent weight of benzene in the exhaust

BZ_{gas} Is the percent weight of benzene in petrol (gasoline)

Ar Is the percent weight of other aromatics in petrol (gasoline)

For Benzene exhaust from petrol vehicles, separate equations were used for three-way catalysts, three way plus oxidation catalysts, and other catalyst types. For vehicles with a three- way catalyst, running on baseline gasoline, the following equation was used :

3-way Bz%THC = 1.077+0.7732* (Volume % benzene)

+ 0.0987* (Volume % aromatics – volume % benzene)

This equation was obtained by the EPA Regulatory Development and Support Division (RDSD) from work done by Chevron Oil Company.

For vehicles with a three-way plus oxidation catalyst, running on baseline petrol the equation used was :

3-way + oxBz%THC = 0.6796* (Volume % benzene)

+0.0681* (Volume % aromatics – volume % benzene)

This equation was obtained from the draft Regulatory Impact Analysis for RVP regulations (EPA, 1098 a).

For vehicles with no catalyst or an oxidation catalyst, the equation used was :

Other Bz%THC = 0.8551* (Volume % benzene)

+0.12198 * (Volume % aromatics) –1.1626

- **Benzene Emission from Gasoline Loading Racks at Bulk Terminals and Bulk Plants :**

Table 5 : Benzene Emission Factors for Gasoline Loading Racks at Bulk Terminals and Bulk Plants

Loading Method	**Gasoline Vapour Emission Factor[a] Ib/1000 gal (mg/liter)**	**Benzene Emission Factor[b] Ib/1000 gal (mg/liter)**
Splash loading – normal service	11.9 (1430)	0.11 (12.9)
Submerged loading[c] normal service	4.9(590)	0.044(5.3)
Balance service[d]	0.3(40)	0.004(0.36)

Source : EPA's Emission Factors (1993)

a. Gasoline factors represent emissions of non-methane VOC. Factors are expressed as mg gasoline per liter transferred.

b. Based on an average benzene/VOC ratio of 0.009.

c. Submerged loading is either top or bottom submerged.

d. Splash and submerged loading. Calculated using a Stage 1 control efficiency

of 95 percent.

- **Gasoline Vapour and Benzene Emission from a Typical Service Station :**

Table 6 : Gasoline Vapour and Benzene Emission Factors for a Typical Service Station

Emission Source	**Gasoline Vapour Emission Factor[a] Ib/1000 gal (mg/liter)**	**Benzene Emission Factor[b] Ib/1000 gal (mg/liter)**
Underground storage Tanks – Tank	11.5(1,380)	0.104(12.4)

Filling Losses – Splash Fill		
Underground storage Tanks – Tank Filling Losses –Submerged Fill	7.3(880)	0.066(7.9)
Underground storage Tanks – Tank Filling Losses – Submerged Filling[c]	0.3(40)	0.003(0.4)
Underground storage Tanks – Breathing losses	1.0(120)	0.009(1.1)
Vehicle Refueling[d] – Displacement Losses - Uncontrolled - Controlled	11.0(1.320) 1.1(132)	0.099(11.9) 0.0099(1.2)
Vehicle Refueling[d] – Spillage	0.7(84)	0.0063(0.76)

Source : EPA's Emission Factors (1993)

a) Typical service station considering a gasoline throughout of 19,000 liters/day (5,000).

b) Based on gasoline emission factor and an average benzene/VOC ratio of 0.009

c) Calculated using a Stage 1 control efficiency of 95 percent.

d) Vehicle refuelling emission factors can also be derived for specific geographic locations and for different seasons of the year using the MOBILE 5a. EPA's mobile source emission factor computer model.

- ## Gasoline Vapour and Benzene Emission from a Typical Bulk Plant :

Table 7 : Gasoline Vapour and Benzene Emission Factors for a Typical Bulk Plant

Emission Source	Gasoline Vapour Emission Factor[a] Ib/1000 gal (mg/liter)	Benzene Emission Factor[b] Ib/1000 gal (mg/liter)
Storage Tanks – Fixed Roof – Breathing Loss	5.0(600)	0.5(5.4)
Storage Tanks – Fixed Roof – Working Loss Filling Emptying	9.6(1150) 3.8(460)	0.086(10.3) 0.34(4.1)
Gasoline Loading Racks Splash Loading (normal service) Submerged Loading (normal service)	11.9(1430) 4.9(590) 0.3(40)	0.107(12.9) 0.044(5.3) 0.002(0.4)

Splash and Submerged Loading (balance service)[C]		

Source : EPA's Emission Factors (1993)

(A) Typical bulk plant with gasoline throughout of 19,000 liters/day (5,000 gallons/day)

(B) Based on gasoline emission factors and an average benzene /VOC ratio of

0.009

(C) Calculated using a Stage 1 control efficiency of 95 percent.

- **Benzene Emissions from Locomotives and Aircraft Loading and Take Off :**

Table 8 : Benzene Emissions Factors for Locomotives and Benzene

Content In Aircraft Loading and Take Off Emission's

Source	**Toxic Emission Fraction**	**Emission Factor (Ib/gal)**	**Weight Percent Benzene**
Line Haul Locomotive	0.0106[a]	0.00022	-
Yard Locomotive	0.0106[a]	0.00054	-
Military Aircraft	-	-	2.02
Commercial Aircraft	-	-	1.94
Air Taxi Aircraft	-	-	3.44
General Aviation	-	-	3.91

Source : EPA's Emission Factors (1993)

a. These fractions are found in Appendix B6 of EPA, 1993, and represent toxic emission fractions for heavy-duty diesel vehicles. Toxic fractions for locomotive are assumed to be the same, since no fractions specific for locomotive are available. It should be noted that these fractions are based on g/mile emissions data, whereas emission factors for locomotives are estimated in Ib/gal. The toxic emission fractions were multiplied by the HC emission factors to obtain the toxic emission factors.

Toluene and Xylene are used as solvent in rubber and plastic cement and in manufacturing of some compounds. During the production process. Toluene and Xylene vaporised and find their way into the air.

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KINETICS AND METABOLISM :

About 50% of benzene is absorbed by inhalation & absorption of it via skin is limited. The high lipophilicity and low water solubility of benzene favour its distribution to fat-rich tissues. Benzene distributed by blood accumulates in fat-rich tissues like adipose tissue bone marrow & liver.

Benzene is readily absorbed by the body during inhalation or ingestion and is rapidly distributed throughout the body, particularly in fatty tissues. Metabolism occurs primarily in liver and to less extent in the bone marrow, producing intermediates, which account for the toxicity of benzene. In human, half-life of benzene is 1 - 2 days. Accumulation is not expected for benzene or its metabolites. Benzene is primarily exhaled through the lungs unchanged or excreted as metabolites in the urine.

Benzene is oxidized by cytochrome P-450- dependent mixed-function oxidase system. In humans voluntarily exposed to 100ppm (320 mg/m^3) benzene for 5 hours, 61% absorbed benzene was metabolised to phenol, 6.4% to catechol & 2% to hydroquinoue while 26% was exhaled unmetabolized. The major part of the metabolites was excreted as sulfate or glucoronic acid conjugates.

Metabolites of benzene are responsible for haematotoxicity. The bio-transformation path ways are the formation of phenol via epoxide & catcehol via benzene dihydrodiol. Hydro-quinone, catechol and hydroxy hydroquinone are converted to p-benzosemiquinone and p- benzoquinone, to o-benzoquinone and to o- hydroy-p-benzosemiquinone and hydroxy – p – benzoquinone respectively. The copy of reactions is enclosed.

These metabolites bind covalently to microsomal proteins or mitochondrial DNA metabolism leads to opening of benzene ring & this pathway plays a role of heamotoxicity.

