Ambient concentration of benzene in air due to vehicular movement in Mumbai

An USEPA study on air toxics related to vehicular emission[1] establishes benzene in air as a pollutant strictly related to industrial activities and automotive emissions. Efforts to reduce lead content of the fuel gasoline and to maintain the octane number have led to an increase in benzene and other aromatic hydrocarbons in gasoline. An increase in the concentration of these chemicals in the air as a primary pollutant and as precursors of photochemical smog is an obvious result.

Benzene is readily absorbed into the body when breathed into the lungs and about half of it is retained. It is more soluble in fat than in water and thus is distributed in the body in fatty tissues, including the brain and the bone marrow where cells are made[2,3]. It is thus important to know the levels of benzene in air. Vehicles are one of the major sources of benzene in air. The respiratory route is the major source of human exposure to benzene, and much of this exposure is by way of gasoline vapours and automotive emissions[4]. A study done by USEPA found that mobile sources account for approximately 85% of the total benzene emission[5].

The policeman at a traffic intersection is likely to be exposed to higher levels of vehicular emissions. So also people moving on the kerbside, roadside markets, shopkeepers, shoppers and people living in settlements on the footpath (a common phenomenon in Indian urban areas) form a vulnerable population which is likely to be exposed to high levels of vehicular emissions.

An attempt has thus been made to determine the levels of benzene in ambient air in different areas of an urban settlement of a coastal city within 5 m of vehicular movement corridors.

Mumbai is located on the west coast of India with Arabian Sea to its west and the Bombay Harbour and the outlet of Thane creek to the east. The city is a hub of commercial, industrial and port activities.

The principal aim of the study was to determine levels of benzene due to vehicular movement and thus the sampling locations selected represented petrol pumps, traffic junctions, arterial roads, highways and parking areas.

Two petrol pumps on the commercial streets, viz. Dr A. B. Road and J. M. Mehta Marg with heavy traffic inflow were selected. Sampling was carried out in the middle of the petrol pump area where vehicles halt for filling petrol, close to the dispensing unit.

The traffic junctions include Haji Ali, Worli and Kalbadevi. They were chosen in such a manner that there were multiple road junctions and the number of vehicles plying were high during peak hours. Haji Ali is close to the seashore and a part of the traffic movement here contributes to

Table 1. Concentration of benzene in air

Location*	Date	Minimum (ppm)	Maximum (ppm)	Average
Petrol pump				
Dr A. B. Road	20.05.2000	0.354	0.852	0.471
	02.08.2000	0.252	0.596	
	03.12.2000	0.318	0.455	
J. M. Mehta Marg	27.05.2000	0.498	0.658	0.465
	05.08.2000	0.272	0.549	
	22.12.2000	0.254	0.505	
Traffic intersection				
Haji Ali	05.05.2000	0.077	0.409	0.280
	13.08.2000	0.131	0.486	
	23.12.2000	0.179	0.399	
Worli	22.06.2000	0.248	0.330	0.245
	25.08.2000	0.089	0.168	
	06.01.2000	0.195	0.440	
Kalbadevi	12.05.2000	0.192	0.317	0.319
	01.09.2000	0.249	0.465	
	15.12.2000	0.315	0.377	
Arterial road				
Santacruz	19.04.2000	0.075	0.102	0.078
Chakala	27.08.2000	0.058	0.079	
	18.12.2000	0.065	0.092	
Mahim	05.06.2000	0.042	0.055	0.049
	02.07.2000	0.007	0.088	
	29.11.2000	0.045	0.058	
Tilak Marg	24.06.2000	0.060	0.158	0.149
	29.07.2000	0.040	0.165	
	05.01.2000	0.201	0.275	
Chembur	27.04.2000	0.029	0.081	0.137
	07.08.2000	0.060	0.165	
	16.01.2000	0.172	0.315	
Highway				
Western express	20.05.2000	0.095	0.350	0.203
	02.09.2000	0.135	0.197	
	04.12.2000	0.120	0.324	
Eastern express	21.06.2000	0.031	0.061	0.046
	28.06.2000	0.037	0.055	
	28.11.2000	0.025	0.068	
Parking area				
Liberty cinema	11.05.2000	0.255	0.501	0.368
	27.11.2000	0.375	0.475	
	07.09.2000	0.285	0.322	
Natraj cinema	09.06.2000	0.250	0.345	0.275
	18.09.2000	0.244	0.251	
	05.01.2000	0.238	0.323	

