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Department of Botany, University of Karachi, Karachi, Pakistan

Biomonitoring of heavy metal contamination in *Pongamia pinnata* and *Peltophorum pterocarpum* growing in the polluted environment of Karachi, Pakistan

Muhammad Shafiq, Muhammad Zafar Iqbal, M. Saeed Arayne, Mohammad Athar*

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Summary

Determination of some of the important heavy metals like lead and cadmium was carried out in the city environment of Karachi. Foliage parts of two roadside trees, *Pongamia pinnata* (L.) Merrill and *Peltophorum pterocarpum* D.C. Backer ex K. were used to carry out such investigation. Five roadside points were selected for the study in different parts of the city. The investigations showed that high level of lead and cadmium was found in the foliage of *P. pinnata* and *P. pterocarpum*, which were growing along the busy roads of the city. The level of Pb and Cd in the foliage of the above mentioned trees was quite high at M.A. Jinnah road as compared to Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus. Low traffic activities at the University Campus showed lowest lead and cadmium levels in the foliage of both tree species than the other point of the city. In this study, *P. pinnata* showed more accumulations of lead and cadmium than *P. pterocarpum*. This difference might be due to large surface area of the foliage in *P. pinnata* that is available for exposure to any pollutants as compared to *P. pterocarpum*. *P. pinnata* is a useful plant species in removing different heavy metals from the urban environment of the city. It is therefore suggested, that *P. pinnata* should be given more preference for future plantation in the areas, particularly along the busy roads and highways.

Introduction

In recent year's concern over the air pollution problem has increased tremendously in the wake of population explosion, industrialization, urbanization, transportation and other human activities (SHAH et al., 2004). Trace elements are known to be essential for all plants. A feature of the physiology of these elements is that although many are essential for growth, they can also have toxic effects on cells at higher concentration (BERBER et al., 2010). Contamination of vegetation by airborne trace metals is particularly massive in urban areas, notably along highways (AKSOY and OZTURK, 1996).

Emissions from autovehicular activities contribute most of air pollution problems and affect the growth of plants. Atmospheric trace metal levels have been reported to exhibit great variations due to automobile activities. For the last 40 years road transport emissions were considered to be the principal source of lead in the urban environment (AKBAR et al., 2006). There are about 50 metals that are of special interest with respect to the toxicological importance to human health, plants and animals (BURHAN et al., 2001). Lead and cadmium are the toxic elements of primary importance in ecotoxicology (BRECKLE and KAHILE, 1992). High level of lead was found in roadside plants. An enhancement of lead was found in roadside soil and vegetation due to combustion of leaded petrol by automobile exhaust in Baghdad city (KHALID et al., 1981). Palm leaves, which were collected from 25 different sites of Baghdad city, showed a relative increase of Pb deposition due to vehicles using leaded petrol (HANNA and AL-BASSAM, 1983). Increased fallout of different types of metals from vehicles in Karachi city is increasing day by day. YOUSAFZAI (1991) found high level of Pb (810-4527 ppm) and Cd (0.2-4.5 ppm) in the street dust of metropolitan city of Karachi. Considerable higher levels of Pb, Cu and Zn have been recorded in soil of the stands where *Suaeda fruticosa* and *Salsola baryosma* have been associated with *Prosopis juliflora* along the super highways (IQBAL et al., 1998). SHAFIQ et al. (2011) found highest levels of Pb (95 ppm) and Cd (2.96 ppm) in *Alstonia scholaris* and high levels of Pb (89 ppm) and Cd 1.76 ppm) in *Cassia siamea* from Karachi.
Traffic emissions on roads are the main cause of heavy metal accumulation on the surrounding environment including vegetation, which might have an ecological effect on them. CASSELLES (1998) found that some heavy metals such as Pb decrease in the leaves of plants with increasing distance from the road. High lead concentrations that were attributed to vehicle emission sources were reported in Amman City Center (JARADAT et al., 1999).