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HEALTH EFFECTS :

- General Exposure and Daily Intake :

Benzene is ubiquitous in the environment, resulting in the exposure of most humans to trace levels (or more) of this chemical. Exposure in the general population is primarily to air borne benzene and derives from active and passive tobacco smoke, industrial activities, and use of the automobile (gasoline fumes from refilling, etc. and exhaust emissions). Estimates of the daily amounts of benzene consumed in drinking – water and food-stuffs vary considerably and are of the order of µg/day. Depending upon the assumptions made with respect to levels of benzene from tobacco products and foodstuffs, estimates for the exposure of the general smoking population in industrialized countries range from 2000 to 3500 µg benzene/day. Adult (70kg) non-smokers are considered to be exposed to about 200 to 1700 µg benzene/ day (about 3 to 25 µg/kg body weight per day). It would be helpful to have more information on total human exposure, particularly in developing countries.

Table 8 : Estimated Daily Intake of Benzene* From Different Sources

Sources		Conc. in µg
Ambient air	- Rural	15
	- urban	400
Cigarette smoke	- 10 per day	300
	- 20 per day	600
Food		100-250
water		1-5

- Sources : Ambient air – Department of the Environment; (Based on rural daily mean of 0.5 ppb and urban maximum daily mean of 12.2 ppb at Exhibition Road, London. Intake calculated using the World Health Organisation method)

About 50% of inhaled Benzene in air is absorbed. Benzene intake based on 24 hour exposure volume of 20 m^3 at rest will be 10 mg/day for each 1 mg/m^3 benzene in air. The daily adult intake at a typical benzene level of 16 µg/ m^3 will, therefore, be about 160 µg. Together with other pollutants, benzene also participate in photochemical process which result in formation of oxidants and smog. Exposure to high level of benzene causes neurotoxic symptoms. Persistent exposure to high level of toxic level of benzene may cause injury to human bone-marrow. Early manifestation of toxicity are anaemia, leucocytopania or thromo-cytopania. Benzene is a known human carcinogen (IARC Group).

Typical in vehicle and refueling exposure in US in 1987-1991 are reported to be 40 ug/m^3 (12ppb) and 288µg/m^3 (89ppb), respectively

- Occupational Exposure :

The major factors controlling industrial exposure to benzene are process technology, worker practices and the efficiency and sophistication of engineering controls. When appropriate engineering controls are in place, available monitoring data indicate that exposures of workers involved in the production, handling and use of benzene and benzene- containing materials which vary from non-detectable levels to approximately 15 mg/m^3 (8-h TWA), in addition to the amounts estimated for the general population. In developing countries the exposure can be several times higher. Due to the nature of the processes involved, a small percentage of workers may be exposed to more than 320 mg benzene/shift. In some developing countries, benzene exposure may be sufficiently high to cause acute toxicity. Dermal exposure to benzene has generally not been included in these estimates.

As regards to permissible level of benzene concentration for occupational exposure, American Conference of Government Industrial Hygienists prescribes a threshold limit value (TLV) of 0.5 ppm (1622 µg/m^3) (TWA). OSHA regulations also call for human exposure limit of less than 0.5 ppm. National Institute of Occupational Safety and Health (NIOSH) suggests Recommended Exposure Limit (REL) of 320 µg/m^3 (o.1ppm)

The results of a Benzene exposure survey study carried out in USA in different Industries & occupations are given in the following table-9.

Table 9 : Percentage of Employees in the USA Potentially Exposed to

Benzene

Industry Sector	**Percentage of observations in each exposure category according to range of 8-b TWA benzene concentrations (mg/m^3)**						
	0.32	0.33-1.6	1.61-3.2	3.3-16.0	16.1-32	32+	Total number of employees
Petrochemical plants		74.6		23.0	2.4	0.0	4300
Petroleum refineries	64.6	26.1	4.6	3.8	0.5	0.4	47,547
Coke and coal chemicals	0.0	39.3	27.6	27.5	4.4	1.3	947
Tyre manufacturers	53.4	37.5	6.3	2.8	0.0	0.0	65,000
Bulk terminals	57.8	32.8	5.3	3.7	0.3	0.1	27,095
Bulk plants	57.8	32.8	5.3	3.7	0.3	0.1	45,323
Transportation via tank truck	68.4	23.1	5.3	2.9	0.1	0.2	47,600
Total							2,37,812

Thus, a non- smoker living in an unpolluted rural area may be exposed to as little as 120 µg benzene daily, while a 20 cigarettes per day smoker living in a city may be exposed to as much as 1,250 µg daily

• Toxicological & Carcinogenic Effects :

Long term exposure to benzene in air causes leukaemia in human beings. In animal studies, leukaemias, lymphomas and other types of tumours are observed. Exposure to benzene is linked to genetic changes, increased proliferation of bone marrow cells and occurrence of certain chromosomal aberrations in humans and animals. US EPA has classified benzene as Group A human carcinogen. The International Agency for Research on Cancer (IARC), Lyon (France) has list ed benzene as carcinogenic to humans. In addition a number of noncancer health effects are associated with benzene exposure such as disorders of blood, harmful effects on bone marrow, anaemia and reduced abilities of blood to clot, damage to immune system and a reproductive and developmental toxicant . WHO estimates a 4 in 1 million risk of leukaemia on exposure to benzene to a concentration of 1 ug/m^3 (0.31 ppb)

High levels of benzene exposure produce haematotoxic effects like leucopenia, lymphopenia & anaemia in laboratory animals. Exposure to high levels of benzene causes neurotoxic symptoms.

Substances that can induce benzene –metabolizing enzymes are likely to modify the haematotoxicity of benzene. It has been found that benzene itself, Phenobarbital, Toluene & ethanol can modify the metabolism & haematotoxicity of benzene if animals an pretreated with these substance. Toluene has been found to inhibit the metabolism of benzene & decrease its haemototoxicity. Ethanol inhances the haemototoxicity of benzene in mice.

Acute lethal doses of benzene in experimental animals cause narcosis, ventricular tachycardia and respiratory failure.

At benzene concentration above 32 ug/m^3 in air, there is a co-relation between phenol excretion in urine and the level of exposure.

Table 10 : Estimated Percentage of Worker Populations that might develop Bone Marrow Depression or Aplastic Anaemia after Chronic Exposure to Benzene

Duration	Exposure	Bone marrow depression	Aplastic anaemia
1 year	320 mg/m^3 (100 ppm)	90	10
	160 mg/m^3 (50 ppm)	50	5
	32 mg/m^3 (10 ppm)	1	0[6]
	3.2 mg/m^3 (1ppm)	0[6]	0[6]
10 years	320 mg/m^3 (100 ppm)	99	50
	160 mg/m^3 (50 ppm)	75	10
	32 mg/m^3 (10 ppm)	5	0[6]
	3.2 mg/m^3 (1ppm)	<1	0[6]

This estimation is an interpretation of the literature and is based on the experience of the Task Group. The speculative nature of this table precludes its use in occasional cases.

The BTX (Benzene Toluene and Xylene) compounds are harmful toxic pollutants causing exposure related health effects in human beings. This group of volatile organic compounds (VOCs) are evidently carcinogenic in human beings. The exposure of Benzene may cause respiratory disorders, narcosis, changes in blood pattern, anemia, leucopoenia and leukemia.

Toluene in comparison to Benzene is less toxic may cause drowsiness, impaired coordination etc.. High dose exposure of toluene can produce kidney and liver damage and hyperplasia of brne marrow, anaemia, depression in central nervous system which may lead to impairment of coordination and slowed reaction time.

Acute Xylene exposure may be marked by dizziness, weakness, headache, nausea, vomiting, breathing difficulty and loss of coordination. In severe exposure, there are visuallurring, tremors, heart beat irregulaties, paralysis and loss of consciousness.

Due to exposure associated health aspects of BTX compounds, it is becoming increasingly important to screen their presence and to determine prevailing concentration in the ambient, environment. Benzene is a highly volatile aromatic compound usually component of mineral oil, petrol, coking plant and other products. Benzene is extensively utilized as industrial solvent in manufacturing of lacquers varnishes and paint. Benzene escapes from mineral oil and petrol during storage, transport, loading, unloading or during filling of petrol in motor vehicles. High concentration of Benzene are encountered in the vicinity of petrol filling stations, fuel tank storage sites, coking plant in the vicinity of refineries. Major Benzene emission originates from the motor vehicles .

