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A Sustainable Approach towards Minimizing Atmospheric Benzene by the Use of Plants

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ABSTRACT: Benzene is recognized as human leukaemogen and may cause injury to human bone marrow and damage to immune system. In India, especially in Delhi, from the past 2-3 years (2008 onwards), the concentration of benzene shows a remarkable increase in its diurnal as well as nocturnal trend. Hence, there is a need to minimize the concentration of benzene in air by some cost effective methods. The aim of our present study is to observe the variation in the concentration of benzene at two sites, viz. Site I (Civil Lines, high traffic zone with less vegetative area, alongwith two nearby petrol pumps) and Site II (Jawahar Vatika, University of Delhi, North Campus, less traffic zone with dense vegetative area) during winter months and to suggest some benzene tolerant plants which are used for improving the quality of air to make the environment sustainably secure for the human health. The results shows that the concentration of benzene was found to be higher at Site I than at Site II as Site I has more favourable factors for the production of benzene which includes transport emissions and the nearby petrol pumps. Interestingly, it has been observed that the concentration of benzene crosses the permissible limit at both the sites. For minimize the concentration of benzene in air, common plants like *Dracaena deremensis* and *Chamaedorea Seifrizii* have been suggested to evaluate the tolerance and sensitivity of both plants by taking Air Pollution Tolerance Index (APTI) as a parameter. It was observed that *Dracaena deremensis* was found to be tolerant and also good absorber of benzene in air by NASA study while *Chamaedorea Seifrizii* was found to be sensitive and serve as bioindicator which further help in mitigating the benzene pollution which indirectly support the sustenance of environment and help in protecting human health.
Keywords: Benzene, VOCs, Delhi, Sustainable environment and Plants

INTRODUCTION

Urban air quality is deteoriating due to increase in traffic emissions which are having significant effects on the health of plants as well as humans. The most contributing sector which is responsible for creating air pollution is transportation. The emissions from transport sector are the key factors for the production of primary as well as secondary pollutants, for example it has been determined that volatile organic compound (VOCs) (primary pollutant) emissions from this source account for approximately 35% of all VOC emissions to the atmosphere (Derwent et al., 2000). Due to the implementation of various policies and technologies the vehicle emissions are getting improved and produce more clean air but due to the dramatic increase in the vehicular growth the situation of increasing air pollution is getting worsen (Kahn, 1996). There are various air pollutants which are produced due to traffic emissions. Benzene, toluene, ethylbenzene, and xylenes (BTEX) are one of the category of pollutants which are most abundant and responsible for deteoriating the atmospheric chemistry (Brocco et al., 1997) and are considered to be the markers for human exposure to VOCs, therefore, they remain in the centre of attention and hence their monitoring is very necessary (Bergow et al., 1996; Bertoni et al., 2002). Vehicular emissions accounting for approximately 70% of remaining all the sources emissions and another 10% comes from other sources like distillation, evaporation of industrial solvents, refining and evaporation of gasoline from vehicles (Lenz and Cozzarini, 1999; Schauer et al., 2002). Benzene has proven carcinogenic and having mutagenic properties (Agency for Toxic Substances and Disease Registry, 1997). Besides this, the Department of Health and Human

Services (HHS) has determined that benzene is a known human carcinogen (causes cancer). Workers exposed to high levels of benzene in occupational settings were found to have an increase occurrence of leukaemia. Long-term exposure to high levels of benzene in the air can lead to leukaemia and cancers of the blood-forming organs. Toluene, ethylbenzene, and the xylenes are also classified hazardous air toxics or air toxics in Canada (CEPA, 1999) and the United States (USEPA, 1990).

In India and in other western countries, benzene and toluene are potentially toxic air pollutants among volatile organic compounds (VOCs) (Tyagi et al., 1999, 2004; CPCB,1999-2000). According to an estimate made by Department of Environment, WHO (1993), 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 ug/ m^3 will, therefore, be about 160 ug. WHO (1993) also estimates 4 in 1 million risk of leukaemia on exposure to a concentration of 1 ug/ m^3 (0.31 ppb). Together with other pollutants, benzene also participates in photochemical process, which result in formation of oxidants and smog. In India, especially in Delhi, from the past 2-3 years (2008 onwards) as per analyzed by Delhi Pollution Control committee and Central Pollution Control Board secondary data, the concentration of benzene shows a remarkable increase in its diurnal as well as nocturnal trend. Interestingly, it has been observed that even after the implementation of new control technologies like use of CNG considered to be best alternative fuel, there is no significant change reported so far in the criteria pollutant concentrations. Hence, there is a need to minimize the concentration of benzene in air by some cost effective methods. Therefore it’s our matter of interest in the present study to observe the variation in the concentration of benzene at two sites, viz. Site I (Civil Lines, high traffic zone with less vegetative area, alongwith two nearby petrol pumps) and Site II (Jawahar Vatika, University of Delhi, North Campus, less traffic zone with dense vegetative area) during winter months (Oct-Nov, 2010) and to suggest some benzene tolerant plants which are used for improving the quality of air to make the environment sustainably secure for the human health.