There are several direct and indirect methods of estimating the trace metal levels in urban environment. Plant materials such as tree bark, tree rings and leaves of higher plants have been used to detect the deposition, accumulation and distribution of metal pollution for many years (AKSOY and SAHLN, 1999). To study airborne dust particles deposited in the polluted areas, the most suitable method is leaf collection (FREER-SMITH et al., 1997).

Karachi is a densely populated city with major industrial units of the country. A high rate of economic growth during the last few decades has resulted in mass-scale urban mobility. Large scale urban mobility demands large transport system to carry people and goods from one place to another. The transport system in the city emits toxic materials such as carbon particles, unburned and partially burned hydrocarbons, fuels, tar materials, lead compounds and other toxic elements in the environment. The city presents heavy vehicular activities and high concentration of trace metals in the air. Pollutant like SO_2 (100-134 µg m^{-3}), CO (7-5 mg m^{-3}), NO_2 (38-63 µg m^{-3}) (GHAURI et al., 1988) and Pb (4527 ppm), Cd (4.5 ppm), Zn (2215 ppm) and Cu (275 ppm) (YOUSUFZAI, 1991) from these sources are considered to be important in deteriorating air quality of the city. The aim of the present research was to determine the heavy metals content (lead and cadmium) in the foliage of some important plants (*Pongamia pinnata* and *Peltophorum pterocarpum*) growing in different areas of the city of Karachi, Pakistan.

Materials and methods

Site description

Karachi is situated on the coast along the Arabian Sea at a latitude of 24° 48' N and longitude of 66° 55' E. The soil is calcareous, marine in origin and belongs to upper tertiary period. Moving away from the coast, the ground rises gently forming a large plain to the north and east on which the city is built. The city is between 1.5 and 37 m above sea level. CHAUDHRY (1961) has characterized the climate of Karachi as subtropical maritime desert. Average wind

* Corresponding author

velocity is 12 m s^{-1} during June and July and 3.5 m s^{-1} from January to March. During the southwest monsoon season winds blow from the sea towards the coast, whereas during the northeast monsoon their direction is reversed. Therefore, pollutants are pushed inland during the southwest monsoon season and are blown out to sea during the northeast monsoons (UNEP, 1992). Pollution and traffic density data and estimated pollutant level has been observed (Tab. 1-2).
The hot and humid rainy season, which is variable, lasts from June to September. Minimum rainfall is 1 mm in the month of October whereas, the maximum rainfall (85 mm) occurs in the month of July. The winter season is very short lasting from middle of November to middle of February. Temperature is mild with no frost. Dew formation is quite common, the relative humidity is high. The climatic conditions at the control site (Karachi University Campus) are not different from other sites of the city.

Tab. 2: Estimated emission of pollutant from vehicles in Pakistan, 1996, 1997 and 2000) Tons x 10^3

Pollutants	1996	1997	2000	Source
CO	6000	6500	8000	Qureshi (2000)
HC	1250	1340	1650	
Nox	440	460	540	
SO_2	69	72	85	
PM^{10}	125	135	160	
Total No. of Vehicles	3276000	3515000	4291000	

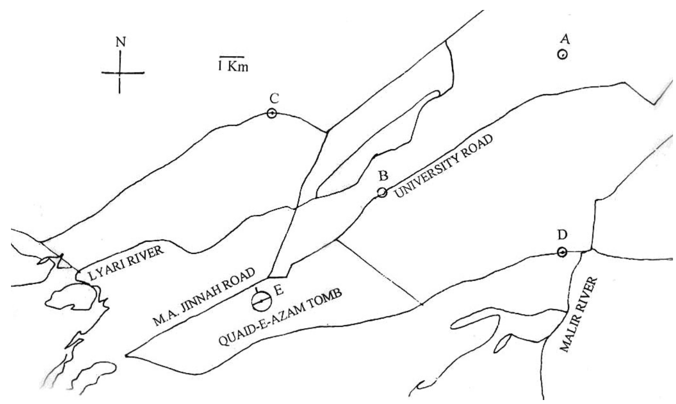

Fig. 1: Map of the study area (A = Karachi University, B = Gulshan-e-Iqbal, C = Nazimabad, D = Shahrah-e-Faisal, E = M.A. Jinnah Road).

