AMBIENT AIR QUALITY AND THE AIR POLLUTION TOLERANCE INDICES OF SOME COMMON PLANT SPECIES OF ANAND CITY, GUJARAT, INDIA

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Abstract: The present study was performed to measure the air pollution status of Anand City and its impact on the prevalent vegetation in the urban habitat. SPM, Sox and NOx were measured using HVAS in the dry season. Ten sampling sites with one control site were chosen as sampling site based on the traffic density. Concentration of NOx, SOx and SPM varied between 0.74 ug/m^3 to18.52 ug/m^{3,} 1.09 ug/m^3 to 8.13 ug/m^3 and 148.68 ug/m^3 to 1959.57 ug/m^3 respectively Only SPM was observed above the standard limits. The concentration of air pollution parameters however indicated nonsignificant variation among different sites as per two way ANOVA at 0.05 level of significance. NOx was higher in the trafficked, commercial areas. However SOx and SPM were recorded more in the heavily trafficked area. The positive correlation found between Sox, NOx and SPM also suggests likely same source for these parameters. For APTI calculation four parameters of plant leaf viz. pH, moisture content, chlorophyll and ascorbic acid were analysed for all the three species commonly found in the 11 sampling sites. Species were *Polyalthia longifolia, Peltophorum pterocarpum, Azadirachta* Higher APTI was observed in *Polyalthia longifolia* (6.57-10.22)*,* followed by *Peltophorum pterocarpum* (6.81-8.43) and *Azadirachta indica* (6.01-7.59). So it can be concluded that *Polyalthia longifolia* is a more tolerant species than the other two species.

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Introduction

In today's world air pollution does not need any introduction. Pollution is invariably associated with environmental degradation. There does not seem to be any life form not affected by air pollution. Definition says "Any abnormal increases or decrease in the concentration of the normal components of atmosphere is known as air pollution" (Mudakavi, 2010). Due to increasing number of industries, vehicular exhaust and decreasing plant cover coping with the increasing human population, ambient air is becoming heavily polluted day by day. Air pollution has detrimental effect on nearly all phases of our lives including health effects like eye irritation, Skin irritation, headache, sneezing, coughing, suffocation, chest pain, breathing problems etc and welfare effects on vegetation, soil, water, manmade materials, climate, and visibility.

In plants air pollutants lead to stunted growth, altered biochemical compositions and less productivity (Chakraborty et. al. 2009). It also imparts leaf injury and causes change in stomatal movements and thus the rate of photosynthesis . The adverse effects of air pollutants on plant can be studied by calculating an index known as Air pollution tolerance index (APTI). Its calculation is based on four parameters viz. chlorophyll, Ascorbic acid, pH, Relative water content. Since the sensitivity and response of different plants to air pollutants are variable, the identification and categorization of plants into sensitive and tolerant groups is important because the former can serve as indicators and the latter as sinks for the abatement of air pollution in urban and industrial habitats (Singh et. al. 1991). The plant species which are more sensitive act as biological indicators of air pollution. This is a useful tool to understand the response of plants to air pollution at physiological and biochemical levels by analyzing the possibility of synergistic action of pollutants (Lakshmi *et al*., 2009). Air pollution tolerance index (APTI) is used by landscapers to select plant species tolerance to air pollution (Agbarie, 2009). By using the data obtained from detailed biochemical estimations of plant samples (including chlorophyll, ascorbic acid, pH and relative water content), APTI. Till now there are no published data on the ambient air quality status of Anand city as well as the APTI values of the plants growing in this area. So the main objective of the current study was to find out the ambient air quality as well as APTI. The present study owes its significance to the fact that this site has a semi arid to arid climate which fosters the transfer of huge amount of suspended particulate matter into the lower levels of the atmosphere in the dry seasons. The vehicular pollution is also growing at an alarming rate. The city's industrial belt (Gujarat Industrial Development Corporation) consisting of chemical, dyes, paints, and engineering equipment manufacturing industries also contributes to atmospheric pollution (Bhattacharya et. al. 2011).