METHODOLOGY

For the assessment of atmospheric benzene concentration at selected sites viz. Site I (Civil Lines, high traffic zone with less vegetative area, surrounded by shopping complexes, small scale industries and along with two nearby petrol pumps. In short this site is recognized as traffic intersection, petrol pump, commercial and industrial) and Site II (Jawahar Vatika, University of Delhi, North Campus, i.e. institutional area, less traffic zone with dense vegetative area and surrounded by residential flats (Figure 1). In short this site is recognized as institutional and residential) during winter months (Oct-Nov, 2010).

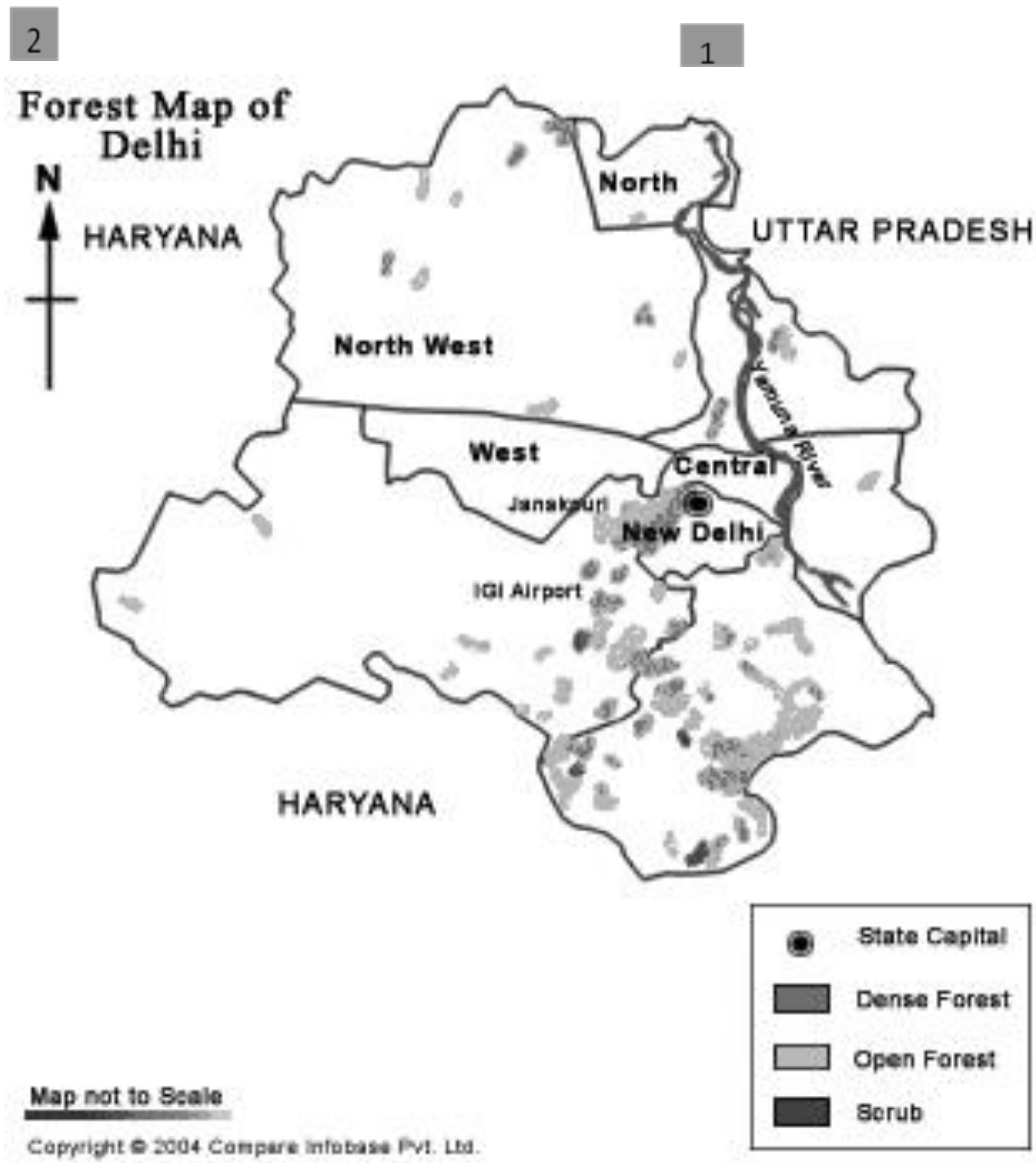

Fig.1 Map of Delhi showing sites

1. Civil Lines (Site I)
2. Delhi University (Site II)

Organic Vapour Sampler (OVS) APM 856 (Envirotech Instruments Pvt. Ltd. India), consisting of fabricated diffusive glass sampling tubes and regulated air suctioning pump, was used for the monitoring of benzene in air. The ambient air was sucked through known amount of activated charcoal (18-35 mesh size)contained in sealed glass tubes procured from Envirotech Instruments Pvt. Ltd. This method is TO-17 Method given by USEPA, 1999. The activated charcoal samples were transferred from the sealed tubes into a glass vial and sealed immediately in order to prevent further adsorption of compounds. These were stored at 4°C until analysis. To the sample vial, 2ml of carbon disulphide was added and shaken gently for 40 minutes (Chan et al., 1999). Carbon disulphide was filtered out with Teflon syringe filter (0.22µm).

Analysis was done by GC –FID (Shimazdu, GC-2010) equipped with Omega SPTm column (30mX 0.25 mm id). GC oven was programmed for 50°C, hold for two minutes and ramped to 260°C at a rate of 10°C / min with 12 minutes hold at 230°C. Nitrogen was used as carrier gas with flow rate of 1.21 ml / min and split ratio of 1:10. The standard calibration mixture containing benzene, toluene, ethylbenzene, o-xylene, m-xylene and p-xylene procured from Supelco was used for calibration. Calibration standards were prepared by diluting the stock standard mixture. The quality assurance and quality control (QA/QC) measures included laboratory and field blank and replicates were taken for measurements of samples. For laboratory blank, unexposed charcoal tubes were analyzed for VOCs similar to the exposed ones.