Selection of sites

The site in urban area is disturbed mainly by autovehicular activities, includes all main traffic network (Gulshan-e-Iqbal, Nazimabad, Shahrah-e-Faisal and M.A. Jinnah Road) whereas, Karachi University is relatively a clean area (Shafiq et al., 2011). Brief description of the study area is given below (Fig.1):

A. M.A. Jinnah Road: This site is the most congested site along the Quaid-e-Azam tomb. The density of traffic from Gulshan-e-Iqbal, Nazimabad, Liaquatabad and Shahrah-e-Faisal passes through this road. Multistoryed buildings are common at this site. The slow movement of traffic starts building up toxic pollutants in the area.

B. Shahrah-e-Faisal: Shahrah-e-Faisal has many multistoryed buildings. This site is 15 km from the eastern site of the Quaid-e-Azam tomb and heavily influenced by traffic activities.

C. Nazimabad: Nazimabad handles a large traffic volume, moving from north to west of the city. This site is about 10 km away from the North of Quaid-e-Azam tomb.

D. Gulshan-e-Iqbal: Gulshan-e-Iqbal is located about 8 km North East of the Quaid-e-Azam tomb. This place is comparatively open with low traffic. However, traffic congestion in the morning hours is common due to trade activities at old vegetable and fruit market.

E. Karachi University Campus: Karachi University Campus is situated at the outskirts of the city. This site is relatively free from the autovehicular activities as compared to other sites of the city.

Tab. 1: Pollution level of Karachi city

Pollutants		Max.	Min.	Ave.	Source
SO_2	(µg m^{-3})	134	25	61.3	Ghauri *et al.,* a report of SPARCO (1988)
NO_2	(µgm^{-3})	544	38	104	Ghauri *et al.,* a report of SPARCO (1988)
O_3	(µg m^{-3})	50	36	43	Ghauri *et al.,* a report of SPARCO (1988)
Sulphur	(ppm)	565	91	266	Iqbal, Tropical Ecology (1988)
Pb	(ppm)	2677	4	1488	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Cd	(ppm)	1.2	0.2	0.8	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Cu	(ppm)	187	3	134	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Zn	(ppm)	638	6	285	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
Mn	(ppm)	305	4	173	Yousufzai, Pak. J. Sci. & Ind. Res. (1991)
CO	(ppm)	10	2	6	ZiaurRehman, Environmental News (1993)
CO_2	(ppm)	350	170	260	ZiaurRehman, Environmental News (1993)
HC	(Vol. %)	2.3	0.4	1.3	ZiaurRehman, Environmental News (1993)
PM	(µg cm^{-3})	566	67	316	ZiaurRehman, Environmental News (1993)

Note: NO_2, O_3, CO, CO_2, HC, PM are in the air. Other values were of street dust. In organic chemistry, a hydrocarbon (HC) is an organic compound consisting entirely of hydrogen and carbon (Wikipedia, 2012).

Karachi University Campus is clean and 20 km away from Quaid-e-Azam tomb.