Material and methods

Study area

Anand a small town of Gujarat, located at 22º34′N72 º 56′E22.5 ºN72.93 ºE It has an average elevation of 39 meters (127 feet).City has an area of 22.7 square kilometers .Urban area of the Anand city is 172 square kilometers including 25 villages around the city. During last few years Anand city had rapid urbanization as well as industrialization. As a result both private and mass transportation vehicles are also increasing day by day.

Apart from the control site ten sampling locations were chosen on the basis that the sampling station was in the free atmosphere that is without interferences from stagnant spaces and large buildings (figure 1). The sampler was located 1.5 meter above the ground. Description of the sites is given below.

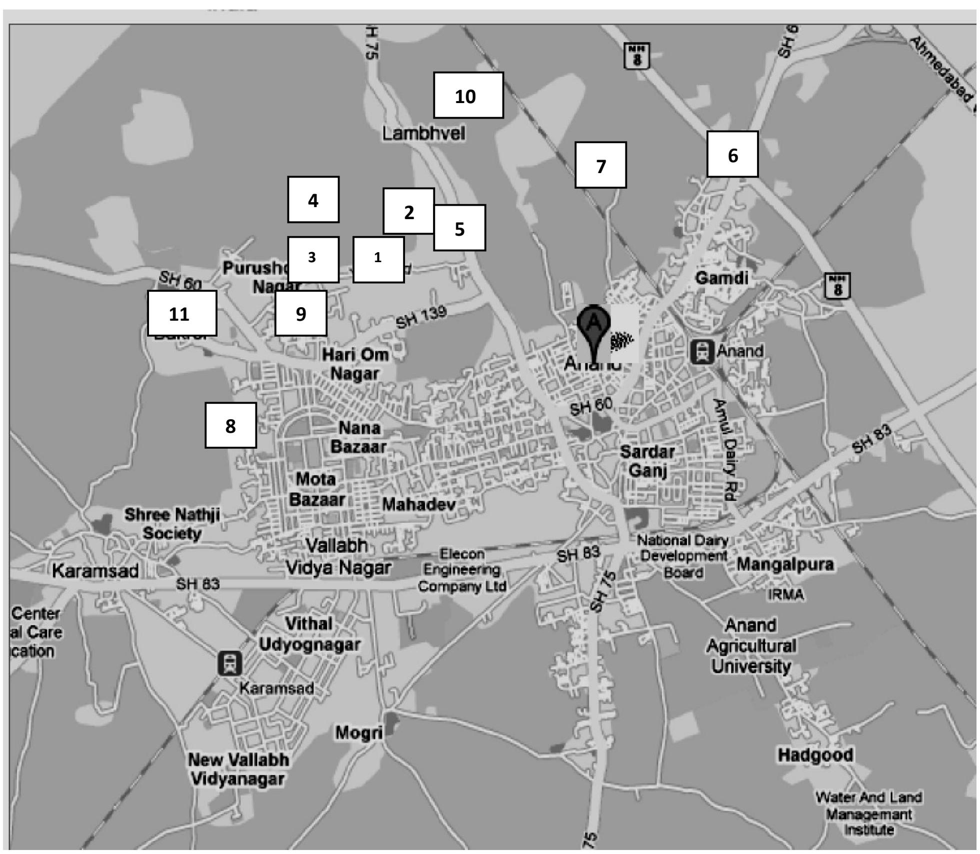

Fig. 1. Sampling stations in the study area of Anand city

Site1:- CONTROL (ENVIRONMENTAL LAB ISTAR)
This area is environmental lab of ISTAR. This area is having very low vehicular pollution and having good greenery nearby so this site is selected as the control site.
Site 2:- NANA BAZAAR
This area is residential and commercial area. In this area some of the hostels and residential complexes and some commercial complexes are present. This is medium trafficked area.
Site 3:- MOTA BAZAAR
This is the central area of Vidyanagar with several institutions, hostels and commercial joints. This area is heavily trafficked
Site 4:- UNIVERSITY CIRCLE
This area is near the Sardar Patel University so called as university circle. Some of the colleges, university departments, student hostels and residential areas are present in this area. This area also has medium traffic.
Site 5:- A-V ROAD
This road connects Anand and Vidhyanagar This road is about 1.5 kms long. Along this road there are several commercial complexes and residential complexes. Heavy traffic prevails on the road.
Site 6:- RAILWAY STATION
This area is having very heavy traffic due to presence railway station and Amul Dairy.
Site 7:- BUS SATND
This road is about 1 km long and it covers bus stand, a petrol pump and some collages. This road is rushed with buses and auto rickshaws for whole day. This road is considered as heavy traffic road.
Site 8:- NEW VIDYANAGAR
This area is on the other side of GIDC. In this area mostly collages and hostels are present. This area is away from the city area so less no of vehicles passes and this area also have good greenery.
Site 9:- JANATA CHOKDI
This area is near by the GIDC area and connects the highway. Most of the industries are small scale and few are large scale industries. The industries comprises of paints, electrical, engineering instruments, fertilizer, metal processing etc. this road has a heavy traffic load.
Site 10:- LAMBHEL ROAD