the traffic of two main express highways of Mumbai, namely the western express highway and the eastern express highway. Worli is at the junction of multiple roads catering to the western express highway and major roads of Mumbai. Kalbadevi junction is amidst commercial activities. The major portion of the traffic here is made up of taxis, trucks and buses. Samplers were located at the road divider at the traffic junctions.

Arterial roads selected were Santacruz Chakala, Mahim, Tilak Road and Chembur. Santacruz Chakala joins the western express highway. Mahim is close to the seashore and Tilak Marg at Dadar T.T. joins the eastern express highway. The sampling location at Chembur was an arterial road joining the Mumbai–Pune highway. Samplers were placed at the side of the road.

Location on the eastern express highway was in front of Sion Hospital and that on the western express highway near the airport. Samplers were placed at the divider of the road.

The parking areas selected were cinema hall parking. Sampling was carried out during 14:00–16:00 h, 17:00–19:00 h and 20:00–22:00 h. Samplers were located at the entrance/exit of the parking area. Sampling height at all the locations was approximately 3 m.

At traffic junctions and petrol pumps, four-hourly samples were collected during peak hours, i.e. 8.00 am to 12.00 noon, and 5.00 to 9.00 pm. At all other locations, three eight hourly samples during 2.00 to 10.00 pm, 10.00 pm to 6.00 am and 6.00 am to 2.00 pm in a day were collected. Each location was sampled thrice, once in each season, namely summer, winter and monsoon. Summer was considered from March to June, monsoon from July to October, and winter from November to February.

The USEPA compendium method TO-17 was used for sampling and analysis. Varian GC-MS (Model Saturn 3) with injection mode of sample introduction with DB 624 capillary column of 30 m length, 0.32 mm interval diameter and 1.8 microfilm was used. Helium gas with a flow rate of 1 ml/min was used as carrier gas with split ratio of 1 : 25; the GC oven was programmed for 35°C hold for 2 min and ramped to 210°C at a rate of 10°C/min. Ion trap temperature was maintained at 125°C while acquisition mass range was from 35 to 260 amu in E1 mode. The percentage accuracy of the method is in the range 0.03 to 16.

The values reported in the present work represent the concentration in the microenvironment around the sampling point. Sampling locations in the present study were chosen to represent emissions from the vehicular movement. Hence the samplers were placed within 5 m of the vehicles. The sampled air thus does not represent a well-mixed environment. Concentration in ambient air would depend on further dispersion.

Table 1 presents the observed maximum and minimum concentration. The concentration observed in the present study is high. Maximum concentration has been observed at petrol pumps (0.852 ppm), followed by parking areas (0.244 to 0.501 ppm) and traffic junctions (0.077 to 0.486 ppm). At arterial roads and highways, maximum concentration of benzene observed is 0.315 and 0.350 ppm respectively. The high concentration of benzene may be attributed to vehicular emissions. These concentrations represent the levels to which roadside shoppers, kerbside users and policemen are likely to be exposed. Earlier studies[6,7] reported concentrations of benzene in ambient air at Mahul, Vashi and Trombay area of Mumbai, to range from 13.5 to 38.7 ppb. However, in that study care was taken to avoid sampling direct vehicular emissions. Studies on benzene in different areas with similar type of activities have been reported as: Kolkata (1997) – 28.55 mg/m^3 (benzene)[8], Bangkok (1997) – 12.34–35.82 mg/m^3 (benzene)[9], Dhaka (2002) – 10.56 mg/m^3 (benzene), 135–1479 mg/m^3 (TVOC)[10].