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Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

BENZENE IN AIR AND IT'S EFFECT ON HUMAN HEALTH

METHODOLOGY OF MEASUREMENT:

- **Active Sampling:**

(I) The charcoal tubes are available in different sizes and contain varying amount of activated charcoal. The tubes contain two layers : the sampling layer and the control layer. The ambient air is sucked through the tubes in a way that first of all, the air flow save the sampling layer. This results in an enrichment of the relevant substances in the activated charcoal. Desorption of the absorbed Benzene is done using Carbon Di-Sulphide (CS_2). The substances desorbed in the CS_2 are analysed by capillary gas chromatography. A flame ionisation detector (FID) is used for analysis while quantification is performed using the internal/ external standard.

(II) Thermal desorption tubes are used for absorption of Benzene in place of charcoal tube, for which the sampling methodology is same as used for charcoal tube. These tubes are directly connected to the thermal disrobers installed with the gas chromatograph. The thermal desorption techniques offer the advantage of a greatly improved analytical sensitivity, as solvent is not used in this process and the collected sample is not diluted. In most, cases, analytical recovery is close to 100% and desorption efficiency corrections are not required. To be suitable for thermal desorption, sorbents must meet exacting specifications that include low contaminant background, high thermal stability and sufficient adsorptive strength to retain components of interest and should also release them quickly when heat is applied.

- **Passive Sampling:**

Controlled diffusion with an activated charcoal tube is used to enrich the substances targeted for analysis. A diffusion sampling system comprises a sampling layer and a diffusion path in front of this layer. The diffusion path is filled with porous cellulose acetate, to prevent convection currents. The sample is taken by exposing the tube to ambient air (protected from rain). During this exposure time, the analytes stream into the activated charcoal due to the concentration gradient between the air and the desorption layer and are absorbed by the charcoal. Once the sample has been collected, the tubes are taken to the laboratory where desorption is done and the substances dissolved in the CS_2 are analyzed using capillary gas chromatography (GC) equipped with flame ionization detector (FID).

Collection (Trapping) of the Air Borne Benzene and Analysis by Gas Chromatography

Gas Chromatography with mass specific and flame ionisation detector (FID) is used to analyse the highly volatile Hydrocarbons present in air samples. As these samples contain very low concentration of the substances to be analysed – at level lower than the detection limit of the analytical techniques in question – samples have to be enriched prior to determination.

Adsorption tubes containing various solid adsorption materials, are used for this purpose. Activated charcoal has highly favourable adsorptive properties, particularly for the acquisition of aromatic hydrocarbons in ambient air. There are two ways of enriching the sample test substances collected for analysis – Pumped sampling which involves sucking of ambient air through adsorption tubes by means of a pump and Passive sampling in which tubes are exposed to the surrounding air and the substances contained in the air are taken up by diffusion. Gas chromatography analysis is performed after the enriched components are desorbed thermally or using desorbing solvents.

Samples collected through active or passive sampling technique (sorbent tubes) may be desorbed by conventional solvent (generally Carbon disulphide) or thermally (generally using standard automated thermal desorption apparatus). Desorbed samples may be analyzed using gas chromatograph (GC) fitted with capillary column and flame ionization detector (FID) or mass spectrometric detector (MSD, generally used for confirmation of analytes – USEPA – TO-17 method).

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Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

BENZENE IN AIR AND IT'S EFFECT ON HUMAN HEALTH

Concentration of Benzene in Ambient Air in Delhi (CPCB

Measurement) :

- **Active Sampling:**

Benzene levels in Delhi's air environment measured as per standard procedure for active sampling (2 hrly thrice a day) using low flow personal pumps for sampling and analysis by using Automated Thermal Desorption (ATD) -capillary GC-FID. The results are summarized in following table.

Table 11 : Benzene Levels in Delhi's Urban Environment, 1998

S.No.	Location	Concentration ug/m^3	
		August, 1998	**November 1998**
1.	Residential Area	110* (21-267)	248+ (187-308)
2.	Traffic intersection	116** (70-163)	382** (271-540)
3.	Petrol Pump	169** (83-238)	428+ (294-456)

Note 1) * Average of 4 values measured at three location

2) ** Average of 4 values measured at each of four locations

3) + Average of 4 values measured at each of five locations

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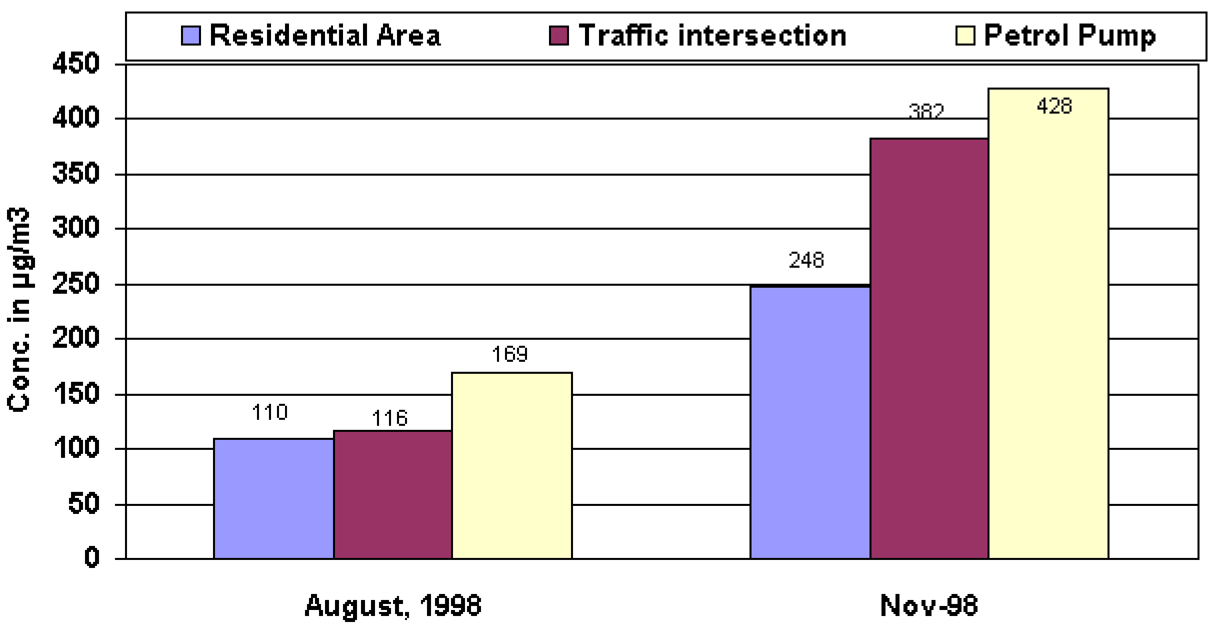
Figure 1 : Benzene Levels in Ambient Air in Delhi During 1998.



Results clearly indicate increasing order from residential to Traffic intersection to Petrol pump.

- **Passive Sampling:**

Benzene levels in Delhi's urban environment measured also as per M/S Drager's (Germany) standard procedure for passive sampling (fortnightly basis) i.e. conventional CS_2 desorption capillary GC-FID analytical techniques. The results are summarized in following table.

Table 12: Benzene Concentration (µg/m of Air) in Delhi's Urban Environment.