Pongamia pinnata (L.) Merrill (Charr) is a medium sized, almost evergreen tree and spreading shady crown. It is indigenous to the foothills of the Himalayas, but cultivated in plains for its ornamental value. *Peltophorum pterocarpum* D.C. Backer ex K. Heyne is native to Ceylon and North Australia, commonly cultivated as roadside tree in gardens and in plains of Pakistan. The leaf samples of common roadside trees like *Pongamia pinnata* and *Peltophorum pterocarpum* having uniform growth and diameter breast height (DBH) were chosen from each site. The samples affected by traffic were obtained from road edge at a distance of one meter. Leaf samples of three individual of each species were randomly collected from each area at two-meter height throughout the plant canopy to give representative average sample. Unwashed leaf samples were oven dried at 80° C for 24 hours and made in powdered form. 0.5 g powdered leaf sample was taken in 100 ml Pyrex beaker and 10 ml concentrated nitric acid was added. The beaker was partially covered with watch glass to avoid any loss of acid. Later, the beaker was kept on the hot plate in fume chamber for digestion. The sample was digested till a clear solution resulted. The watch glass was removed from the top of the beaker and heating continued till the volume of content was reduced to 1-2 ml. Evaporation was allowed but not to dryness. Later the content was cooled down. The content was dissolved in 0.1N HCl, filtered through Whatman filter paper No. 44 and the volume was made up to 50 ml in volumetric flask. Digested plant material solution was analyzed for metal contents on the atomic absorption spectrophotometer (Perkin Elmer 3100) using appropriate cathode. A series of standard solutions for each element in the range of absorbance noted for unknown samples were simultaneously run on atomic absorption spectrophotometer. The calibration curves obtained for absorbance versus concentration data were statistically analyzed using fitting of straight line by least square method. Three replicates were used in this analysis. Concentration of elements is expressed as μg g^{-1}. All reagents were of Analar grade. All glassware's were carefully cleaned with double distilled water and later rinsed with deionized water. The analyses of lead and cadmium were performed at wavelengths 283.3 nm and 228.8 nm, respectively.

To confirm the validity of data, a comparison from control and between the means of treatment was done by Duncan's multiple range tests. The data collected was statistically analyzed by analysis of variance techniques on personnel computer software package, CO-Stat version 3. Nomenclature of the plant species was followed according to STEWART (1972).

Results

The analysis showed high levels of lead and cadmium in the leaves of *Pongamia pinnata* and *Peltophorum pterocarpum* collected from the polluted as compared to less polluted sites of the city (Fig. 2 - 3). A significant ($p<0.05$) difference was found in BP content in the leaves collected from the polluted and less polluted areas. The values were found higher in the city environment than at Karachi University Campus. Highest concentration of lead detected in the leaves of *P. pinnata* was 106 μg g^{-1} at M. A. Jinnah Road, while, the lowest level of 18 μg g^{-1} was recorded in leaves collected from the Karachi University Campus. At Shahrah-e-Faisal, the concentration of lead in *P. pinnata* leaves was 71 μg g^{-1}, while, an average level of lead content was recorded from Nazimabad (54 μg g^{-1}) and Gulshan-e-Iqbal (43 μg g^{-1}). Level of lead in the leaves of *P. pterocarpum* ranged between 7-81 μg g^{-1}. Lowest level of lead (7 μg g^{-1}) was found in leaf samples collected from Karachi University Campus, while highest level of lead (81 μg g^{-1}) was recorded at M.A. Jinnah Road. Level of lead in *P. pterocarpum* leaves was found at Gulshan-e-Iqbal (14 μg g^{-1}), Nazimabad (36 μg g^{-1}) and Shahrah-e-Faisal (57 μg g^{-1}) sites, respectively.

Cadmium analyzed in leaves of *P. pinnata* and *P. pterocarpum* showed low levels as compared to lead. The leaves of both the tree species showed high level of cadmium in samples collected from the city area as compared to Karachi University Campus. Cadmium level in leaves of both tree species was found in the range of 0.26-2.10 μg g^{-1}).

Cadmium was highest (2.10 μg g^{-1}) in the leaves of *P. pinnata* at M.A. Jinnah Road whereas, the lowest level of cadmium (0.26 μg g^{-1}) was recorded at Karachi University Campus. Cadmium was found higher at Shahrah-e-Faisal (1.16 μg g^{-1}), while at Nazimbad and Gulshan-e-Iqbal, the concentration of cadmium in leaves of the same species was 0.63 μg g^{-1} and 0.43 μg g^{-1}, respectively. Different level of cadmium was also observed in the foliage of *P. pterocarpum* collected from both polluted and less polluted sites of the city. The level of cadmium in the leaves of *P. pterocarpum* was in the range of 0.46-1.53 μg g^{-1}. Highest cadmium level (1.53 μg g^{-1}) was detected