This road is about 3-4 kms long. This road joins Anand with Nadiad. This area has medium traffic load and both sides of the road is covered with trees.
Site 11:- KARAMSAD ROAD
This area connects Vidyanagar and Karamsad. This area mostly consists of residential complexes, societies and come of the hostels. The source of air pollution in this area is vehicles.

Sampling Period and Time

The sampling has been done in 3 phases. First phase sampling has been done in the month of December , second in January and third in February. The data represented in the result section is average of three sampling. The sampling was done for 4 hours during the day time, with a flow rate of one liter per minute by high volume air sampler (Model no. HNS: HVS: 21).

Air pollutant sampling and measurement

Suspended particulate matter was sampled by HVAS and estimated by gravimetric method (Singh et al, 1991). Particulates were filtered as deposit on a porous filter paper from known volume of air sample by HVAS. Fiber glass filters without any visible defects such as pinholes, deposits, and other imperfections were employed. The filter was equilibrated in the dessicator for 24hrs and weighed to the nearest milligrams before fixing it on the face plate of the filter holder. The weight of material deposited was found, while the volume of air sampled was computed from the flow rate and duration of sampling.
SOx was estimated by West-Geake method by using sodium tetra-chloromercurate as absorbing medium and NOx was estimated by Jacob and Hochheiser method using sodium hydroxide as absorbing media.

Plant parts sampling, preparation and analysis

For APTI leaf samples were collected from three common plant species found in all the sampling sites viz. *Polyalthia longifolia, Peltophorum pterocarpum***,** and *Azadirachta indica.* Polythene bags were used for storing leaf samples during transportation. The leaf samples were refrigerated at about 0^0 C, when they had to be stored. The samples were estimated for Leaf-extract pH (Singh et al. 1983), relative moisture content (Wealtherly, 1965), total chlorophyll (Arnon, 1949) and ascorbic acid (Keller and Schwanger, 1977).

Estimation of Leaf-extract pH

0.5 g of leaf material was ground to paste and dissolved in 50 ml of deionized water and Leaf-extract pH was measured by using calibrated digital pH meter (model).

Estimation of relative moisture content

Fresh leaf samples collected from the study area were brought immediately to the laboratory and washed thoroughly. The excess water was removed with the help of blotting paper. The initial weight of samples were taken (W1 g) and kept in oven at 60^oC until constant weight was obtained and the final weight was taken (W2 g).

Estimation of Total Chlorophyll and Ascorbic acid

Acetone extraction method (Arnon 1949) and ascorbic acid was estimated by 2,6-dichlorophenol indophenol's dye method.

