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Air pollution induced changes in photosynthetic pigments and accumulation of heavy metals in medicinal plant neem (*Azadirachata indica*)

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Abstract: Vegetation naturally cleans the atmosphere by absorbing gases and particulate matter through leaves as plant leaf act as a persistent absorber when exposed to the polluted environment. Road side plants are good bio-indicators of air pollution. Analysed data reveals that TSPM and RSPM level was exponentially higher during winter and summer season. The concentration of SO_2 and NOx was greatly influenced by the automobile emission. Higher concentration was found in commercial area while NOx concentration was found higher than SO_2. In our study chlorophyll and carotenoid content in all season in neem was highest at residential area and least at commercial area, while phaeophytin was highest at residential area and lowest at industrial area. Phaeophytin content was maximum in summer (in residential area) and minimum in monsoon (industrial area). The protein content was lowest at winter in residential area and higher in monsoon at industrial area. The activity of peroxidase was highest at commercial area in winter and lowest in monsoon at industrial area. During summer in neem leaves average concentration of Pb, Mn, Fe, Zn and Cu in residential areas was 21.58, 6.95, 82.43, 11.65 and 6.22 $\mu g\ g^{-1}$ dry weight respectively. During mansoon and winter average concentration of Pb, Mn, Fe, Cd, Cr, Zn and Cu was 19.67, 14.66, 126.63, 0.14, 0.09, 17.56, 11.95 and 11.17, 15.18, 119.96, 0.08, 0.11, 17.75 and 9.67 $\mu g\ g^{-1}$ dry weight respectively. At locations of commercial area average concentration of Pb, Mn, Fe, Zn and Cu during summer was 28.36, 6.90, 108.11, 12.87 and 10.32 $\mu g\ g^{-1}$ dry weight respectively. During mansoon concentration of Pb, Mn, Fe, Cd, Cr, Zn and Cu was 16.18, 16.40, 136.65, 0.10, 0.12, 22.14 and 11.98 $\mu g\ g^{-1}$ dry weight respectively. In winter average concentration of metals in the similar order was 14.69, 14.94, 118.21, 0.13, 0.10, 16.95 and 11.23 $\mu g\ g^{-1}$ dry weight respectively. Average concentration of Pb, Mn, Fe, Cr, Zn, Cu and Cd at industrial locations during summer was 25.06, 5.10, 119.97, 0.98, 7.92, 8.96 and 0.99 $\mu g\ g^{-1}$ dry weight respectively. During monsoon concentration of Pb, Mn, Fe, Cd, Cr, Zn and Cu was 23.24, 15.14, 139.80, 0.08, 0.12, 22.22 and 12.35. In winter the concentration of Pb, Mn, Fe, Cd, Cr, Zn and Cu was 10.66, 15.16, 111.68, 0.11, 0.10, 16.81 and 11.34 $\mu g\ g^{-1}$ dry weight respectively.

Key words: Air pollution, SO_2, NOx, Chlorophyll, Phaeophytin, Carotenoid, Protein, Peroxidase, Heavy metals