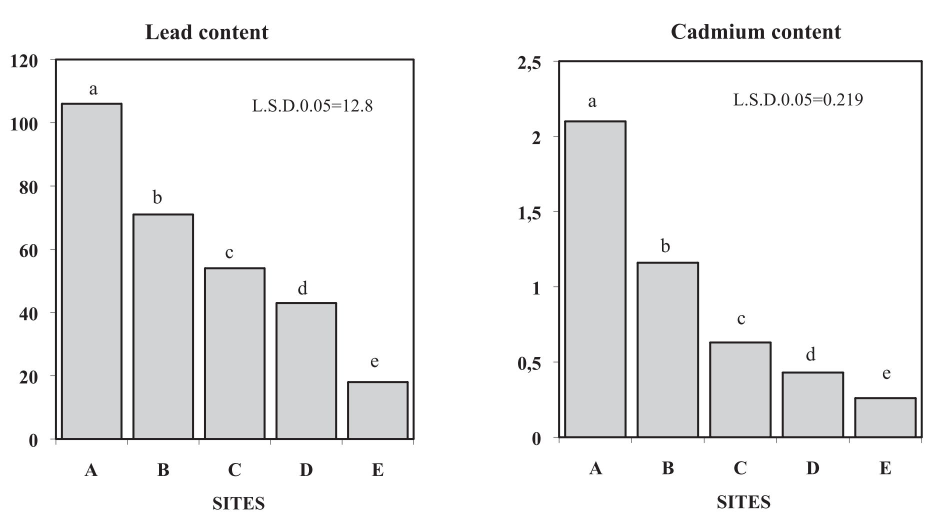

Fig. 2: Level of lead and cadmium μg g^{-1} in the foliage of *Pongamia pinnata*.
All values are significantly ($p<0.05$) different according to Duncan's Multiple Range Test.
SITES A = M.A. Jinnah Road, B = Shahrah-e-Faisal, C = Nazimabad, D = Gulshan-e-Iqbal, E = Karachi University Campus
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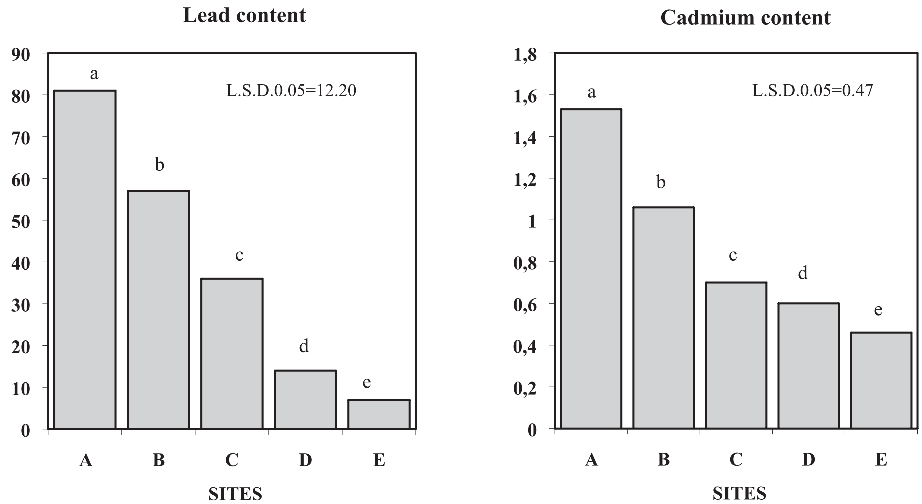

Fig. 3: Level of lead and cadmium µg g^{-1} in the foliage of *Peltophorum pterocarpum*.
All values are significantly ($p<0.05$) different according to Duncan's Multiple Range Test.
SITES A = M.A. Jinnah Road, B = Shahrah-e-Faisal, C = Nazimabad, D = Gulshan-e-Iqbal, E = Karachi University Campus

at M.A. Jinnah Road, while the lowest was recorded at Karachi University Campus (0.46 µg g^{-1}). Cadmium level at Shahrah-e-Faisal (1.06 µg g^{-1}), Nazimabad (0.70 µg g^{-1}) and Gulshan-e-Iqbal (0.60 µg g^{-1}) was in between M.A. Jinnah Road and Karachi University Campus.