Statistical analysis

Correlation and ANOVA was performed using Excel Statistical analysis tool pack, 2007.

APTI given by APTI = {[A (T + P) + R] / 10}.Where A is the ascorbic acid in mg/g; T is the total chlorophyll in mg/g; P is pH of leaf sample; and R is relative water content (RWC) of leaf (%).

Result

Air pollutants

The results obtained after the analysis of three major air pollutants namely SO_X, NO_X, and Suspended Particulate matter (SPM) are given in Table 1. The values represented in the table are the average values of three phases of sampling. Concentration of NOx ranged from 0.74 ug/m^3 to 18.52 ug/m^3 at the sampling sites. However, the concentration of NOx at control site was much lower (0.02 $\mu g/m^3$). The maximum concentration of NOx was observed at site 2, i.e. at Nana Bazaar and minimum concentration of NOx is at site 11, i.e. at Karamsad road. But the maximum and minimum SOx concentration was recorded at Railway station (8.13$\mu g/m^3$) and in Karamsad road (1.09$\mu g/m^3$) respectively. Apart from the control site minimum SPM concentration was again in Karamsad Road, 165.17$\mu g/m^3$ and maximum in Janta Chokdi, 1959.57$\mu g/m^3$. The SPM load was quite high in site 2, 4, 6, 9 and 10. Two factor ANOVA was performed on the data and it was found that there is no significant variation in NOx, SOx and SPM level of the different sites at 0.05 level of significance.

When the three pollutants were correlated the correlation co-efficient was found positive between SPM-SOx (r=0.776), SPM –NOx (r=0.673 and also between SOx-NOx (r=0.41) signifying same pollution source, which may be vehicular emissions, The meteorological condition during the sampling period was as follows. The wind speed at all the sites was mostly calm or light air and only in Lambhel road the wind speed was gentle breeze according to Beaufort scale. The range of wind speed was 1 to 9.34 Km/hr. Relative humidity was less as the study period was during the dry winter months. It ranged from 35% to 58%. The temperature during sampling ranged between 23.5^{0}C and31^{0}C.

APTI

For APTI calculation four parameters of plant leaf viz. pH, moisture content, chlorophyll and ascorbic acid were analysed for all the three species commonly found in the 11 sampling sites. The results obtained are shown in Figure1 to Figure 4. The pH of the leaves of three species at control site was almost neutral. However, at the other sites pH was mostly acidic. Species wise variation of pH was not much. For *Polyalthia longifolia* the pH value ranged from 5.4 to 6.3 at polluted sites, whereas for *Azadirachta indica* and *Peltophorum pterocarpum* the range was from 5.8 to 7 and 5.4 to 6.8 respectively. In the control site the pH was nearly neutral whereas in the other sites it was found to be slightly acidic in all the three species (Figure 2). The maximum shift of pH of plant leaves towards acidic side from the control site to the polluted site was 15.7% in *Polyalthia longifolia* 10.8% in *Azadirachta indica* and 6.9% in *Peltophorum pterocarpum*. Chlorophyll concentration was relatively higher in all the species in the control site compared to few the other instances. Total chlorophyll content was higher in the relatively polluted sites. For *Polyalthia longifolia* it was 1.6 mg/g in control site and in other sites it ranged from 0.98 to 1.5mg/g. whereas, in *Azadirachta indica* the total chlorophyll concentration in control site was 1.05 mg/g and in other sites it ranged from 0.7 to 1.14 mg/g. In *Peltophorum pterocarpum* leaves total chlorophyll was 1.06 mg/g in control site and in other sites the range was 0.78-1.11 mg/g (Figure 4). Relative water content in *Polyalthia longifolia, Azadirachta indica* and *Peltophorum pterocarpum* of control site was 69%, 57% and 66%. While in the other sites it ranged from 60-78%, 53-70% and 59-76% in the three species respectively (Figure 3). Similarly, ascorbic acid content in leaves of the three species were, 0.46, 0.58 and 1.23 mg/g in control site and ranged as 0.491-4.00 mg/g, 0.302-2.88 mg/g and 1.6-3.96 mg/g in other sites respectively(Figure 5). Relative water content in the plant leaves of the three species was mostly high in the polluted sites than in the control site. Similarly, ascorbic acid content in plant leaves were found higher in most of the polluted sites than the control sites and only site 11 showed lower ascorbic acid content in *Azadirachta indica* and *Peltophorum pterocarpum* than the control site.