S. No.	Area /Category	Benzene Concentration (µg/m^{3}of Air)						
		Aug' 98	**Nov' 98**	**May' 99**	**Jun' 99**	**Jul' 99**	**Aug' 99**	**Sep' 99**
1.	Residential and Mixed Use	-	88* (76-99)	21** (11-29)	12** (5-17)	13**	18**	15**
2.	Traffic Intersection	42* (39-45)	195* (193-196)	38* (32-43)	20* (16-24)	22*	24*	25*
3.	Petrol Pump	164+ (61-365)	182+ (91-414)	-	-	-	-	-

Note 1) * Average of 4 values measured at one location

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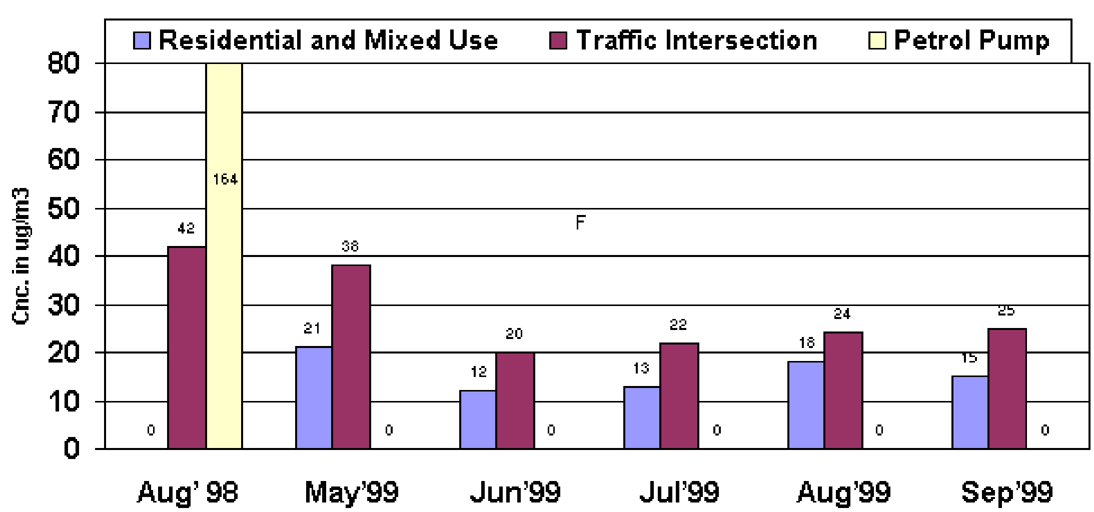
Fig. 2: Benzene Concentration in Ambient Air in Delhi.



The levels of Benzene measured at ITO (B.S.Z. Marg) during Aug. 1998 & Aug. 1999 has shown a marked decrease of about 43% from 42 µg/m^3 to 24 µg/m^3 .

The results of active sampling were in higher side probably due to several factors i.e. adsorbent material used, moisture content & presence of other pollutants in the air which need to be standardized. Whereas results of passive sampling were found in tune with on-line BTEX analyzers & portable G.C.

• Routine Benzene Monitoring (Passive sampling) in Delhi :

CPCB has been monitoring Benzene in Delhi at seven locations from May 1999 to April 2000, comprising Residential, Industrial & Commercial areas. Monthly variations in Benzene levels have been shown in **Figure-3 .**

- The maximum Benzene concentration has been observed at Moti Nagar with 75 µg/m^3 during December 2000.

- The minimum Benzene concentration observed at J.N.U. was 6 µg/m^3 during June & July 1999.

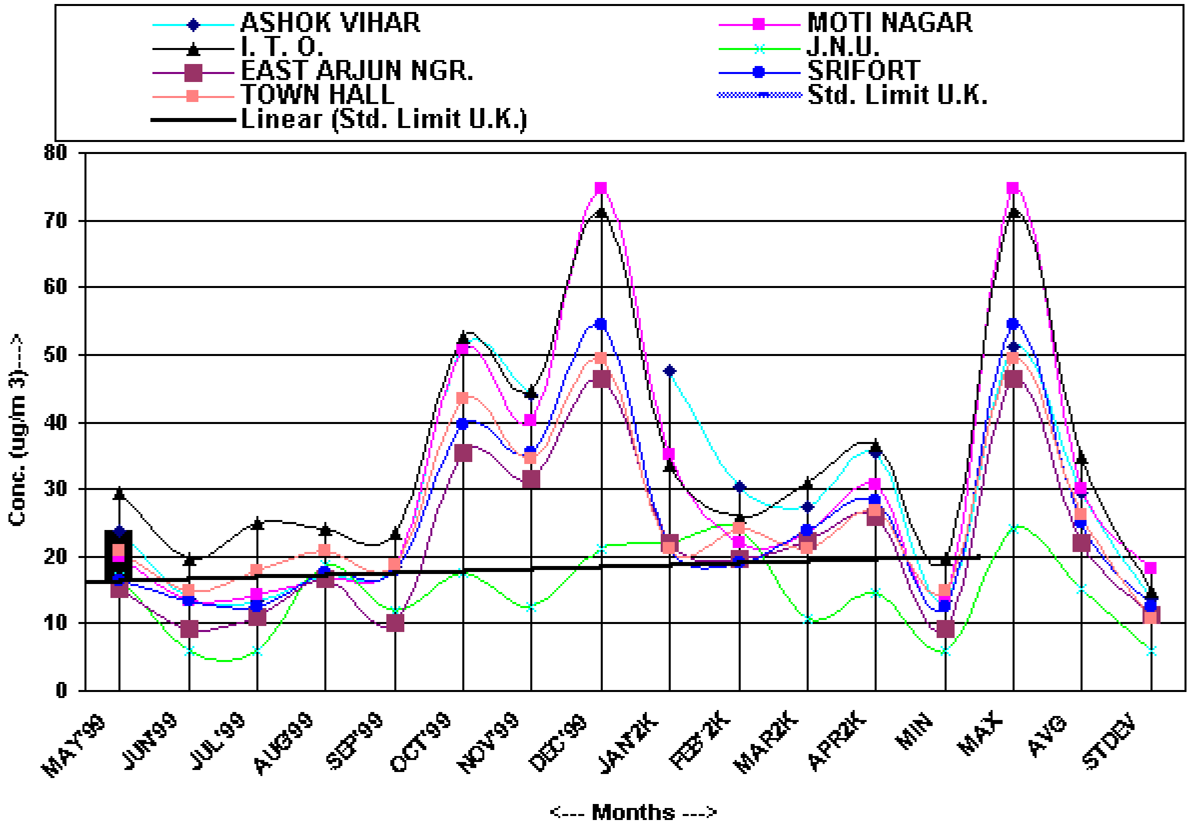
- Benzene levels during winter season were observed higher & varies between 17 µg/m^3 at JNU and 56 µg/m^3 at ITO. Lower values were observed during summer and monsoon ranging between 12 µg/m^3 at JNU (both season) and 29 µg/m^3 and 24 µg/m^3 during monsoon and summer respectively at ITO.

- The monthly average values observed at all locations during monitoring period varies between 15 µg/m^3 at JNU and 35µg/m^3 at ITO.

- **Overall (all seven locations) annual mean Benzene concentration has been calculated 26 µg/m^3 during May 1999 to April 2000, which is 1.6 times higher than United Kingdom's annual running mean standard i.e. 16 µg/m^3 (5 ppb).**

Fig.3 : Benzene Level By Passive Sampling in Delhi During May 1999

-2000.



- **Routine Benzene Monitoring (Passive sampling) in Kanpur :**

CPCB has been monitoring Benzene in Kanpur city at five locations from June 1999 to May 2000, comprisin Residential, Industrial & Commercial areas. Monthly variations in Benzene levels have been shown in **Figure: 4.**

- The maximum Benzene concentration has been observed at Dada Nagar with 90 μg/m^3 during November 1999.