Concentration of benzene observed both during day and night at petrol pumps did not show any specific correlation. The concentration at petrol pumps was however observed to be related to quantities of petrol delivered during the sampling period (Figure 1). Concentration at traffic junctions and traffic flow pattern do not show any major variation during morning and evening peak hours. Concentration of benzene observed also did not show any variation. Diurnal variation at arterial roads and highways is shown in Figure 2. It is observed that

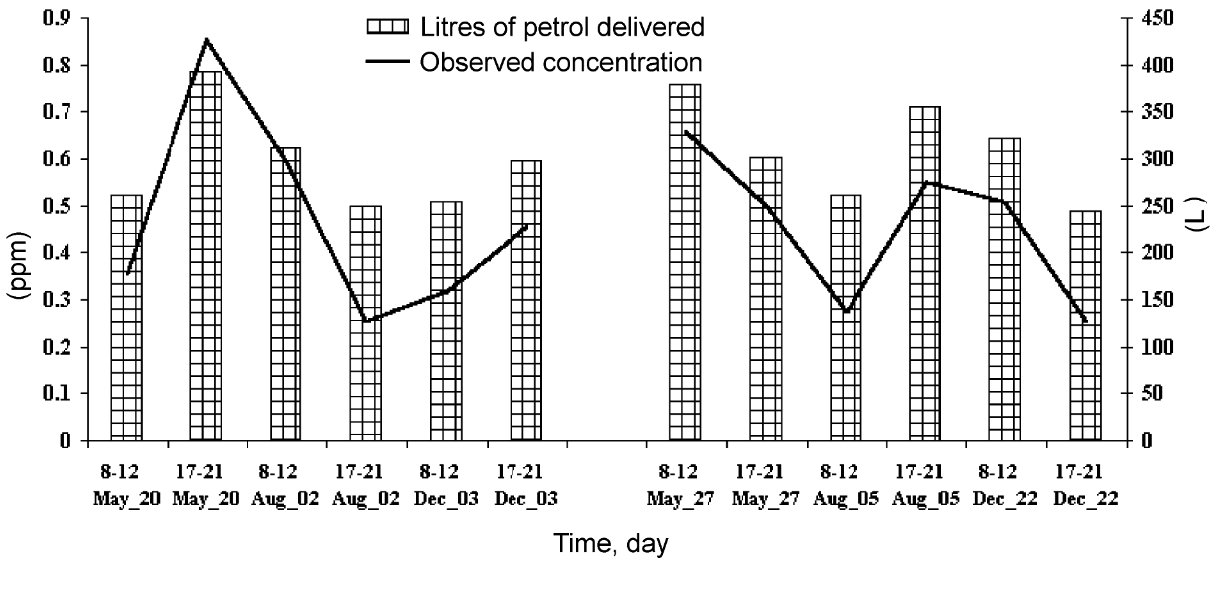

Figure 1. Concentration of benzene in air at petrol pumps and quantity delivered.