Discussion

There has been increasing a continuing interest in the study of heavy metal content of roadside trees. Current research reports found high levels of lead and cadmium contents in the foliage of plants species growing in the urban environment of city. The Pb content in this study was found in the range of 7-106 µg g^{-1} with great differences among sites and plant species. In the present study the concentration of lead in leaves sample of *P. pinnata* and *P. pterocarpum* was found high at the polluted site as compared to Karachi University Campus. This high level of lead at polluted site might be due to presence of high lead additive compounds used in petrol. The concentration of Pb in its petrol reported in 1991 was the highest (1.5-2.0 g Pb L^{-1}) of all produced by the various Asian countries and far exceeded WHO guide lines of of 0.15 g Pb L^{-1} (Parekh et al., 2002). A complete monitoring data on both metals is sparse. However, it should be noted that lead content of petrol are quite high (1.5-2.0 µg^{-1}), which are above the guideline of World Health Organization (0.5-1.0 µg^{-1}) (UNEP, 1992). Furthermore, the lead-based anti-knock substance (tetraethyl lead) added to the petrol often being released into the atmosphere is deposited along the road-sides (Kazmi et al., 2002), thereby raising the level of lead in plants. Air borne Pb is closely associated with the density and congestion of motor vehicle traffic. It is therefore not surprising to see that Pb concentrations in the leaf of trees growing at M.A. Jinnah Road was high as compared to leaf samples collected from other less polluted sites (Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus) of the city. Accumulation and deposition of metals on the surface of leaves can increase the metal concentrations. The higher level of Pb in the leaf of *P. pinnata* (107 µg g^{-1}) was recorded at M.A. Jinnah road, which might be due to the large surface area that is available for exposure to any pollutant. Aksoy et al. (2000) found high level of Pb (15.98- 177 µg g^{-1}) in unwashed leaves sample of *Robinia pseudo-acacia* L. growing along roadside. High concentration of Pb in leaves sample of *P. pterocarpum* was also found at M.A. Jinnah Road, where the traffic density was highest as compared to Karachi University Campus. The amount of lead potentially available to plants in any given locality obviously depends on the density of vehicles. Low vehicular traffic activities at the campus showed lowest lead contents for *P. pinnata* and *P. pterocarpum*. The cadmium level in the air is also an important component leading to the problems of environmental pollution. Lagerwerff and Specht (1970) have suggested that cadmium is found in lubricating oils as a part of many additives. The concentration of cadmium in leaf sample of tree species collected from M.A. Jinnah Road, Shahrah-e-Faisal, Nazimabad, Gulshan-e-Iqbal and Karachi University Campus showed a distribution similar to those obtained for lead. The data emphasized that motor vehicles traffic load is a major cause of high level of Cd content in leaves *P. pinnata* and *P. pterocarpum* collected from the polluted areas of the city. The flow of traffic at M.A. Jinnah Road near Quaid-e-Azam tomb is quite slow due to the presence of traffic signals. The area is rather congested with the result that pollutants emitted from the motor vehicles remained suspended in the atmosphere for some time and ultimately deposited on the surface of leaves. Level of cadmium was found in the range of 2.96-0.26 µg g^{-1}. Maximum level of cadmium (2.96 µg g^{-1}) was found in the foliage of *P. pinnata* at M.A. Jinnah road, which is highly polluted site of the city. Similarly Aksoy and Sahln (1999) had investigated high level of cadmium (1.38 µg g^{-1}) in unwashed leaves of *Eleagnus angustifolia* L. collected from the crowded parts of city center in Kayseri (Turkey). Ara et al. (1996) had also found Cd content in the leaves of *Ficus religiosa* (0.04 ppm) and *Eucalyptus* sp., (0.03 ppm) from some other polluted area of the city. These results indicate that metal aerosols after deposition on the leaf surface are responsible for increase in the level of cadmium in the city samples as compared to Karachi University Campus. Moreover, in the present study it was observed that *P. pinnata* leaf sample collected from the polluted sites showed a tendency of higher concentration of lead and cadmium than *P. pterocarpum*. These atmospheric pollutants can play an important part in growth and development of plants growing in the polluted environment. The quantification of such contaminants has come to a priority issues for the betterment of the environment. It might be also helpful in understanding the current level of available pollutant in order to raise the alarm about excessive atmospheric contaminants levels increasing due to automobile activities. The results reported here demonstrate that leaves of both tree investigated served as a good bioindicator and can be used in elemental air pollution monitoring studies in urban sites. The use of plants as a complementary tool to traditional (instrumental) methods of studying atmospheric pollution from anthropogenic and natural sources became an established technique in the past 30-40 years because of the development of powerful analytical techniques (Berlizov et al., 2007). A comprehensive review on the use of plants for air-monitoring purposes was given by Mulggrew and Williams (2000). Bioindicators can be defined as organisms (a part of an organism or a population of organisms) which are able to give information's on the quality (of a part) of its environment (Figueiredo et al., 2007). Heavy metals from vehicular emissions have continuously added to the pool of contaminants in the environment (Hashisho and El-Fadel, 2004). In present investigation, a comparative study of the capabilities of both investigated tree species support that leaves of both tree species can be used for air pollution monitoring in urban sites, where severe environmental conditions are resulting due to automobile activities.