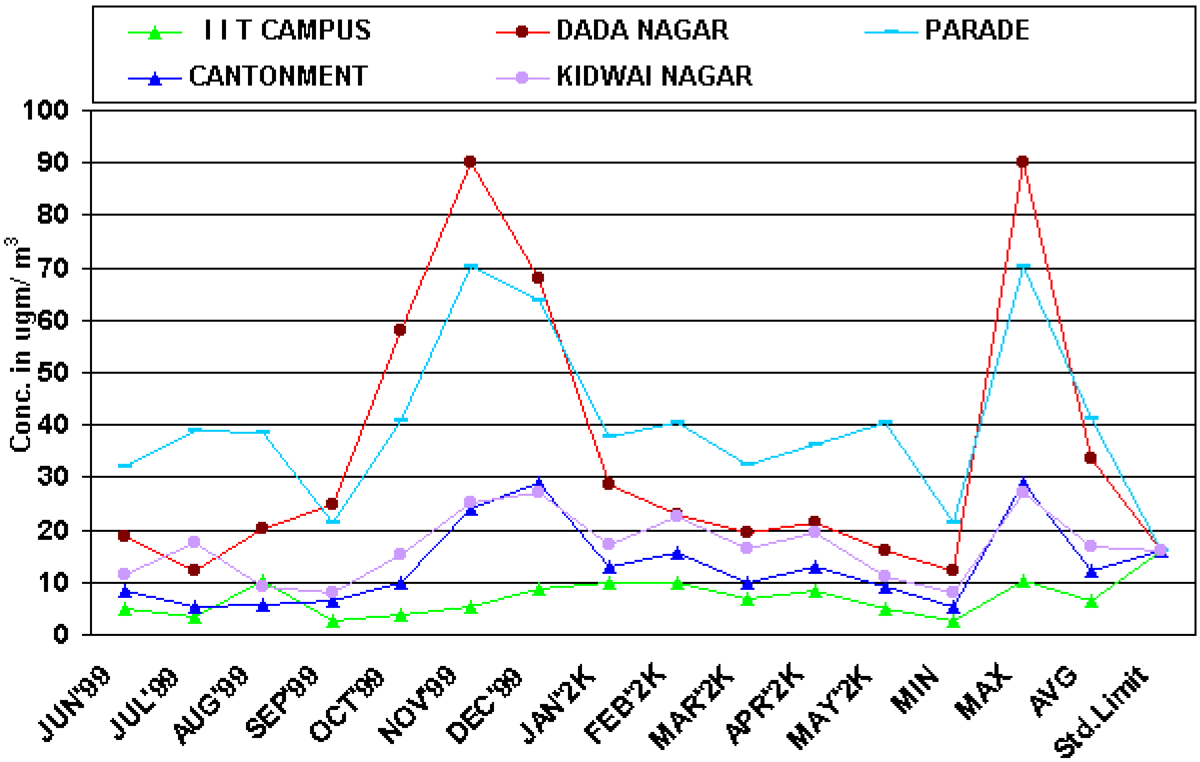
- The minimum Benzene concentration observed at I.I.T. Campus with 3 μg/m^3 during September1999.

- Benzene levels during winter season were observed higher & varies between 8 μg/m^3 at IIT Campus and 54 μg/m^3 at Dada Nagar. Lower values were observed during summer and monsoon ranging between 6 μg/m^3 and 5 μg/m^3 at IIT Campus both season and 35 μg/m^3 and 33 μg/m^3 during summer and monsoon respectively at Parade.

- The monthly average values observed at all locations during monitoring period varies between 7 μg/m^3 at IIT Campus and 41 μg/m^3 at Parade.

- Overall (all five locations) annual mean Benzene concentration has been calculated 22 μg/m^3 during June 1999 to May 2000, which is 1.4 times higher than United Kingdom's annual running mean standard i.e. 16 μg/m^3 (5 ppb).

Fig. 4:Benzene Level By Passive Monitoring in Kanpur During 1999-2000



BTX Monitoring in Ambient Air

CPCB initiated Benzene monitoring in ambient air at selected locations with a view to collect background Benzene levels in ambient air, their seasonal & diurnal variations. **Passive monitoring** & Benzene is being conducted at **7 locations in Delhi (with effect from May1999) and 5 locations in Kanpur (with effect from June 1999**) using Orsa 5 Drager tubes (German make) containing coconut charcoal on fortnightly basis. Samples thus collected are extracted using Carbon –di-Sulphide and analysed using Capillary Gas Chromatography with Flame Ionisation Detector.

During one year study period (1999-2000), Benzene concentration range between 6µg/m^3 and 75 µg/m^3 in Delhi with overall average annual average of 26 µg/m^3 while Benzene concentration range between 3 µg/m^3 and 90 µg/m^3 in Kanpur with overall average annual average of 22 µg/m^3 .

CPCB also initiated **On-line BTX monitoring** at selected locations in Delhi. **Benzene levels monitored using on-line BTX analyser (GC-PID based model MLU-950) varies 2.3µg/m^3 and 38.1 µg/m^3 with overall average of 12.5 µg/m^3** average values for Toluene , m,p- Xylene, o- Xylene & Ethyl Benzene were recorded as 40.90, 17.30, 7.0 & 5.6 µg/m^3 respectively. BTX analyser has been used to assess half an hourly values round the clock during sampling period.

On line Active BTX monitoring in Delhi :

CPCB initiated On-line BTX monitoring at ITO during Nov. 2000 subsequently at CPCB premises at East Arjun Nagar

During Nov. 2000, Feb.2001 & March 2001.

The monitoring of BTX in ambient air was conducted using continuous online instrument (MLU 950 of Synspec) from 28th March to 31st March and from 01st April to 04th April 2001 under foot over bridge at BSZ Marg, I.T.O., from 12th April to 18th April 2001 in Jhilmil Industrial Area, G.T.Road, Shahdara , from 09th May to 16th May 2001 at National Physical laboratory, Pusa Road, from 13th to 16th Sept 2001 at Hotal Taj Palace, Dhaula Kuan, from 17th to 21st Sept 2001 at Safdarjung Hospital, from 22nd Sept. to 5th Oct. 2001 at ITO and from 9th to 12th Oct.,2001 at Britannia Chowk, Ring Road.

Results of monitoring of BTEX in $\mu g/m^3$ are shown in **Table-13 and figure 5-8** which shows-

- That average Benzene levels were highest at I.T.O. (BSZ Marg) during winter (Nov. 2000) i.e. 38.1$\mu g/m^3$ and lowest at National Physical Laboratory (Pusa Road) during summer (May, 2001) i.e. 2.3 $\mu g/m^3$.

- **Overall average Benzene conc. for Delhi was calculated 12.5 $\mu g/m^3$ with 16.5$\mu g/m^3$ & 7.0 $\mu g/m^3$ during winter and summer season respectively.**

- Toluene level was observed much high than Benzene and other parameter (i.e. Xylene and Ethyl Benzene) which range between 5.1 $\mu g/m^3$ at NPL Pusa Road (summer) and 152.0 $\mu g/m^3$ at ITO, (winter) with overall average of 40.90 $\mu g/m^3$ **. Overall Toluene level was approximately more than 3 times, when compared with Benzene level.**

- Overall average levels of m,p Xylene, o-Xylene and Ethyl Benzene were observed 17.3, 7.0 & 5.6 $\mu g/m^3$ respectively.

- **Vehicular pollution seems to be the major contributor of high level at ITO during Nov. 2000** due to higher Benzene content in petrol as compared to Oct. 2001. **Benzene content in petrol in National Capital Territory (NCT) and Mumbai has been reduced from 3% to 1% after Nov. 2000.**

Table 13: BTX levels observed in Delhi during Nov. 2000 to Oct. 2001.

Concentrations in $\mu g/m^3$ at 25°C

Locations	Period	Benzene	Toluene	m,p-Xylene	o-Xylene	Ethyl-Benzene
ITO, BSZ Marg	Nov. 2000	38.1	152.0	68.4	26.9	21.9
East Arjun Nagar	Nov. 2000	18.2	73.5	22.1	8.2	7.6
East Arjun Nagar	Feb. 2001	18.2	41.2	16.7	6.4	5.4
East Arjun Nagar	Mar. 2001	12.2	30.9	11.5	4.6	4.1
ITO, BSZ Marg	Mar. 2001	7.4	24.6	14.9	6.4	4.8
ITO, BSZ Marg	Apr. 2001	7.5	24.0	14.9	6.6	4.8
Jhilmil Ind.Area	Apr. 2001	5.6	14.5	9.6	4.2	3.1
NPL, Pusa Road	May. 2001	2.3	5.1	1.4	0.7	0.6
Hotel Taj Palace	Sept.2001	6.0	16.3	6.3	2.6	1.8
SafdarJang Hospita	Sept.2001	9.5	27.5	11.2	4.5	3.4

ITO, BSZ Marg	Sep-Oct.2001	10.1	31.4	15.1	6.0	4.4
Britania Industry chowk	Oct.2001	15.5	50.2	15.9	6.8	5.0
Delhi (Nov.2k-Oct.2k1)	Minimum	2.3	5.1	1.4	0.7	0.6
	Average	12.5	40.9	17.3	7.0	5.6
	Maximum	38.1	152.0	68.4	26.9	21.9
	Winter	16.5	56.0	22.2	8.8	7.1
	Summer	7.0	19.8	10.5	4.5	3.5