To minimize the concentration of benzene in air, as per our objective of the study, two plants were selected like Dracaena deremensis and Chamaedorea Seifrizii at both the sites and analyze their tolerance limit by taking Air Pollution Tolerance Index (APTI) as a parameter. Sampling pattern of both the plant species was done every week in a month and analyzed in duplicates for the authenticity of the data during winter months (Oct-Nov, 2010). To evaluate the susceptibility level of plants to air pollutants four biochemical parameter namely Ascorbic acid, Total Chlorophyll Content, Relative Water Content and Leaf extract pH were measured. These parameters were computed together in a formulation to obtain an empirical value signifying the air pollution tolerance index (APTI) of species (Singh and Rao,1983).The APTI of species was determined by using the formula developed by Singh and Rao (1983)

$$APTI = \frac{A(T+P) + R}{10}$$

Where, A = Ascorbic acid content of leaf in mg/g fresh wt (Law et al., 1983)
T = Total Chlorophyll of leaf mg/g fresh wt (Hiscox and Israelstam, 1979)
P = Leaf extract pH (Singh & Rao, 1983)
R = Percent Relative Water Content (Singh & Rao, 1983)

Based on APTI values the plants were conveniently grouped as follows:

0 - 1 = Most Sensitive
1 - 16 = Sensitive
17 - 29 = Intermediate
30 - 100 = Tolerant

Results and Discussion

For understanding the atmospheric chemistry profile of the benzene at two selected sites i.e. Traffic intersection, petrol pump, commercial and industrial, Site I and institutional and residential area, Site II monitoring was performed in three different seasons viz. summer (Apr-Jun), monsoon (July-Sept) and winter (Oct-Nov). From Table 1 it has been clearly depicted that high concentrations of benzene were recorded during winter months as compared to other months. Therefore, only these two months were selected for further benzene and plant study.

Table 1. Monthly variation of benzene at selected sites, Site I & II.