Introduction

Air pollutants either alone or in combination with other pollutants influences plant physiology. Two important plant mechanisms photosynthesis and protein production decreases due air pollution (Khan *et al.*, 1990; Chaudhary *et al*., 2008). Peroxidase (POD) is an air pollution marker enzyme. Its activity varies with the species of tress, season and concentration of pollutant gases. Particulates cause occlusion of stomata and decrease in the efficiency of gaseous exchange. The harmful effects of air pollution on plants are well established (Gupta and Ghouse, 1986,1987; Vollenweider *et al.,* 2003). Air pollutants influences various anatomical, physiological and biochemical processes of plants (Okano *et al*., 1985; Soda *et al.,* 2000; Vollenweider *et al*., 2003). Generally SO_2, NO_X and SPM are used to have a fair idea of pollution load carried by the air (Persily, 2007). The industrialization is the need of modern world, but its increasing pace has resulted into serious environmental hazards (Kim, 2004). Auto exhaust contribute significantly 70% to the air pollution in urban area (Parker, 1977; Zhu *et al*., 2002). Zielinska *et al*. (2004) reported that the composition of emissions from automobile highly depend on the ambient air quality conditions. Air pollutants cause large scale damage to the plants. Research needs to be expanded to encompass a greater variety of plant responses to interactive stresses caused by air pollutants in more realistic field conditions. In view of the above facts, it is important to assess the ambient air quality of cities and its effect on plants (Klumpp, 2003) as it essential for over all sustainable and eco-friendly development . Air pollutants such as sulfur dioxide, nitrogen oxides, carbon monoxide, unburned hydrocarbons, hydrogen fluoride and particulates are released in the atmosphere by the burning of fossil (Oman *et al.*, 2001). A direct relationship between particulate constituents and street activity was identified by Chabban *et al.* (2000). SO_2 an important gaseous pollutant is released into the urban air by both natural and anthropogenic sources like sulphur bacteria activities, burning of fossil fuel which is used in transportation, domestic sector and power generation (Tripathi and Gautam, 2007; Chaudhary *et al*., 2008).

In urban areas vehicular pollution was the most important source of metals in air (Colombo *et al*., 1999). Heavy metal contamination and their hazardous effects to the biota have been well documented (Raskin and Ensley, 2000; Meagher, 2000). Heavy metal ions such as Cu, Zn, Mn, Fe *etc.* are essential micronutrients for plant metabolism but when present in excess, these and non essential metals such as Cd and Pb can become extremely toxic (EPA, 1998). The soil (common rooting medium), is the primary source of metals in plants. As the trace element content of soil increases, the amount of metal in plant also increases. It also depend on other factors like soil pH, level of organic matter, texture *etc*. Dissolved organic compounds in the soil also increase the availability of metals to the plants roots (Antoniadis and Alloway, 2000). Ray (1990), reported the significant bioaccumulation of heavy metals in vegetables and indigenous weeds in the polluted areas. The least accumulation was found in the leaves and shoots (Barman and Lal, 1994). Heavy metal at higher dose causes metabolic and physiological disorders and finally inhibite growth in most of plant species (Clarie *et al*., 1991). Plants have the ability to grow in sites where soils contain greater than usual amounts of heavy metals or other toxic compounds (Raskin and Ensiley, 2000). Solis moderately contaminated with Cd, Cr, Cu and Ni not cause adverse effects in plants.

The main focus of this work is to provide an assessment of alteration in heavy metal accumulation and biochemical changes in neem plant as indicators of air pollution.

Materials and Methods

Study area and Sampling locations: Lucknow the capital of most populous state UP in the India is situated between 26^{0}52'N latitude and 80^{0}56'E longitude and 120 m above sea level. On the basis of activities performed 12 locations were chosen for air and plant monitoring *viz.* residential (Gomtinagar, Indiranagart, Aliganj, Vikas Nagar) commercial (Hazratganj, Hussainganj, Charbahj, Alambagh, Aminabad, Chowk) and industrial (Amausi, Talkatora).

Air sampling and analysis: In the present study 24 hr sampling is done using high volume sampler (HVS) and respirable dust sampler (RDS). At each location monitoring was carried out for 2 days per month to cover all the season *i.e.* summer, monsoon and winter. Particulate matter was analyzed as per Indian standard method. West and Geake method (1956) and modified Jacob and Hochheiser (1958) were used for analysis of SO_2 and NOx respectively.

Plant sampling and analysis: For the study neem (*Azadirachata indica* A. Juss.) trees were selected. Plant sampling was carried out in summer, monsoon and in winter season. Leaf samples were collected from all the sides of the plant *i.e*. top middle and bottom of the canopy as per the method suggested by Rao (1971). Chlorophyll, phaeophytin and carotenoid were estimated by the method of Arnon (1949). Peroxidase (POD) and proteins were estimated by Puccinelli and Bragloni (1998) and Lowry *et al.* (1951) respectively. Metal analysis was done by the method of Piper (1942) using atomic absorption spectrophotometer (AAS).