Fig. 5 : BTX Profile During Winter in Delhi

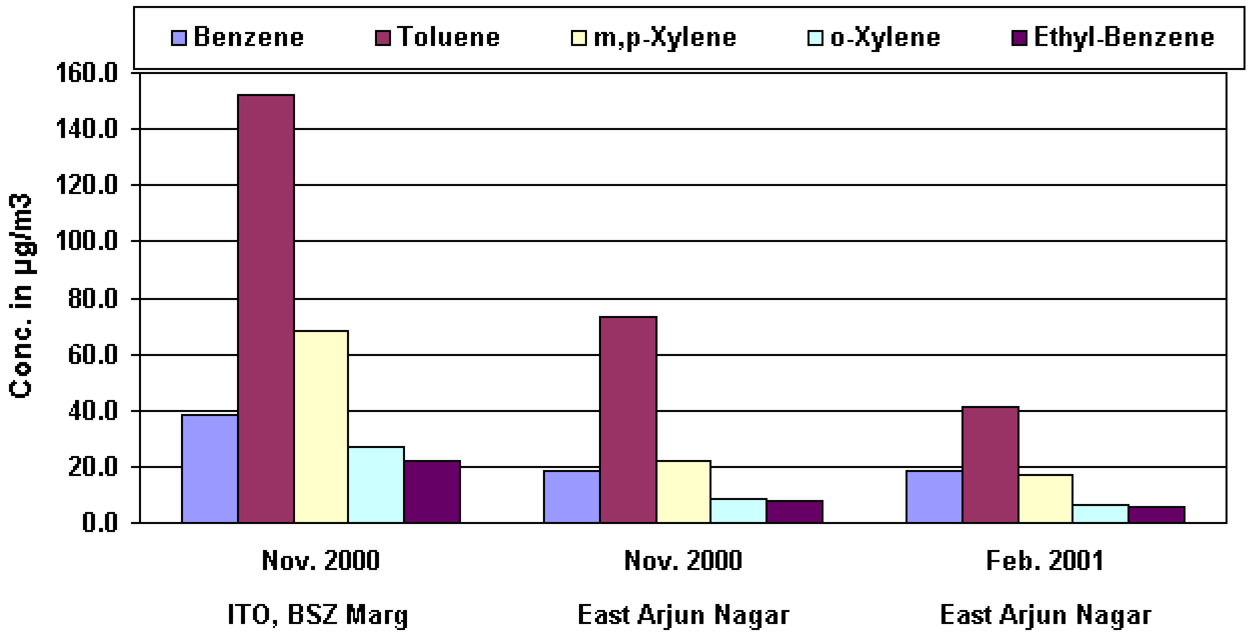


Fig.6: BTX Profile During Summer in Delhi

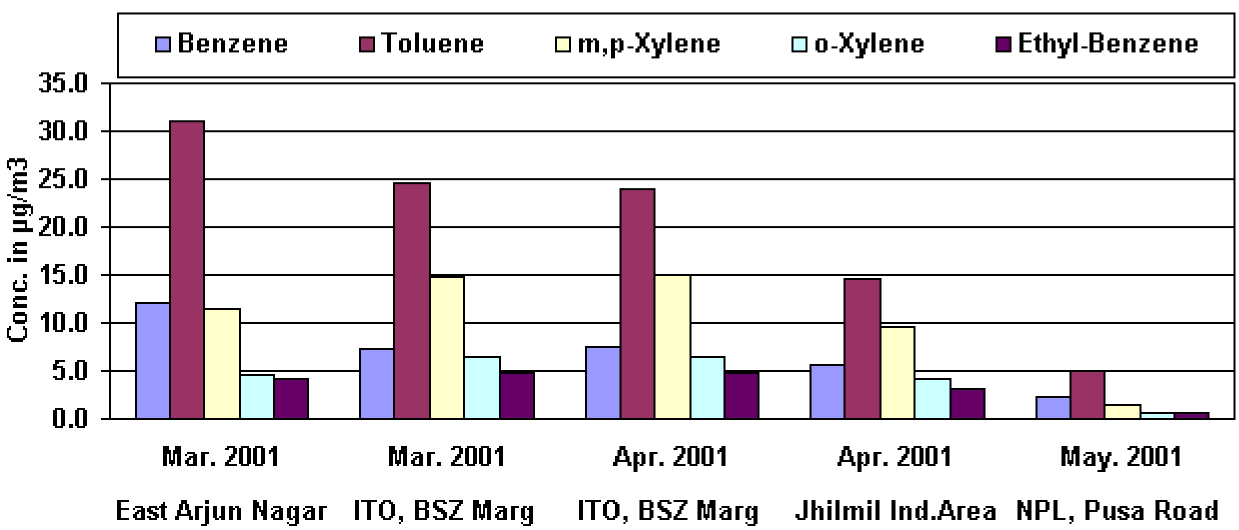


Fig.7: BTX Level Observed In Delhi During Sept -Oct. 2001

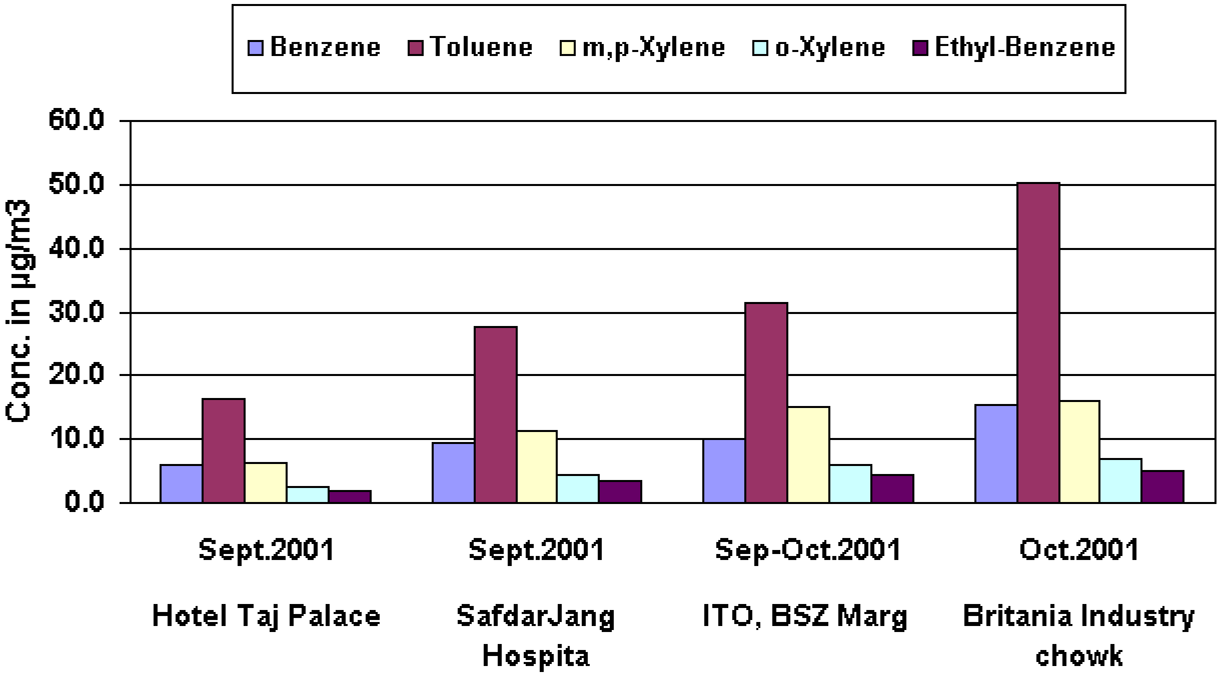
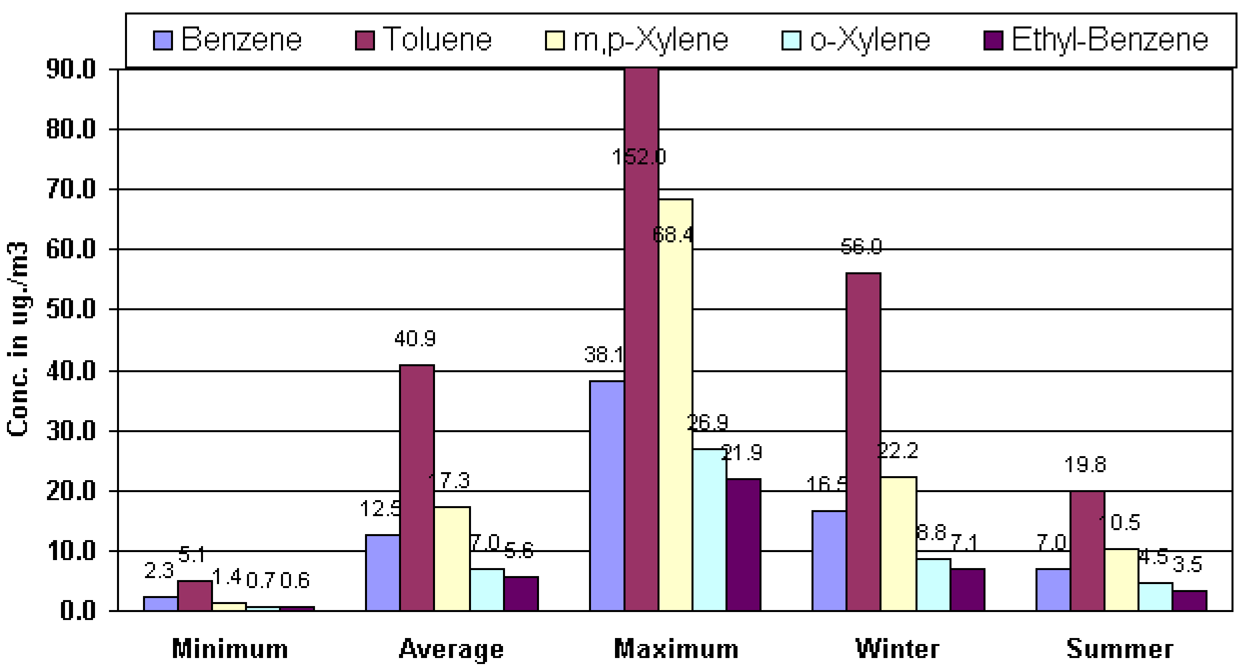


