

## **Bioindicator: A Comparative Study on Uptake and Accumulation of Heavy Metals in Some Plant's Leaves of M.G. Road, Agra City, India**

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**Abstract:** The aim of the present study is to investigate the concentrations of some heavy metals (cobalt, cadmium, lead, nickel and chromium) in the leaves of plants viz: neem (*Azadirachta indica*), kaner (*Nerium oleander* L.), Ashok (*Saraca indica* L.) and imli (*Tamarindus indica*) around the polluted and non polluted sites near Agra region, India. Heavy metal concentrations in leaves were determined by Atomic Absorption Spectrophotometer (AAS). According to our findings the order of heavy metals in plants leaves were found in as follows: Co>Pb>Ni>Cr>Cd. Correlation between heavy metals in different plants at different sites were calculated for each metal separately and a positive correlation is observed. The presence of these metal ions in plant leaves explain the fact that these plant leaves are good bioindicators and can be used in air pollution monitoring studies in industrial areas.

**Keywords:** Accumulation, bioindicators, heavy metals, uptake

### **INTRODUCTION**

Pollution of the environment with toxic metals has increased since increasing industrialization and human activities (Kelly *et al.*, 1999). Emissions of various pollutants into the atmosphere have a lot of harmful effects on plant growth (Dursun *et al.*, 1998). Rapid urbanization, unregulated industrialization growing transport intensity, metal plating and agricultural activities have created a problem of heavy metals contamination in serious stage (Donalás and Edita, 2007; Culbard *et al.*, 1983; Gibson and Farmer, 1983; Haines and Pocock, 1980; Parry *et al.*, 1981; Raven and Leoppert, 1997; Young *et al.*, 1973; Galloway, 1972; Chow *et al.*, 1973; Bruland, 1974, Gibson and Farmer, 1986; Harrison *et al.*, 1981; Li *et al.*, 2001). Although heavy metals constitute an insignificant portion among transport pollutant, they play a potential role in assessing the qualities of the roadside environment. Plants have a major contribution in purifying land, water and environmental air. To grow and complete the life, plants have a great need not only of macronutrients (nitrogen, phosphorus, potassium, sulphur and manganese) but also essential nutrients for ex-heavy metals. The heavy metals limitation in roadsides trees or plants varies in different species. Plants known as hyper accumulators (Atolaye and Aremu, 2007; Shrestha,

2003) which accumulate hundred or thousand times more heavy metals than normal plants. Hyper accumulator plants have a higher requirement of heavy metals in various organs of the plants. Heavy metals and the ratio of metals in various organs of roadside plants species largely depend on plant morph physiological characteristics. On the above basis the current classification divides all plants species into three groups. The accumulator, that store metals mainly in the shoot high and low metal concentration in the soils. The indicators, with plants metals concentration reflecting the metal content in the environment. The excluder, with restricted transfer of heavy metals into the shoots whatever high are metal concentration in the environment and the roots.

Roadside plants are those which grow near roadside or highway and becoming relatively unsafe as a result of environment pollution of different type of heavy metals such as cobalt, copper, nickel, cadmium, lead etc. The advantage of using trees and shrubs for roadside plantings is their long lives and large size. They can make a positive visual impact for a long time (Kotas and Stasicka, 2000). The road side environment becomes harsh and sites usually have been disturbed during construction, resulting in shallow, compacted soils with little or no topsoil. These soils are not favorable for supporting ornamental plant growth so