APTI calculated for the three species studied was comparatively higher in most of the studied sites than the control site. Higher APTI was observed in *Polyalthia longifolia* (6.57-10.22), followed by *Peltophorum pterocarpum* (6.81-8.43) and *Azadirachta indica* (6.01-7.59).

Discussion

Air pollution status

The control site was found unpolluted in terms of NOx, SOx and SPM concentration. The values of all the three air pollutants were lowest at this site. But in the other sites the order of concentration of the three pollutants varied, but sitewise variation of the pollutants were found non-significant by two way ANOVA at α=0.05. However, the single factor ANOVA showed that the variation among the air pollutant concentration was significant at the 0.05 level of significance. The order of sitewise concentration of NOx was:

2>7>3>4>6>5>10>8>9>11. Apart from vehicular emission the reason behind the high NOx concentration at site 2, which is a residential area along with some commercial complexes was may be the burning of wood and coal and other fuels for cooking purpose, by the construction workers at a nearby construction site, and presence of few road side open restaurants in that area. So we can say that it was due to sampling error or due to biased sampling NOx value found higher. Site 7 is bus stand and ample number of heavy vehicles including diesel and gasoline vehicles passes throughout the day, so the site has higher NOx value. Site 3 and 4 are mainly areas with large number of roadside open restaurants and high number of vehicles causing relatively higher NOx value. It is well known that use of LPG gas for cooking purpose emits higher amount of NOx (Delucchi, 1998). However, the NOx value obtained in all the sites are below the National Ambient Air Quality Standard (NAAQS) given by CPCB (2010), which is 80 $\mu g/m^3$. NOx concentration in different cities of Gujarat viz. Gandhinagar, Mehsana, Sabarkantha, Banaskantha, Narol, Surat and Ankleshwar were reported up to 32.47 $\mu g/m^3$, 20 $\mu g/m^3$, 28.66 $\mu g/m^3$, 16.95 $\mu g/m^3$, 19.1 $\mu g/m^3$, 25.12 $\mu g/m^3$ and 23.31 $\mu g/m^3$ respectively. So, compared to other cities of Gujarat the value of NOx in Anand was found quite less (GPCB report, 2010).

The SOx concentration in the sampling sites apart from control site decreased in the order:

6>9>4>5>2>8>10>7>3>11. Site 6 is railway station which has more number of heavy vehicles so due to vehicular emissions the concentration of Sulfur dioxide was high. Site 9 is also an important transportation junction with large numbers of vehicle passing throughout the day. It also has number of fuel filling stations and an industrial area nearby. Site 4 is institutional area with few commercial joints and site 5 is mainly commercial area.in both the sites substantial number of vehicles passes throughout the day. So, it can be inferred that vehicular pollution can be the main source of SOx pollution in these areas. The SO_2 concentration is pretty low in Anand city and within the NAAQS limits, which is 80 $\mu g/m^3$. The value of SOx found in Anand city is quite less than the other cities. The SOx value reported by GPCB in some of the cities of Gujarat is as follows Gandhinagar 12.5 $\mu g/m^3$, Vatva Ahmedabad 29.16 $\mu g/m^3$, Bhavnagar 13.92 $\mu g/m^3$ and Surat 29.59 $\mu g/m^3$.