Fig 8 : Average Benzene, Toluene levels observed in Delhi During Year 2000 to 2001.



Diurnal Variation :

Half hourly observations show (Figure:9) that **concentration of all measured components remain prevalent since**

evening time till midnight which reflect that BTEX compounds do not dissipate into the environment immediately after release. They persist in the lower atmosphere during dark and comparative cooler temperature in the night until oxidised during daylight. It is observed that BTX level build up in high conc. for a longer duration at Traffic intersection as compared to residential & Institutional area.

Fig. 9 : Half Hourly Reading of MLU Analyser on Nov. 16th 2000 at ITO.

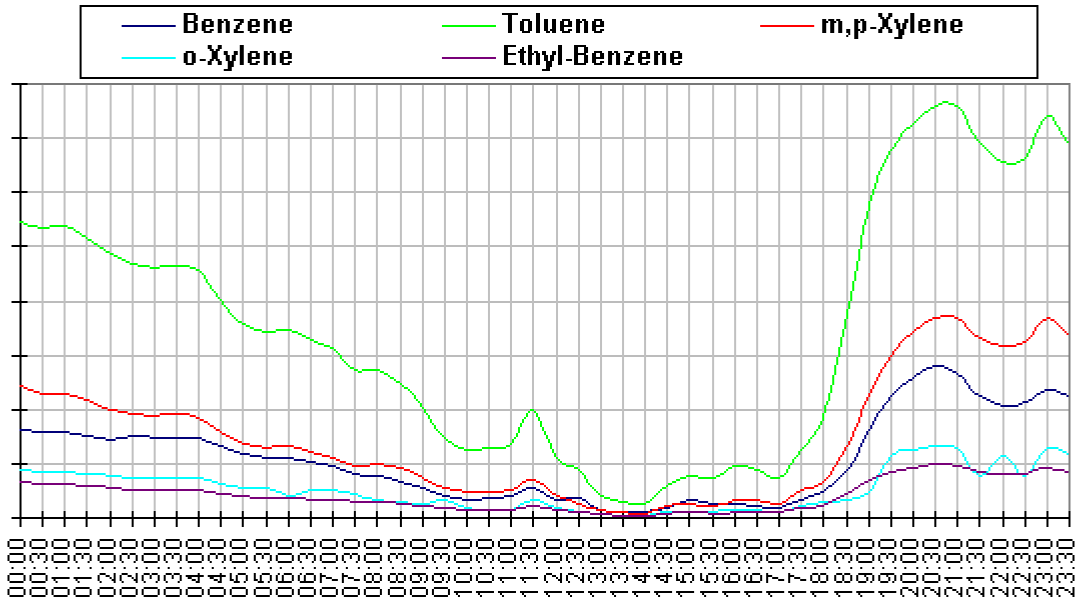


Table 14 : Benzene Emission from Vehicular Monitoring during 1999 in Delhi. (By Using CS2-Method GC-FID, during January, 1999).

S.No.	Type of Vehicle	Sampling Code	Benzene Conc. (mg/m3)
1.	Maruti Car (without catalytic converter	S-39 S-40	53 235
		TOTAL	**288**
2.	Maruti gipsy (with catalytic converter	S-43 S-44	53 94
		TOTAL	**147**
3.	Ambrassoder (with catalytic converter)	S-37 S-38	**21** **145**
		TOTAL	**165**
4.	Three Wheeler (Petrol)	S-33 S-34	330 24
		TOTAL	**354**
5.	Three Wheeler (Petrol)	S-41 S-42	882 280
		TOTAL	**1162**

6.	Two Wheeler Two stroke	S-35 S-36	1574 666
		TOTAL	**2240**
7.	Two Wheeler Two stroke	S-31 S-32	1528 222
		TOTAL	**1750**

Table 15 : Benzene Emission from Vehicular Monitoring during August 1998 in Delhi. (By Using CS2-Method GC-FID During August 1998).

S.No.	Type of Vehicle	Sampling Code	Benzene Conc. (mg/m3)
1.	Two Wheeler with Lead Petrol	LP1 LP2	1133 176
		TOTAL	**1309**
2.	Two wheeler with unlead petrol	ULP1 ULP2	226 138
		TOTAL	**364**

esults clearly indicate increasing order from residential to Traffic intersection to Petrol pump.

- **Passive Sampling:**

Benzene levels in Delhi's urban environment measured also as per M/S Drager's (Germany) standard procedure for passive sampling (fortnightly basis) i.e. conventional CS_2 desorption capillary GC-FID analytical techniques. The results are summarized in following table.

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		Aug' 98	**Nov' 98**	**May' 99**	**Jun' 99**	**Jul' 99**	**Aug' 99**	**Sep' 99**
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2.	Traffic	42*	195*	38*	20*	22*	24*	25*

	Intersection	(39-45)	(193-196)	(32-43)	(16-24)			
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Fig.3 : Benzene Level By Passive Sampling in Delhi During May 1999

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- Overall average levels of m,p Xylene, o-Xylene and Ethyl Benzene were observed 17.3, 7.0 & 5.6 µg/m^3

respectively.

- **Vehicular pollution seems to be the major contributor of high level at ITO during Nov. 2000** due to higher Benzene content in petrol as compared to Oct. 2001. **Benzene content in petrol in National Capital Territory (NCT) and Mumbai has been reduced from 3% to 1% after Nov. 2000.**

Table 13: BTX levels observed in Delhi during Nov. 2000 to Oct. 2001.