Results

The air pollution status of Lucknow city is given in Table 1. The TSPM during summer season at residential, commercial and industrial area ranged between 298.17-347.50, 406.88-514.43 and 418.17-426.18, in monsoon its ranges between 268.96-291.66, 245.72-402.70 and 327.95 -328.08, while in winter season it ranges between 312.11-397.10, 410.00-567.10 and 367.96-476.68 respectively. The RSPM during summer season at residential, commercial and industrial area ranged between 139.36 -157.21, 187.18-257.77 and 162.25-170.91, in monsoon its ranges between 128.39-142.24, 151.95-222.32 and 119.81- 121.98, while in winter season it ranges between 132.89-185.06, 151.20-233.12 and 164.89-176.42 respectively. The SO_2 during summer season at residential, commercial and industrial area ranged between 20.76-28.48, 22.56-36.89 and 22.67-23.59, in monsoon its ranges between 17.63-17.86, 20.97-25.68 and 20.12 -20.65, while in winter season it ranges between 22.18-30.21, 25.97- 35.97 and 21.58-26.59 respectively. The NOx during summer season at residential, commercial and industrial area ranged between 22.59 - 30.84, 29.60-35.28 and 26.61-37.13, in monsoon its ranges between 18.95-22.73, 24.83-26.99 and 22.04 -26.44, while in winter season it ranges between 21.77-45.74, 33.92-45.27 and 28.29-33.24 respectively (Table 1).

The effect of air pollution on medicinal plant neem was given in Table 2, 3. Chlorophyll content in all season in neem was highest at residential area and least at commercial area. The chlorophyll content was lowest in winter and highest in monsoon

Table - 1: Status of air pollution in respect to TSPM, RSPM, SO_2 and NOx (all values are given in μg m^{-3}) of Lucknow city

Locations	Summer				Monsoon				Winter			
	TSPM	RSPM	SO_2	NOx	TSPM	RSPM	SO_2	NOx	TSPM	RSPM	SO_2	NOx
Residential												
Gomti Nagar	298.17	139.36	20.76	22.59	271.80	128.39	17.63	18.95	312.11	132.89	22.18	21.77
Indira Nagar	347.50	155.57	28.48	30.84	291.66	142.24	17.69	22.73	397.10	185.06	30.21	45.74
Aliganj	310.17	157.21	24.25	29.08	289.08	134.50	17.86	19.45	340.90	167.89	22.90	34.38
Vikas Nagar	302.83	148.72	21.0	25.96	268.96	135.14	17.80	18.97	324.58	150.36	22.37	30.78
Commercial												
Hazratganj	423.72	187.18	22.56	35.26	402.70	166.17	21.71	25.51	462.00	201.31	25.97	42.27
husainganj	441.39	204.11	25.38	29.60	360.52	151.95	20.97	24.83	475.07	177.80	27.57	36.05
Charbagh	463.15	200.97	28.28	33.69	345.92	183.54	21.71	26.99	567.10	233.12	35.97	45.27
Alambagh	406.88	257.77	36.89	35.28	360.93	212.56	22.29	25.30	483.82	203.65	29.98	38.84
Aminabad	514.43	240.22	29.16	31.84	382.68	222.32	23.80	26.40	410.00	151.20	31.34	33.92
Chowk	506.23	235.47	31.06	32.74	245.72	208.81	25.68	27.51	485.67	177.89	29.17	38.92
Industrial												
Amausi	418.17	162.25	22.67	26.61	327.95	119.81	20.12	22.04	367.96	164.89	21.58	28.29
Talkotra	426.18	170.91	23.59	37.13	328.08	121.98	20.65	26.44	476.68	176.42	26.59	33.24

season at all locations. The content of phaeophytin in all the seasons in neem was highest at residential area and lowest at industrial area. Average phaeophytin content was maximum in summer (in residential area) and minimum in monsoon (industrial area). Average carotenoid content in neem was highest at residential area and lowest at commercial area. Average content of carotenoid was maximum in monsoon season while minimum in winter season at all the locations. Average protein content in neem was lowest at winter in residential area and higher in monsoon at industrial area. The peroxidase activity in neem was highest at commercial area in winter and lowest in monsoon at industrial area (Table 2).