Comparison of the obtained value of NOx and SOx with the metro cities of India reveal that Anand was much less polluted. As the reported values for NOx in Delhi are 140 µg/m3, Mumbai is 206 $\mu g/m^3$ and Chennai is 44 $\mu g/m^3$. And the reported values for SOx in Delhi are 14 µg/m3, Mumbai is 70 µg/m3 and Chennai is 14 µg/m3 (CPCB, 2010).

The order of SPM concentration in different sites was as follows: 9>4>6>2>7>10>3>5>11>8. Highest SPM load was in Janta Chokdi (Site 9). This site is a main transportation junction connecting several villages nearby so vehicular emissions and number of vehicle passing through this area is quite high. Several heavy engineering and small scale industries are also present in this area. Moreover it contains several commercial center and vegetable markets. The high SPM load in university circle was due to mainly for vehicular emissions during the day time and exhaust from several mini-canteens present in this area. Site 6 is railway station where vehicle load is quite high resulting high SPM values. Site 2 is NanaBazar, where, as mentioned earlier construction work is going on and commercial activities are also present contributing to high SPM load. Except the control site, SPM value was high in all the sites as per the NAAQS value of 100 $\mu g/m^3$. Low relative humidity and semi-arid climate is also another cause of high SPM load in this region.

APTI

Two way ANOVA showed that the variation in pH of plant leaves of different sites was significant at 0.05 level of significance ($F=3.49$, $F_{crit}=2.35$). Acidic pH found in the leaves can be due to synthesis of high amount of ascorbic acid for stress tolerance or may be due to the presence of SOx, NOx in the ambient air causing a change in a pH of the leaf sap towards acidic side (Swami et al, 2004). However, total chlorophyll content of different species varied significantly as showed by two way ANOVA at 0.05 level of significance ($F=16.98$). Maximum reduction in total chlorophyll concentration was observed in *Polyalthia longifolia* (35%), and minimum in *Peltophorum pterocarpum* (26%). *Azadirachta indica* showed a chlorophyll decrease of 33%. Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. It is well evident that chlorophyll content of plants varies according to species, age of leaf and pollution level as well as due to several biotic and abiotic conditions (Katiyar and Dubey, 2001) and degradation of photosynthetic pigment has been widely used as an indication of air pollution (Ninave et al., 2001). Chlorophyll content also varies with the tolerance as well as sensitivity of the plant species i.e. higher the sensitive nature of the plant species lower the chlorophyll content. Studies (Mir et al., 2008; Tripathi et al. 2007) also suggest that high levels of automobile pollution decreases chlorophyll content in higher plants near roadsides.

Lalman and Singh (1990) concluded that the SO_2 fumigated plants undergo several reversible and irreversible physiological and biochemical changes as reflected by foliar injury reduced leaf area and biomass. Decreased photosynthetic activity and poor plant growth apparently reduced the dry matter and yield. SPM decreases the chlorophyll and dry matter production (Mandloi et al., 1988: Rao et al. 1988: Katiyar et al., 2000). Low NO_2 dose is also believed to be toxic or inhibitory to some plant species.

Relative Water Content increased by maximum 11.54% in *Polyalthia longifolia*, 18.57% in *Azadirachta indica* and by 13.15% in *Peltophorum pterocarpum* with respect to the control sites plants. Probable explanation to this is the fact that high water content in a plant body help to maintain its physiological balance under air pollution stress condition (Dedio 1975). High relative water content favors resistance in plants so the RWC was found higher in the polluted site plant leaves. According to two-way ANOVA RWC variation site-wise (F=7.84) as well as species wise (F=16.16) were significant at 0.05 level of significance.