Concentrations in µg/m^3 at 25°C

Locations	Period	Benzene	Toluene	m,p-Xylene	o-Xylene	Ethyl-Benzene
ITO, BSZ Marg	Nov. 2000	38.1	152.0	68.4	26.9	21.9
East Arjun Nagar	Nov. 2000	18.2	73.5	22.1	8.2	7.6
East Arjun Nagar	Feb. 2001	18.2	41.2	16.7	6.4	5.4
East Arjun Nagar	Mar. 2001	12.2	30.9	11.5	4.6	4.1
ITO, BSZ Marg	Mar. 2001	7.4	24.6	14.9	6.4	4.8
ITO, BSZ Marg	Apr. 2001	7.5	24.0	14.9	6.6	4.8
Jhilmil Ind.Area	Apr. 2001	5.6	14.5	9.6	4.2	3.1
NPL, Pusa Road	May. 2001	2.3	5.1	1.4	0.7	0.6
Hotel Taj Palace	Sept.2001	6.0	16.3	6.3	2.6	1.8
SafdarJang Hospita	Sept.2001	9.5	27.5	11.2	4.5	3.4
ITO, BSZ Marg	Sep-Oct.2001	10.1	31.4	15.1	6.0	4.4
Britania Industry chowk	Oct.2001	15.5	50.2	15.9	6.8	5.0
Delhi (Nov.2k-Oct.2k1)	Minimum	2.3	5.1	1.4	0.7	0.6
	Average	12.5	40.9	17.3	7.0	5.6
	Maximum	38.1	152.0	68.4	26.9	21.9
	Winter	16.5	56.0	22.2	8.8	7.1
	Summer	7.0	19.8	10.5	4.5	3.5

Diurnal Variation :

Half hourly observations show (Figure:9) that **concentration of all measured components remain prevalent since**

evening time till midnight which reflect that BTEX compounds do not dissipate into the environment immediately after release. They persist in the lower atmosphere during dark and comparative cooler temperature in the night until oxidised during daylight. It is observed that BTX level build up in high conc. for a longer duration at Traffic intersection as compared to residential & Institutional area.

Fig. 9 : Half Hourly Reading of MLU Analyser on Nov. 16th 2000 at ITO.

Table 14 : Benzene Emission from Vehicular Monitoring during 1999 in

Delhi. (By Using CS2-Method GC-FID, during January, 1999).

S.No.	**Type of Vehicle**	**Sampling Code**	**Benzene Conc.** **(mg/m3)**
1.	Maruti Car (without catalytic converter	S-39 S-40	53 235
		TOTAL	**288**
2.	Maruti gipsy (with catalytic converter	S-43 S-44	53 94
		TOTAL	**147**
3.	Ambrassoder (with catalytic converter)	S-37 S-38	**21** **145**
		TOTAL	**165**
4.	Three Wheeler (Petrol)	S-33 S-34	330 24
		TOTAL	**354**
5.	Three Wheeler (Petrol)	S-41 S-42	882 280
		TOTAL	**1162**

6.	Two Wheeler Two stroke	S-35 S-36	1574 666
		TOTAL	**2240**
7.	Two Wheeler Two stroke	S-31 S-32	1528 222
		TOTAL	**1750**

Table 15 : Benzene Emission from Vehicular Monitoring during August 1998 in Delhi. (By Using CS2-Method GC-FID During August 1998).

S.No.	**Type of Vehicle**	**Sampling Code**	**Benzene Conc. (mg/m3)**
1.	Two Wheeler with Lead Petrol	LP1 LP2	1133 176
		TOTAL	**1309**
2.	Two wheeler with unlead petrol	ULP1 ULP2	226 138
		TOTAL	**364**

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BENZENE LEVELS IN MAJOR CITIES OF THE WORLD :

Table 16 : Benzene levels in major cities of the World.

Location	Benzene Concentration (ug/m^3)		Reference
	Mean	Maximum	
Houston, Texas, USA (1980)	18.8	122.9	Singh et al. (1982)
Pittsburgh, PA, USA (1981)	16.3	210.6	Singh et al (1982)
Oslo, Norway, (1980)	40.0	114.0	Wathne (1983)
Rhine area, Germany, (1983)	4.6-22.4	-	Bruckman et al. (1983)
Black Forest, Germany (1983)	2.0	-	Bruckman et al. (1983)
London, England (1983)	23.0	85.0	Clark et al. (1984)
Bilthven, Netherlands (1982-83)	2.8	10.4	RIVM (1988)
Delhi, India (1999-2000)	25.0 13.0	75.0 38.0	CPCB Study, 1999-2000 CPCB Study, 2000-2001
Berlin	49.0		Seifert and
(1975-76)	43.4		Ullrich (1978)
	68.9		
Stockholm (20 min values)	84		Jonsson and Berg (1978)
	460		
Helsinki (2 h value)	100		Hasanen et al. (1981)
Zurich	188		Grob and Grob (1971)
Belgium (Brussel 68 sites 1994	1.6-11.3		*
Denmark (Copenhagen 1995-96)			1995-96*
Italy (Bari 8 sites 1993)	2.0-4.9		1993*
Germany (13 cities 1993)	2.0-4.9		1993*
Sweden (28 cities winter 1995-96)	2.1-5.0		1995-96*
Netherlands (3 cities 1993-94)	2.4-4.7		1993-94*
U.K.(6 cities 1994)	2.2-4.8		1994*
US Urban (1987-1990)	4-7		1987-1990*

* Source – WHO.

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AIR QUALITY STANDARD FOR BENZENE :

UK Expert Panel on Air Quality Standards :

As regards exposure to general public UK Expert Panel on Air Quality Standards have recommended 5 ppb (16 µg/m^3) as a rolling annual mean ;with a target of 1 ppb (3.2 µg/m^3) for benzene concentration in air . Also they have recommended that this Standard be reduced to the lower level of 1 ppb running annual average, and that the Government set a target date by which this be achieved.

European Commission Limit Value for Benzene :

The limit value must be expressed in µg/m^3, standardized at a temperature of 293 K (20*C) and a pressure of 101.3 kPa.

	Averaging period	Limit Value	Margin of tolerance	Date by which limit value is to be met
Limit value for the protection of human health	Calendar year	5 ug/m^3	5 ug/m^3 (100 %) on 13 December 2000, reducing on 1 January 2006 and every 12 months thereafter by 1 ug/m^3 to reach 0% by 1 January 2010	1 January 2010 (1)
(1) Except within zones and agglomerations within which a time-limited extension has been agreed in accordance with Article 3(2)n m				

Air Quality Standards for Benzene in Different Countries

Country	Standard Concentration measured as	To be achieved by
UK	16 ug/m^3 – running annual mean	31^{st} Dec., 2003
European Commission	5 ug/m^3 –annual average	31^{st} Dec., 2010
Japan	3 ug/m^3 annual average*	Existing Standard
WHO Guidelines	5-20 ug/m^3	

* Prefer GC-MS (sample to be collected with canister or tube or its equivalent method).

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GASOLINE BENZENE REDUCTION PROGRAM IN INDIA :

Period	Benzene Content	Area Covered
Before 1996	No specification	Entire country
April, 1996	5%	Entire Country
April , 2000	3%	Metropolitan Cities
November, 2000	1%	National Capital Territory (NCT) and Mumbai

Source: Air quality Status and trends, CPCB Report NAAQMS/14/2000-2001

Table 17: Specifications for Petrol in India and Europe

PARAMETERS	SPECIFICATIONS				
	India 2000[1]	Mukhapadhyay Committee 2005[2]	Europe 2000[3]	Europe 2005[3]	USA RFG-3[4]
Sulphur (per cent by weight)	0.1-0.5	0.03	0.015	0.005	0.002
Aromatics (per cent by Volume)	No limit	45	42	35	25
Olefins (per cent by Volume)	No limit	18	18	14-16	6
Benzene (per cent by Volume)	3-5	1(in six metros) 3 (rest of the country)	1	1	0.8

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Progressive Phase out of Benzene content in gasoline in Different Countries :

Many countries are progressively bringing down benzene content in gasoline towards 1 vol.% max.

Country	Year	Banzene, Vol % max
USA	1995	1.0
EU	1985 2000	5.0 1.0
Austria	1990	3.0
Italy	1993 1997 1999	3.0 1.4 1.0
Finland	1993 1994	3.0 (95%) Encourages 1.0 do

In India it is desirable to target a maximum benzene concentration of 1.0 vol % keeping in view the high ambient temperatures. In addition there is need to control the aromatic content of gasoline and install vapour recovery system during storage, loading and unloading operations in different stages of product handling from refineries to vehicle tanks.

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