During summer in neem leaves average concentration of Pb, Mn, Fe, Zn and Cu in residential areas was 21.58, 6.95, 82.43, 11.65 and 6.22 $\mu g\ g^{-1}$ dry weights respectively. Cr was found only at Vikas Nagar with a magnitude of 0.90 $\mu g\ g^{-1}$ dry weight and Cd was found at Aliganj (0.10 $\mu g\ g^{-1}$ dry weight). During mansoon average concentration of Pb, Mn, Fe, Cd, Cr, Zn and Cu was 19.67, 14.66, 126.63, 0.14, 0.09, 17.56 and 11.95 while in winter 11.17, 15.18, 119.96, 0.08, 0.11, 17.75 and 9.67 $\mu g\ g^{-1}$ dry weight respectively. At commercial locations average concentration of Pb, Mn, Fe, Zn and Cu during summer was 28.36, 6.90, 108.11, 12.87 and 10.32 $\mu g\ g^{-1}$ dry weight respectively. Cr was found at Charbagh and Aminabad with a magnitude of 0.48 and 0.10 $\mu g\ g^{-1}$ dry weight respectively. During mansoon concentration of Pb, Mn, Fe Cd, Cr, Zn and Cu was 16.18, 16.40, 136.65, 0.10, 0.12, 22.14 and 11.98 $\mu g\ g^{-1}$ dry weight respectively. In winter average concentration of metals in the similar order was 14.69, 14.94, 118.21, 0.13, 0.10, 16.95 and 11.23 $\mu g\ g^{-1}$ dry weight respectively. Average concentration of Pb, Mn, Fe, Cr, Zn, Cu and Cd at industrial locations Amausi and Talkatora during summer was 25.06, 5.10, 119.97, 0.98, 8.96 and 0.99 $\mu g\ g^{-1}$ dry weight respectively. Cr was found only at Talkotora. During monsoon and winter concentration of Pb, Mn, Fe, Cd, Cr, Zn and Cu was 23.24, 15.14, 139.80, 0.08, 0.12, 22.22 and 12.35, 10.66, 15.16, 111.68, 0.11, 0.10, 16.81 and 11.34 $\mu g\ g^{-1}$ dry weight respectively (Table 3).

Discussion

During the present study the concentration of RSPM and TSPM is recorded very high as compared to the prescribed standards of National Ambient Air Quality standards (CPCB, 1995). Higher concentration of TSPM and RSPM in ambient air was due to automobile exhaust (Querol *et al.,* 2002). Concentration of SO_2 and NOx was within the limit at all the locations but is enough to cause injury to plants.

The vehicular emissions have a profound impact on the concentration of different photosynthetic pigments. The shading effects due to deposition of suspended particulate matter on the leaf surface might be responsible for this decrease in the concentration of chlorophyll in polluted area. It might clog the stomata thus interfering with the gaseous exchange, which leads to increase in leaf temperature which may consequently retard chlorophyll synthesis (Mark, 1963; Singh and Rao, 1981; Joshi and Swami, 2009). Darall (1986) also reported that SO_2 might reduced plant growth even at lower concentration, which is not enough to cause visible injury, mainly through its adverse effects on photosynthesis. Chlorophyll content of plant signifies its photosynthetic activity as well as the growth and development of biomass. It is well evident that chlorophyll content of plant varies species to species' age of leaf and also with the pollution level as well as with other biotic and abiotic conditions (Katiyar and Dubey, 2001). The decreased chlorophyll concentration in plant fumigated with SO_2 was often associated with degradation of chlorophyll -a (Khan *et al*., 1990). The reason for degradation of chlorophyll pigments can also be attributed to action of SO_2 and NO_2 on the metabolism of chlorophyll, both of these gases are the constituents of vehicular emissions. The reduction in the concentration of chlorophyll might have also been caused due to the increase in chloophyllase enzyme activities, which in turn affects the chlorophyll concentration in plants (Mandal and Mukherji, 2000). In all the species chlorophyll content was higher in monsoon season, it might be due to the washout of dust particles (which will increase photosynthetic activity) from the leaf surface, low level of pollution and water content of soil. Rao and Leblanc (1966) mentioned that high amount of SO_2 causes destruction of chlorophyll and carotenoid and that might be due to the replacement of Mg^{2+} by two hydrogen atoms and degradation of chlorophyll, carotenoid molecules to phaeophytin. Carotenoids is an accessory pigment responsible for yellow to orange color in plants and is a free radicle scavenger, therefore it is responsible for the protection capacity of the plants (Rawn,1989). Carotenoids protect photosynthetic organisms against potentially harmful photoxidative processes and are essential structural components of the photosynthetic antenna and reaction center (Bartley and Scolnik, 1995). They play pivot role as accessory plant pigments. It was generally observed that at polluted sites senescence occur several weeks early. This early senescence was due to the changes observed in a major group of plant pigments carotenoids.