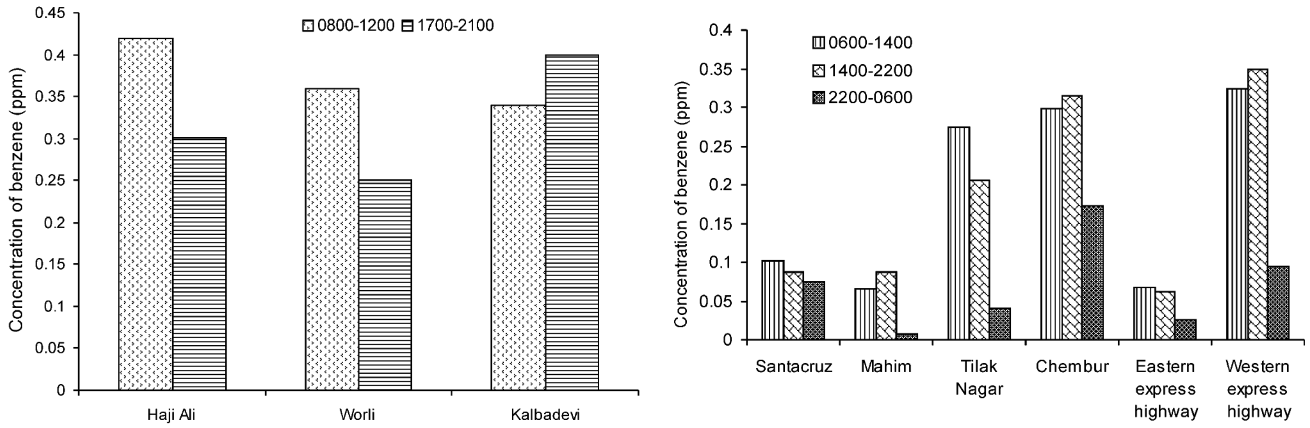

Figure 2. Diurnal variation of benzene concentration at traffic junctions, arterial roads and highways.

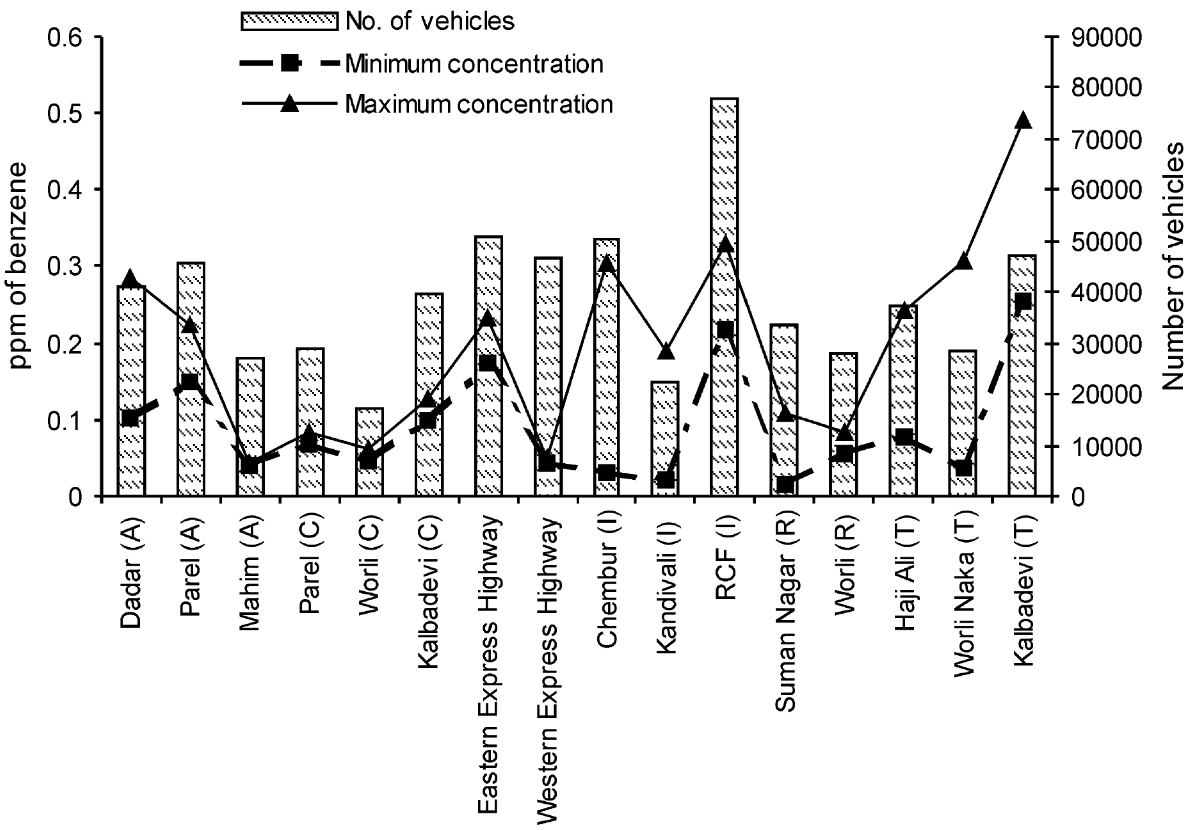

Figure 3. Number of vehicles and benzene concentration at different locations.

concentration of benzene during 22:00 to 06:00 h is low. At Mahim, a location close to the seashore, due to land breeze the benzene concentration during night was much lower. Mumbai being a commercial and industrial centre, fairly uniform vehicular movement is observed throughout the day. No significant change in concentration of benzene was thus observed during the daytime.