Ascorbic acid content in the plant leaves was higher in the relatively more polluted site. The highest increase in ascorbic acid content in the polluted site was 88.5% in *Polyalthia longifolia,* 79.8% in *Azadirachta indica* and 68.9 % in *Peltophorum pterocarpum* compared to the control site plant leaves. Reason may be attributed to the role of Ascorbic acid as a strong reductant and stimulator of many physiological and defence mechanism. Its reducing power is directly proportional to its concentration (Raza et al., 1988, Chen et al., 1990). However, its reducing activity is pH dependant, being more at higher pH levels. Ascorbic acid content in the plant leaves was higher in the relatively more polluted site. Two way ANOVA also suggested that the variation sitewise or specieswise was quite significant at 0.05 level of significance and the F-values were 2.88 and 34.69 respectively.

Based on the above four parameters the APTI values signified that plants growing in the polluted sites have higher APTI value indicating more tolerance. Variation of APTI within the different sites (F=5.27) and within the species (F=13.37) was significant as indicated by analysis of variance at 0.05 level of significance. However all the plants behaved as sensitive towards air pollution since all the APTI values found were below 16 but above 1. This is with reference to the APTI value response given by Lakshmi et al.2009, which indicates that APTI < than 1 is very sensitive, 1-16 is sensitive, 17-29 intermediate, 30-100 tolerant. Similar findings were reported for *Polyalthia longifolia* by Jyothi et al, 2010 (APTI=13.59); Sharma et al. 2010 (APTI=13.28), Chauhan, 2010 (APTI=7.01to5.57). However, APTI values found in the present study for *Azadirachta indica* was less than the previous reported studies of Tripathi et.al, 2009 (APTI=30.5), Adamsab et al.2011 , (APTI=37.74) and Abida et al. , 2010 (APTI= 19.68 to 35.68); Kuddus et al.,2011 (APTI=12.29).

Table 1. Average concentration of air pollutants and some meteorological parameters during study period in the study area:

Site Code	NO_x	SO_x	SPM	Wind Speed	Relative humidity	Temperature
	µg/m^3	µg/m^3	µg/m^3	Km/hr	%	^{0}C
1	0.22	0.02	29.00	2.60	46	28
2	8.52	2.39	1099.44	1.20	44	25
3	5.62	1.45	388.15	2.0	34	23.5
4	5.94	5.30	1541.81	2.38	36	25
5	4.15	3.44	200.51	6.40	42	27.5
6	4.86	8.13	1174.00	4.25	35	24.5
7	8.35	1.64	813.71	9.10	35	28.5
8	1.53	2.23	148.68	1.00	43	29
9	6.93	7.62	1959.57	4.18	38	29
10	2.10	1.62	773.52	9.34	39	30
11	0.74	1.09	165.17	1.40	39	31
Two way ANOVA α=0.05 Between different pollutants Fvalue=15.84, Fcrit=3.49 For Site-wise variation, F=1.01, Fcrit=2.34						

Table 2: APTI of the three plant species at the different sites.

Site code	*Polyalthia longifolia*	*Azadirachta indica*	*Peltophorum pterocarpum*
1	7.30	6.50	7.45
2	8.04	6.06	6.81
3	7.61	7.19	8.25
4	7.76	7.36	8.07
5	7.54	7.16	8.37
6	10.22	7.53	8.43
7	8.31	6.41	7.29
8	6.64	6.13	6.66
9	10.15	7.74	8.26
10	7.88	6.01	7.24
11	6.57	6.49	6.78
Two way ANOVA α=0.05 Within the species F=13.37,Fcrit=2.34 between the sites, F=5.27, Fcrit=3.49			

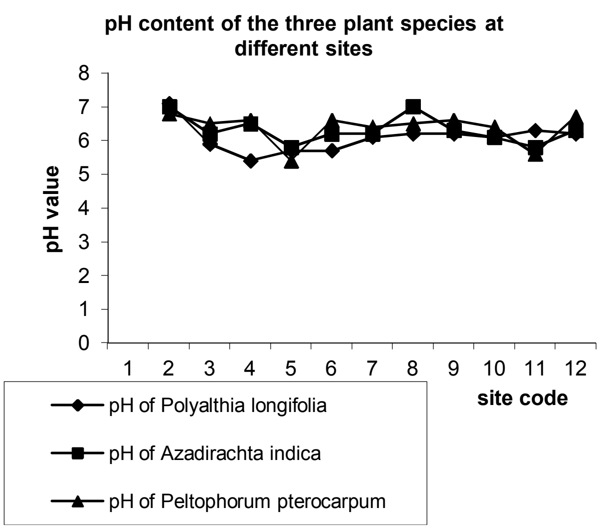

Figure 2. pH content of the three plant species at different site.