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plant selected for use along roadsides must be able to withstand harsh conditions. Thus a best plant for the roadside is selected which help in investigating the environmental pollution as an indicator. Biological indicators have been used for many years to detect the deposition, accumulation and distribution of heavy metal pollution. The major environmental factor that affects metal uptake by plants is soil acidity, its cation exchange capacity, the content of organic and lime moisture potential granulometric composition and the concentration of macro and micro nutrients. Even this to grow and complete the life, plants needs not only macronutrients (nitrogen phosphorus, potassium, sulfur and magnesium) but also essential nutrients such as iron, zinc, nickel copper and lead (toxic metals). So plants take up toxic metals too. Many toxic metals such as zinc, manganese, nickel and copper are essential micronutrients. Thus plants may also be used as bioindicator for the environmental studied. Many scientists have also studied on it as. Naithani *et al.* (2010) have investigated in their study the presence of lead, cadmium, chromium, nickel, arsenic and mercury in two major ingredients (*Azadirachta indica* and *Curcuma longa*) of a polyherbal product-Ampucare. Majolagbe *et al.* (2010) had investigated 10 different species of trees from 42 sampling locations taken in Oyo town, southwest, Nigeria. The barks of these trees were analysed for trace metals: lead, copper, cadmium, chromium, zinc and iron, employing Flame Atomic Absorption Spectrophotometry. Yaşar *et al.* (2010) have studied the leaves (washed and unwashed) and bark samples of *Cercis siliquastrum L.* and *Subsp. siliquastrum* and soil samples collected from 59 different localities, belonged to five stations (urban, urban park, urban roadside). Nazli and Hashim (2010) have investigated that Mangrove forests in Peninsular Malaysia were increasingly threatened by heavy metal pollution. Due to their unique location, mangroves receive heavy metal pollution from upstream areas and the sea. In their study, the concentrations of Cadmium (Cd), Chromium (Cr), Copper (Cu), lead (Pb) and Zinc (Zn) in an important mangrove species, *Sonneratia caseolaris*, were measured. Kord *et al.* (2010) found in their study that, the pine tree (*Pinus eldarica* Medw.) needles were evaluated as the biomonitors of heavy metal contamination in Tehran, Iran. An experiment was carried out by Auda and Shakh Ali (2010) on carrot (*Daucus carota L.*) at the Ministry of Local Government (Al Zahra Municipality), Gaza Strip, Palestine. Its aim was to study the effect of (Cd and Zn) at different rates (10, 20 and 40 µg/g Cd) and (75, 150 and 225 µg/g Zn) on carrot plants. Pirzada *et al.* (2009) have reported that the indication provided by roadside plants have great significance in ecological terms particularly when environmental pollution is matter of concern. Soil and plant samples from ten locations along Islamabad highway were analyzed for lead

concentration (mg/kg) using AAS. Knezevic *et al.* (2009) have analyzed heavy metal contents in the trees, performed at the plantation of *P. elongata* and *P. fortunei* near Bela Crkva in the region of Banat, Belgrade, Serbia. Stankovic *et al.* (2009) have analyzed the heavy metal contents zinc, iron, lead, copper, nickel, chromium, manganese, cadmium, arsenic and mercury in leaves of the trees growing in urban part of the city of Belgrade, Serbia, wider city area and rural area in the leaves of the species *Paulownia longleaf* growing in the urban condition, samples were collected (leaves) from three locations. Jayakumar and Jaleed (2009) have studied the heavy metals cobalt and legume plant *soybean* to test the heavy metal accumulating ability of *soybean*. Cobalt was given to *soybean* (*Glycine max*) plants in pot culture by soil drenching method. Suzuki *et al.* (2009) have reported in their finding that the leaves of roadside *Rhododendron pulchrum* sweet may be used as a bioindicator of traffic-related heavy metal pollution in Okayama (U.S.A.) and keeping the previous study carried out on metal contamination in plant leaves the present study is undertaken. To this end, we undertook research to determine the content of heavy metals in four plants' leaves that growing in the region of Agra, India, along with statistical analysis in order to determine the correlation between different metal ions.

## MATERIALS AND METHODS

**Location of the sampling area:** To determine the toxicity of heavy metals in leaves of some higher plants, leaves samples were collected during summer of year 2010 in April, from naturally growing plants of Neem (*Azadirachta indica*), Kaner (*Nerium oleander L.*), Ashok (*Saraca indica L.*) and Imlı (Tamarindus indica) around the polluted and non polluted area of Agra .

Two areas were taken in under this study. The first one named "nonpolluted area" because it is far from man traffic road and hardly any industry. The second one "polluted area" is located near the main traffic road and also some local factories near it. Plant samples (leaves), which were collected from nonpolluted area, are named "control group" whereas sample collected from polluted area are named "exposure to pollution."

- **None polluted area (control group):** Raja Balwant Singh College, Faculty of Education campus, Lajpat Kunj, Agra.
- **Polluted area (exposure to pollution):** M. G. Road Agra is the main traffic road of the Agra city as shown in Fig. 1. Thousands of vehicles pass daily on this road because it is connected road to many links roads which goes to entire city, we have divided M.G. road into four sites for the sampling of leaves under polluted area:

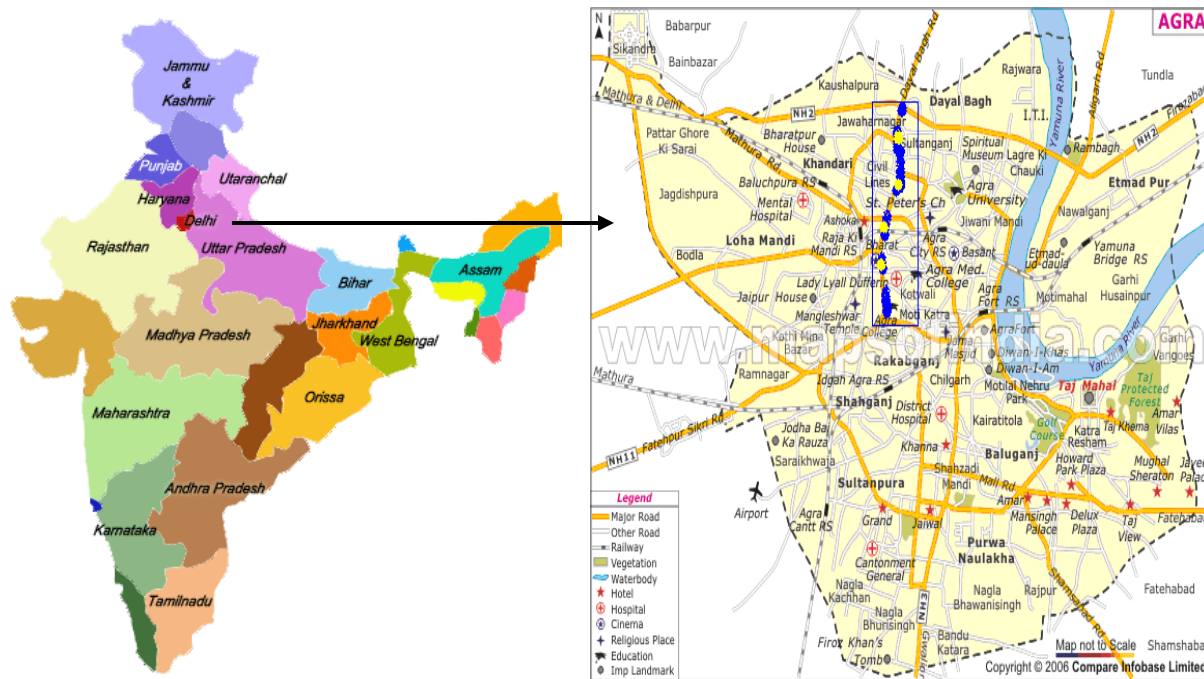


Fig. 1: Location of sampling area-polluted and control ground

- Bhagwan Cinema to Civil Court
- Civil Court to Sursadan
- Sursadan to Hariparvat
- Hariparvat to St. John's college

**Preparation of the samples:** Collected leaves were washed with tap water thoroughly to remove adhering unwanted materials and dried in an air. After drying 500 gm of plant leaves were placed in a porcelain dish and then was put in a muffle furnace and the temperature was raised to 450°C for the complete ashing of the leaves. Ash obtained from the muffle furnace is cooled and a fixed amount (5 gm) of ash was transferred into a 100 mL beaker and then dissolved in minimum amount of aquaregia (HNO<sub>3</sub> + 3HCl), evaporated to dryness on a heating mantel (Quraishi *et al.*, 2008). If the ash does not become white add more 1ml of the aquaregia, evaporate again to dryness and then cool and filter the solution through an acid washed filter paper in a 100 mL volumetric flask and dilute it with distilled water up to the mark. The obtained solution is then filtered through whatmann filter paper. After this the heavy metal concentration of chromium, lead, nickel, cobalt and cadmium in the filtrate were determined by atomic absorption spectrophotometer.

**Instrumental analysis:** The final metal ion concentrations in the samples were determined by using a Atomic absorption spectrophotometer (ECIL) 4141A. Standards stock solutions were prepared and linear calibration curves were obtained with correlation coefficients of R<sup>2</sup> = 0.99 or better. Three replicates of each sample were analyzed and the mean value reported.

**Estimations and calculations:** In our present study we have done standard deviation calculation with the help of Microsoft office excels.