In conclusion, the present study brings out the clear picture about the levels of trace metals present in the biological material collected from the different site of the city. The relatively higher levels of both metals are indicative of the fact that the local atmosphere is undergoing to an alarming situation for the plant health due to automobile activities. It is high time to evolve an air pollution abatement strategy to ward off people against the hazardous effects arising from elevated trace metal levels (Shah and Shaheen, 2007). Metal contamination from automobile activities sources is an important environmental concern around the world and in Pakistan. Due to rapid urbanization and industrial development in recent years, atmospheric pollution has caused serious deterioration of the terrestrial environment in many countries. The result could be used as preliminary baseline data for trace elements concentrations in the ecosystems for future assessment and monitoring. Environment friendly organization in public and governmental sectors, environment management worker, policymakers, scientists, educators and researcher are providing informative data on the biomonitoring of various types of pollutants. It is based on the sampling and analysis of the materials collected from the contaminated site. Plant, soil, water and air samples are most commonly measured. This technique helps in investigating the level of contamination of pollutants in any given environment. The results of these measurements provide information and guide about the current level of pollutants in the environment. It is logical to conclude that heavy metals, which are discharged into the atmosphere through motor vehicles exhaust, are deposited on and penetrate into leaves. Leaf at its various stages of development serves as a good indicator to air pollutants. Pollutants derived from the auto-emission can directly affect the foliage of plants by entering the leaf, destroying individual cells, and reducing the plant ability to produced food. Reduction in leaf length, width, area and dry weight of roadside plants was the witness of bad effects of the city environment. It is found that the plants growing close to the busy road of the city are highly affected by autoemission. The inhibitory effects on the growth of plants are due to the presence of toxic material in the auto emission. Overall study reveals that, high level of lead and cadmium was found in the foliage of plants growing in the polluted city environment. However, high level of metals was detected in *P. pinnata* as compared to *P. pterocarpum.* It is therefore, suggested that *P. pinnta* should be given more preference over *P. pterocarpum* for further plantation in the city, particularly along the busy roads to lessen the burden of pollutants from the urban environment. Continuous monitoring and measurements of heavy metal are required from plants growing adjacent to roadways.

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Address of the author:

Dr. Muhammad Shafiq, Department of Botany, University of Karachi, Karachi-75270, Pakistan

Prof. Dr. Muhammad Zafar Iqbal, Department of Botany, University of Karachi, Karachi-75270, Pakistan

Prof. Dr. M. Saeed Arayne, Department of Chemistry, University of Karachi, Karachi-75270, Pakistan

Dr. Mohammad Athar, California Department of Food and Agriculture, 3288 Meadowview Road, Sacramento, CA 95832, USA

Current address: Department of Food science and Technology, University of Karachi-75270 Pakistan

E-mail: atariq@cdfa.ca.gov)