Protein carries out important enzymatic activities and is vital for the rapid rate of biochemical reaction in cells. Two other important functions of proteins are, as major H^+ ion buffers and as structural component of cells. Many have reported decrease in protein content on SO_2 fumigation (Khan *et al*., 1990) and the tentative reasons attributed to this loss are either the breakdown of the existing protein molecules or reduced biosynthesis. It is well known that SO_2 and NOx in combination adversely affect the plants as well as the protein content as observed by Anbazhagan *et al*., 1986). Peroxidase (POD) occur in a wide variety of plants including deciduous and evergreen. The level of peroxidase enzymes is universally accepted as an indicator parameter to environmental pollution especially air pollution (Khan *et al*., 1990). Peroxidase serve in interlinked primary protection mechanism. Peroxidase act on the end product (H_2O_2) (Bennett *et al*., 1984). Peroxidase reduced H_2O_2 catalysing by air pollutants (Scandalios, 1993). Varshney and Varshney (1985) reported increase in peroxidase activity in plant cells under a variety of stresses, such as mechanical injury and attack by pathogens or an influence of environmental pollution. The increase in peroxidase

Table - 2: Effect of air pollution on pigments *i.e.* chlorophyll, phaeophytin and carotenoid (mg g^{-1} fresh wt. of tissue), protein (mg g^{-1} fresh wt. of tissue) and peroxidase (U) in leaves of neem plant

Locations	Chlorophyll			Phaeophytin			Carotenoid			Protein			Peroxidase		
	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W
Residential															
Gomti Nagar	3.73	3.99	1.25	3.03	2.54	3.56	1.11	1.03	0.65	0.95	2.01	0.41	0.69	0.25	6.99
Indira Nagar	2.01	3.24	1.76	3.13	2.28	3.24	1.01	1.14	0.74	7.12	5.34	0.51	0.76	0.38	5.62
Aliganj	2.83	3.01	1.84	4.01	2.16	3.19	1.21	1.27	0.69	1.52	2.00	0.81	0.58	0.15	7.01
Vikas Nagar	2.73	2.94	2.00	4.20	2.22	3.65	0.86	1.35	0.67	7.08	4.98	1.06	0.92	0.12	7.97
Average	**2.83**	**3.30**	**1.71**	**3.59**	**2.30**	**3.41**	**1.05**	**1.20**	**0.69**	**4.17**	**3.58**	**0.70**	**0.74**	**0.23**	**6.90**
Commercial															
Hazratganj	1.96	3.24	2.01	3.22	2.01	3.11	0.88	1.25	0.72	2.54	4.66	1.21	1.22	0.68	7.60
husainganj	1.88	3.16	2.24	3.19	2.24	3.19	0.91	1.07	0.61	2.61	4.74	1.11	1.03	0.81	7.02
Charbagh	1.79	3.29	1.14	3.21	1.94	3.25	1.00	1.17	0.64	3.15	4.91	1.14	2.11	0.98	7.35
Alambagh	2.01	3.10	1.16	3.11	1.98	3.01	0.89	1.33	0.84	2.69	6.62	1.30	0.99	1.01	6.01
Aminabad	1.89	3.32	2.36	3.03	2.24	3.36	0.55	1.14	0.97	4.46	5.00	1.17	6.10	0.54	8.11
Chowk	1.51	3.41	2.08	3.25	2.29	3.29	0.83	1.00	0.98	2.24	5.01	1.20	9.90	0.81	8.24
Average	**1.84**	**3.25**	**1.83**	**3.17**	**2.12**	**3.20**	**0.84**	**1.16**	**0.79**	**2.95**	**5.16**	**1.19**	**3.56**	**0.81**	**7.39**
Industrial															
Amausi	2.92	3.19	2.28	2.28	2.14	3.01	0.83	1.25	0.95	4.12	5.49	1.01	1.22	0.27	5.00
Talkotra	2.22	3.03	1.34	2.31	1.86	3.21	0.92	1.07	0.70	4.46	4.95	1.00	1.40	0.17	5.08
Average	**2.57**	**3.11**	**1.81**	**2.30**	**2.00**	**3.11**	**0.88**	**1.16**	**0.83**	**4.29**	**5.22**	**1.01**	**1.31**	**0.22**	**5.04**