Months	Benzene (µg/m^3) – Site I	Benzene (µg/m^3) – Site II
Apr	22.04 ± 0.65^c	1.11 ±0.33^b
May	17.04 ± 0.11^c	0.86 ±0.26^c
Jun	9.33 ± 0.32^d	0.42±0.33^c
July	3.33 ± 0.14^e	0.24±0.11^c
Aug	2.05 ± 0.10^e	0.13±0.22^c
Sept	1.88 ± 0.08^e	0.08±0.13^d
Oct	250.04 ± 2.95^b	2.32 ±0.23^b
Nov	1685.21±2.62^a	4.31 ±0.34^a

SiteI (traffic intersection) & Site II (institutional and residential)

Note: Each value represents mean of 15 replicates + standard error. Data followed by different letters in a column are significantly different at P≤0.05. Data followed by same letters in a row are non-significant at P≤0.05.

The general trend of variation in meteorological parameters is shown in Table 2. Relative humidity upto 45% and wind speed upto 0.9% are most favourable conditions responsible for having high concentrations of air pollutants during winter season (Bloomer *et al*., 2010) and Table 2 showed similar results. From Table 1, it has been clearly depicted that the average concentration of photochemical pollutant i.e. benzene in both the winter months were found to be higher at Site I as compared to Site II. This is because Site I is near to traffic intersection, petrol pump, commercial and industrial with high peak volume of traffic which ultimately resulted in high emissions from gasoline exhaust whereas Site II is away from traffic intersection so there very less chances for the production of air pollutants. Moreover, Site I is surrounded by various eating points and hospital nearby which attracts commuters causing formation of large queues, leading to idling of vehicles, which further added to the exhaust load. In addition to that, neither hospital nor the market complex have adequate parking space which leads to overcrowding and congestion of the roads, shoppers and other pedestrians crossing the main road further slows down the traffic on the main road and thus more idling and slowing down of vehicles leads to higher pollution emission at that site. During idling and deceleration, exhaust of motor vehicles contains high amounts of unburnt hydrocarbons, (i.e., 500-1000 and 3000-12,000 ppmv respectively) in comparison to acceleration and cruising phases (50-800 and 200-800 ppmv respectively) (Tamsanya and Chungpaibulpatana, 2009). From the above observation, it was found that, Site I has high traffic pollution whereas Site II had very less concentrations of photochemical pollutants which make this site somewhat equivalent to control site.

Table 2. Variation in Meteorological Parameters at different sites during winter months i.e. Oct - Nov, 2012.

S.N.	Parameters	Site I	Site II
1.	Ambient temperature (^{o}C)	14.94 – 20.87	13.45 – 21.18
2.	Relative Humidity (%)	38.76 – 43.39	37.43 – 42.13
3.	Wind Speed (km/hr)	0.13 – 0.42	0.16 – 0.53
4.	Solar radiation (W/M^2)	125.00 – 134.76	126.76 – 130.87

Site I (Traffic intersection) Site II (Institutional and Residential area)

For the present study, benzene was selected. The criteria of selection of this pollutant was that, benzene is the most carcinogenic compound in nature among BTEX according to Lee et al., 2002. The average concentrations of benzene was estimated in the range of 250.04 ± 2.95 µg/m^3 in the month of October, whereas in November month, the estimated average concentrations of benzene was 1685.21±2.62 µg/m^3 (Table 1). Site II which is institutional and residential and about 500m away from the nearest main road, exhibited estimated average benzene concentration in the range of 2.32 ±0.23 µg/m^3 whereas in November, concentration of benzene was observed in the range of 4.31 ±0.34 µg/m^3 (Table 1). The pollution variability was high during November month as compared to October, irrespective of the sites due to the fact that November is colder month than October. Higher winter concentration was probably related to increased atmospheric stability, thermal inversion and poor dispersion condition (Lal, 2010).