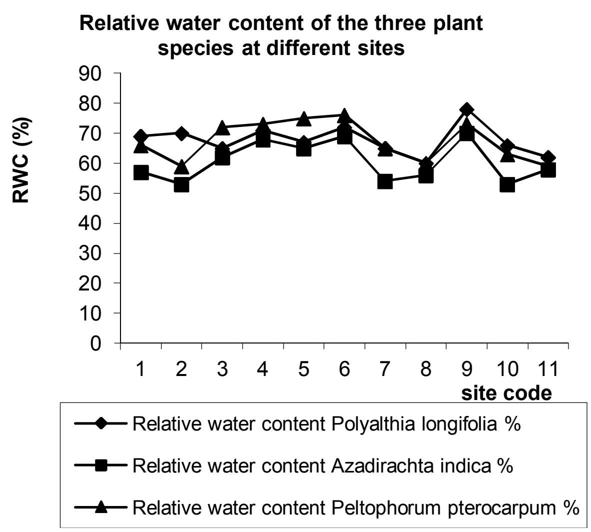

Figure 3. RWC of the three plants at different site.

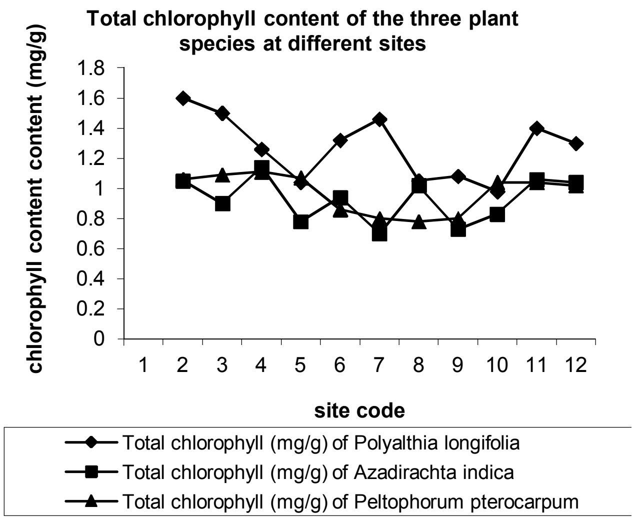

Figure 4. Total chlorophyll of the three plants species at different site.

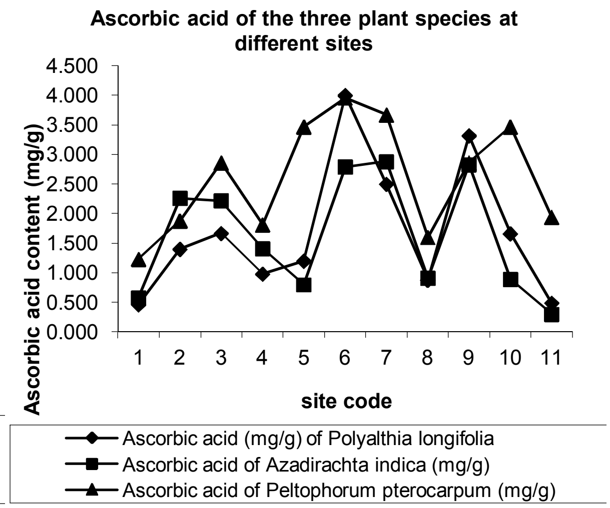

Figure 5. Ascorbic acid content of the three plant species at different site.

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Short title: Ambient air quality and APTI of Anand city

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