S = Summer, M = Monsoon, W = Winter

Table - 3: Heavy metals accumulation in leaves of neem plant (µg gm^{-1} dry wt.)

Locations	Pb			Mn			Fe			Cd			Cr			Zn			Cu		
	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W
Residential																					
Gomti Nagar	14.90	18.65	10.22	6.04	12.19	15.22	81.56	100.3	120.20	BDL	0.01	0.05	BDL	0.05	0.09	10.80	16.29	13.42	4.51	10.16	8.45
Indira Nagar	16.20	16.35	13.21	6.01	16.12	16.19	70.09	143.5	119.21	BDL	0.41	0.08	BDL	0.08	0.08	10.50	20.14	20.14	7.55	16.20	9.10
Aliganj	22.10	25.14	10.10	8.05	16.12	14.19	80.54	121.21	109.21	0.10	0.05	0.10	BDL	0.11	0.16	12.90	18.19	19.16	5.84	10.21	10.00
Vikas Nagar	33.11	18.54	11.14	7.70	14.21	15.12	97.53	141.51	131.20	BDL	0.08	0.08	0.90	0.13	0.12	12.40	15.62	18.29	6.98	11.21	11.12
Average	**21.58**	**19.67**	**11.17**	**6.95**	**14.66**	**15.18**	**82.43**	**126.63**	**119.96**	**0.10**	**0.14**	**0.08**	**0.90**	**0.09**	**0.11**	**11.65**	**17.56**	**17.75**	**6.22**	**11.95**	**9.67**
Commercial																					
Hazratganj	28.20	14.85	14.31	8.50	21.14	15.16	96.80	143.81	142.61	BDL	0.08	0.12	BDL	0.11	0.08	12.70	21.24	19.42	9.70	16.82	10.19
husainganj	30.10	16.21	10.14	4.86	20.22	15.02	88.91	141.51	131.25	0.21	0.13	0.10	BDL	0.13	0.13	10.10	24.21	18.22	9.57	14.14	12.16
Charbagh	30.40	19.25	16.12	7.16	16.45	15.18	113.91	152.31	108.45	0.84	0.15	0.24	0.48	0.19	0.14	13.50	21.39	16.94	16.47	10.92	10.16
Alambagh	35.20	14.21	20.11	6.01	11.29	14.15	100.50	141.72	116.20	0.21	0.08	0.19	BDL	0.15	0.08	12.50	25.24	15.22	9.44	11.92	11.45
Aminabad	29.20	12.36	12.14	7.22	10.15	16.20	120.50	121.23	98.56	0.55	0.03	0.08	0.10	0.05	0.07	17.80	19.42	15.13	8.55	8.65	13.20
Chowk	17.08	20.18	15.29	7.64	19.12	13.92	128.02	119.19	112.13	BDL	0.10	0.07	BDL	0.08	0.09	10.60	21.34	16.78	8.17	9.43	10.19
Average	**28.36**	**16.18**	**14.69**	**6.90**	**16.40**	**14.94**	**108.11**	**136.65**	**118.21**	**0.45**	**0.10**	**0.13**	**0.29**	**0.12**	**0.10**	**12.87**	**22.14**	**16.95**	**10.32**	**11.98**	**11.23**
Industrial																					
Amausi	15.19	20.13	10.19	5.40	11.18	14.12	122.40	140.41	108.14	0.98	0.08	0.08	BDL	0.10	0.08	8.54	24.14	15.19	10.29	13.41	11.14
Talkotra	34.92	26.35	11.13	4.80	19.10	16.20	117.54	139.48	115.21	0.99	0.07	0.13	0.98	0.13	0.11	7.29	20.29	18.42	7.62	12.84	15.12
Average	**25.06**	**23.24**	**10.66**	**5.10**	**15.14**	**15.16**	**119.97**	**139.80**	**111.68**	**0.99**	**0.08**	**0.11**	**0.98**	**0.12**	**0.10**	**7.92**	**22.22**	**16.81**	**8.96**	**12.35**	**11.34**