For improving the air quality, certain measures were adopted, but the most cost-effective way of decreasing the concentration of air pollutants in the atmosphere, certain plant species were recommended which are having the quality of absorbing toxic pollutants from air and help in the reduction of pollutants in the atmosphere. Therefore, in the present study, after discussing the trend of benzene pollution at selected sites, two plant species namely, Dracaena deremensis and Chamaedorea Seifrizii which are according to literature reported (NASA Clean Air Study, 2010) the most benzene absorbing species were selected and analyzed for Air Pollution

Tolerance Index (APTI) at both the sites. No visible injury due to pollution impact was identified at Site I. A comparison of Site I & II Table 3(b) showed that all the parameters (total chlorophyll, ascorbic acid, pH and relative water content) were declined in Chamaedorea Seifrizii registered a declining trend at Site I (traffic intersection) as compared to Site II (institutional and residential). On the other hand, Dracaena deremensis remained unaffected at both the sites. In case of Dracaena deremensis, there was no significant difference found in chlorophyll and pH content while high ascorbic acid activity and RWC was observed at Site I as compared to Site II Table 3 (a). When the plant is exposed to any external stress e.g. ozone stress then its uptake occurs through leaf stomata. Once penetrated in the leaf apoplast, O_3 is rapidly converted to ROS (reactive oxygen species) like O_2, H_2O_2, peroxyl radical, and other active O_2 species which are toxic in nature and can oxidize -SH groups of proteins and cause lipid oxidation and/or peroxidation (Hippeli and Elstner, 1996), decrease the amounts of Rubisco and inhibit photosynthetic activity (Hoigné and Bader, 1976).

Table 3a. Variation in biochemical parameters and APTI values in *Dracaena deremensis* at Site I and Site II during winter months (Oct-Nov'10).

Parameters	Unit	Site I (Polluted)	Site II (Less polluted)
Chlorophyll (Chl)	mg/g f.w.	8.36 ± 0.89[a]	7.13 ± 0.12[a]
Ascorbic Acid (AA)	mg/m^3	67.88 ± 1.99[a]	40.54 ± 3.99[b]
pH (pH)	-	6.9 ± 3.33[a]	6.2 ± 1.13[a]
Relative Water Content (RWC)	%	63.98 ± 2.41[b]	49.23 ± 1.72[a]
APTI	-	54.76 ± 0.32[a]	52.99 ± 0.78[a]

Table 3b. Variation in biochemical parameters and APTI values in *Chamaedorea Seifrizii* at Site I and Site II during winter months (Oct-Nov'10) .

Parameters	Unit	Site I (Polluted)	Site II (Less polluted)
Chlorophyll (Chl)	mg/g f.w.	2.64 ± 1.24[b]	4.22 ± 0.14[a]
Ascorbic Acid (AA)	mg/m^3	18.04 ± 2.38[a]	16.97 ± 1.23[a]
pH (pH)	-	4.10 ± 2.10[b]	6.01 ± 1.17[a]
Relative Water Content (RWC)	%	27.02 ± 0.84[a]	25.71 ± 1.15[a]
APTI	-	9.33 ± 0.33[b]	20.56 ± 0.54[a]

Note: Each value represents mean of 13 replicates ± standard error. Data followed by different letters in a row are significantly different at P≤0.05. Data followed by same letters in a row are non-significant at P≤0.05.