Figure 3 shows the correlation between number of vehicles crossing the sampling location and benzene concentration observed. It also shows that at Mahim arterial road, though the number of vehicles is high, the concentration is not high. This may be due to the fact that this location is close to the sea coast and because of the sea breeze pollutant concentration is diluted. In the highways, although vehicle counts are similar, concentration of benzene at the western express highway is lower than that at the eastern express highway. This is because the number of lanes on the eastern express highway at the location Sion is 3 + 0, whereas at the western express highway at Santacruz airport it is 3 + 3. The conjunction on the eastern express highway results in high levels of benzene. At traffic junctions, the concentration of benzene and vehicle counts do not show linear dependence. Amongst the traffic intersections Haji Ali is next to the sea coast, Worli Naka is about 500 m away from coast while Kalbadevi is a congested commercial area and the sampling location is surrounded by tall buildings. Maximum benzene concentration is observed at Kalbadevi traffic junction. The observed concentration is thus not related only to the number of vehicles but also to meteorology, ventilation available, site built-up plan, age and type of vehicles, etc.

A short term (30 min) ambient air quality standard of 30 $\mu g/m^3$ for benzene has been established in Texas, USA[11]. If this standard is adopted for comparison of the results of this study, we find that benzene concentration in ambient air has exceeded this limit in all vehicular corridors in Mumbai city.

The high benzene concentration obtained in the present work indicates that though ambient concentrations of benzene may be low in urban settlements, kerbsides, roadside market places (common in Indian urban areas) and traffic intersections are areas of high benzene levels and a large number of people are likely to be exposed to benzene for short and long durations. The concentration of benzene in air cannot be related to only the number of vehicles. The ventilation available, age and type of vehicle and meteorology also contribute significantly. Concentration of benzene at the traffic corridors should as well be studied along with that in ambient air on a continuous basis to safeguard the health of commuters, shopkeepers and shoppers.

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Microbially induced impact on physico-chemical properties of porous lime stones: A case study from Kandhar fort

Since ancient times all types of material have been used by Indians to make artifacts, from simple mono components to complex structures integrating inorganic and organic matter. Such artifacts, even if made with resistant stones and other materials, are influenced by environmental parameters. Historical monuments located specially in tropical wet and dry climates (10–20° of the equator) undergo the process of biodeterioration due to environmental factors such as high temperature, high relative humidity and heavy rainfall followed by winter which favours the growth and sustenance of a variety of living organisms on stone surfaces. All these factors interact synergetically with constitutive stone materials (sandstone, limestone and marbles) and induce changes in their structural and physico-chemical properties[1–5].

Researchers have shown that bacteria on stone surfaces produce corrosive organic acids when exposed to pollutants, resulting in significant stone degradation. The scientific understanding of these processes remains limited and because of the major variables involved. It is difficult to assess the relative importance of microbial processes in microbial-induced stone degradation[6–9]. Exposure of historical monuments to extremely high concentrations of atmospheric pollutants like carbon dioxide, sulphur oxides, nitrogen oxides, particulate matter, ammonia, ozone, hydrogen fluoride and hydrogen chloride in recent decades has highlighted concern about these issues[10].

Marathwada region of Maharashtra is famous for the caves at Ajanta and Ellora[11]. There are a few monuments in the region; one of them is the historical fort at Kandhar, famous for its land fort (180°50′N, 10′E). Its construction is attributed to Rastrakuta Krishna III of