activity varies with the plant species and the concentration of pollutants. Khan and Malhatora (1982) reported that leaves of the resistant plants might have high peroxidase activity.

Plants normally uptake or accumulate metals via root which are available in the soil solution. Metals from the automobile exhaust ultimately fall on the soil surface which is normally inorganic. A number of factors are responsible for the uptakes of metals from the soil by roots and also translocation to the upper parts. Lead is a toxic element and not required by plants. At elevated levels Pb is toxic to any living being. Lead concentration was higher during summer season in plant species and comparatively less in winter season, it might be due to the transportation activity and other abiotic factors. Normally lead uptake by the root remains in the lower part of the plant. Lead concentration is higher than normal background concentration which is 2.1 and 2.5 mg kg^{-1} in grass and clover plants (Pais and Jones, 1997). Mn is an essential element and is required for many biological activities specially chlorophyll pigmentation. It is known that Mn is emitted from automobile exhaust, that which Mn concentration was higher in heavy traffic area. In general hetrogenous accumulation was found in all seasons. Iron is an essential nutrient as it activity participates in different metabolic pathways. The concentration of Fe in leaves tissue showed little variation among different locations. In plants Cd ions have a strong affinity to the sulphahydral and phosphate groups of certain compounds, which involved in metabolic processes. This affinity might be the reason of Cd toxicity (Carlson and Bazaz, 1977). It has been established that Cr is an essential nutrient (Mertz, 1969) but not for plants (Huffman and Alloway, 1973). Normally the chromium has been found in plant tissues in small quantity. The toxicity of chromium at higher concentration has been reported in different plant species (Joshi *et al*., 1999). Zinc (Zn) is important element for both plants and animals. It plays an important role in several plant metabolic processes, it activates enzymes, incorporated in metallo-enzymes of the electron transport system and is involved in protein synthesis, carbohydrate, nucleic acid and lipid metabolism. It forms complexes with RNA, DNA and effect their stability. Zn concentration was high in soil, air and plant tissue in traffic areas. Generally plants are sensitive to leaf tissues concentration ranging from 60-90 µg g^{-1} dry weight (MacNicol and Beckett, 1985). It is also reported that most plants show potential phyto-toxicity at leaf tissue concentration above 200 mg kg^{-1} dry weight (Davis and Beckett, 1997). The toxicity symptoms of Cu are visible when the plant tissue its concentration reaches 20-30 mg kg^{-1} dry weight (Reuther and Labanauskas, 1966). A heterogeneous accumulation of metals among the plant species suggested that the species depends on the metals for their accumulation.

The study and above discussion reveals that the pollutants such as RSPM, SPM, SO_2 and NO_2 from automobile exhaust not only cause bad air quality condition around nearby areas but also cause significant reduction in chlorophyll pigments and significant increase in level of antioxidant enzymes and various metals concentration.

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