Thus, those plants which are having high ascorbic acid activity can prevent the production of ROS by scavenging H_2O_2 (Mehler, 1951). Also, it is a strong reductant and high amounts of this substance favours pollution tolerance in plants (Keller and Schwager,1977; Lee, 1985). The level of this acid declines on pollutant exposure (Keller and Schwager,1977). Thus, plants maintaining high ascorbic acid level even under polluted conditions are considered to be tolerant to air pollutants. Ascorbic acid, through its reducing power, protects chloroplasts against SO_2^-induced H_2O_2, O_2^- and OH accumulation, and thus protects the enzymes of the CO_2 fixation cycle and chlorophyll from inactivation (Tanaka et al., 1982). Together with leaf pH, it plays a significant role in determining the SO_2-sensitivity of plants (Chaudhary and Rao,1977; Rao, 1983). Its reducing power is more at higher and less at lower pH values (Seyyednjad, 2011). Thus, it may be possible that ascorbic acid protects chloroplasts and chlorophyll functions from pollutants through its pH-dependent reducing power.In case of total chlorophyll, decline in chlorophyll content has been observed in Chamaedorea Seifrizii but not in Dracaena deremensis. Kuddus et al., 2011 suggested that tolerance of plants to any of the pollutant may be linked with synthesis or degradation of chlorophyll and those having high chlorophyll content under field conditions are generally tolerant to air pollutants. A considerable loss in total chlorophyll in the leaves of plants of Chamaedorea Seifrizii at Site I supports the argument that chloroplast is the primary site of attack by air pollutants such as SPM, SO_2 and NO_X, O_3 (Tripathi and Gautam, 2007). Air pollutants enter into the tissues through the stomata and cause partial denaturation of the chloroplast and decrease pigment contents in the cells of polluted leaves. Thus, for example, Rao and Leblanc, 1966 mentioned that high amount of gaseous SO_2 causes destruction of chlorophyll and that might be due to the replacement of Mg^{+2} by two hydrogen atoms and degradation of chlorophyll molecules to phaeophytin. No significant change was observed in pH in case of Draceana deremensis (Table 4 (a)), at both the sites. Moreover, the pH in Draceana deremensis, was reported to be more than Six, whereas, in Chamaedorea it was four at Site I. In the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in sensitive than in tolerant plants (Joshi et al., 2009). The change in leaf extract pH might influence the stomatal sensitivity due to air pollution. Saxena et al., 2011, observed that pH on the higher side could provide tolerance in plants against pollutants. Thus, a higher level of leaf-extract pH under polluted conditions increase the tolerance ability of Draceana deremensis whereas, Chamaedorea Seifrizii with less pH came out to be sensitive towards pollutant stress. In case of Relative Water Content, significant difference has been observed at Site I & II in case of Dracaena while no significant change has been recorded in Chamaedorea at both the sites (Table 4(a &b)). Moreover the value of RWC was found to be higher in case of Dracaena as compared to Chamaedorea at both the sites. High water content within a plant body helps to maintain its physiological balance under stress conditions such as exposure to air pollution. High RWC favours drought resistance in plants. Due to air pollution, there is reduction in transpiration rate due to damage caused to the leaf engine that pulls water up from the roots (1-2% of the total); consequently, the plants neither bring minerals from the roots to the leaf where biosynthesis occurs nor cools the leaf (Swami et al., 2004). Moreover, RWC is associated with protoplasmic permeability, more so in the case of sensitive species (Oliver et al., 2011). Air pollutants increase cell permeability (Xu et al., 2009). Pollutant induced increased permeability in cells causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Houimli et al., 2010). It is likely, therefore, that plants with high RWC under polluted conditions may be tolerant to pollutants.

As per the present study, Dracaena deremensis came out to be the tolerant species at both the sites while Chamaedorea Seifrizii was under sensitive range at polluted site (Site I) and comes under intermediate range at unpolluted site (Site II). Sulistijorini, 2008 found the similar result, where the APTI values in plants were less in polluted site as compared to unpolluted site, though the difference in APTI values were not significant. Plants growing in air Polluted environment often responded and showed significant changes in their morphology, physiology and biochemistry (Karthiyayini et al., 2005). These plants can be effectively used as bioindicators of the air pollutants. Although the sensitivity to air pollutants varies across the plant community with some being ‘tolerant’ showing no or minimal symptoms and other being ‘Sensitive’ that shows symptom even if the air pollutants increases in small amounts (Priyanka and dibyendu, 2009). Similar responses was observed in our study where Tolerant species (Dracaena deremensis) didn’t respond significantly to the changing environment condition and sensitive species (Chamaedorea Seifrizii) responded to even minute changes in the environment of both the selected sites. Thus, the APTI value of a particular geographic area can be used for biomonitoring of that area. The APTI value represented in Table 4 (a&b), shows that amongst the selected plant species, Dracaena deremensis had a higher APTI value, and was most tolerant at all the sites throughout the study period on the other hand Chamaedorea Seifrizii with least APTI value was sensitive and came under sensitive range at polluted site (Site I) whereas intermediate at unpolluted (Site II) during the study period. The plants have the potential to serve as excellent quantitative and qualitative index of pollution since biomonitoring of plants is an important tool to evaluate the impact of air pollution on plants (Sadeghian and Mortazaienezhad, 2012). Thus, Dracaena deremensis was tolerant at selected sites and according to literature reported (NASA Clean Air Study, 2010) good absorbers of benzene in air whereas Chamaedorea Seifrizii act as bioindicator.

CONCLUSION

From the present study it has been concluded that, the concentration of benzene was higher at those areas which are at or near to traffic intersection and also the petrol refueling stations nearby were proved to be major reason for the increment in the value of benzene in air. Moreover, for improving the quality of air in the atmosphere two plant species were selected and Dracaena dermenisis was found to be under tolerant category both and and good absorbers of benzene in air whereas Chamaedorea Seifrizii was found to be sensitive and serve as bioindicator..

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