**Percentage reduction:** Percentage reduction of heavy metals in the leaves of collected from polluted site was determined in comparison with leaves of control site using the following formula (Grigalaviciene *et al.*, 2005):

$$\text{Percentage reduction(\%)} = \frac{\text{Mean value for foliage of control area plant} - \text{Mean value for foliage of polluted area}}{\text{Mean value for foliage of control area plant}}$$

**Correlation coefficient (R):** The correlation coefficient *r* is a measure of the linear relationship between two attributes or columns of data. The correlation coefficient is also known as the Pearson product-moment correlation coefficient. The value of 'R' can range from -1 to +1 and is independent of the units of measurement. A value of 'R' near 0 indicates little correlation between attributes; a value near +1 or -1 indicates a high level of correlation. When two attributes have a positive correlation coefficient, an increase in the value of one attribute indicates a likely increase in the value of the second attribute. A correlation coefficient of less than 0 indicates a negative correlation. That is, when one attribute shows an increase in value, the other attribute tends to show a decrease.

Consider two variables *x* and *y*:

- If  $R = 1$ , then  $x$  and  $y$  are perfectly positively correlated. The possible values of  $x$  and  $y$  all lie on a straight line with a positive slope in the  $(x, y)$  plane
- If  $R = 0$ , then  $x$  and  $y$  are not correlated. They do not have an apparent linear relationship. However, this does not mean that  $x$  and  $y$  are statistically independent
- If  $R = -1$ , then  $x$  and  $y$  are perfectly negatively correlated. The possible values of  $x$  and  $y$  all lie on a straight line with a negative slope in the  $(x, y)$  plane

**Covariance:** Covariance is a measure of the linear relationship between two attributes or columns of data. The value of the covariance can range from -infinity to +infinity. However, if the value of the covariance is too small or too large to be represented by a number, the value is represented by NULL. Correlation coefficients between heavy metals in the different plants samples as mean heavy metal content of different places were calculated for each metal separately (correlation graphs).

## RESULTS AND DISCUSSION

**Metal ion concentration:** Environment Pollution with toxic metals has increased dramatically since the increasing of the industrial revolution (Zaidi *et al.*, 2005). Pollution by heavy metals such as cobalt, cadmium, lead, nickel and chromium etc is a problem of concern (Onder *et al.*, 2007). Heavy metals levels in plants have increased considerably due to traffic pollution especially from usage of leaded petrol and exhaust combustion. So it has become necessary to conduct this study to exhibit and determine the kind of

environmental pollution and how far they exhibit and efficient as the bioindicator in reducing the degree of pollution in environment. Level of heavy metals in plants samples collected from different roadside areas of Agra city in April 2010 are given in Table 1-7 and Fig. 2-6. Variance analyses of plants sample with heavy metals are given in correlation graphs (Fig. 7-21).

Lead is one of the major heavy metal considered as an environmental pollutant (Sharma *et al.*, 2005). Lead is considered as a general protoplasmic poison which is accumulative and slow acting. Besides natural weathering processes the main source of lead pollution are exhaust fumes of automobiles, chimneys of factories using lead, effluents from the storage battery, industry, mining and smelting of lead ores and roadsides vehicles pollutions (Eick *et al.*, 1999). The results of our analysis show that there are significant differences for lead between sampling sites in control and polluted area. Maximum lead content is 29.54  $\mu\text{g/g}$  found in *Azadirachta indica* plant and lowest concentration is 8.84  $\mu\text{g/g}$  found in *Saraca indica* in civil court to Sursadan area. The lead content of second site (Civil court to Sursadan) are higher than that of other sampling sites, all of them are along the main road. Many researchers have notified that heavy metal contents were higher in plants samples collected near a main road (Cabrera *et al.*, 1999; Simon *et al.*, 1999; Vidal *et al.*, 1999; Madejon *et al.*, 2002; Shallari *et al.*, 1998; Viard *et al.*, 2004). The addition of artificial fertilizer and pesticides causes an increase of lead levels in agricultural plants and roadside plants. The lead content in the plants samples in polluted area (as shown in the Table 1 and Fig. 2) are higher than the normal value (5-10)  $\mu\text{g/g}$  in plants. Table 6 shows the concentrations (Mean $\pm$ S.D.) of lead metal in all plants samples. This indicates that the range of lead is (14.70 $\pm$ 4.93) to (21.00 $\pm$ 3.06)  $\mu\text{g/g}$ , which is higher

Table 1: Concentration of the lead metal in  $\mu\text{g/g}$

Plant name	Polluted area				Non polluted area
	Site 1	Site 2	Site 3	Site 4	
Ashok ( <i>Saraca indica L</i> )	8.84	19.4	19.78	10.80	5.34
Neem ( <i>Azadirachta indica</i> )	17.44	29.54	19.78	15.48	5.24
Imli ( <i>Tamarindus indica</i> )	24.46	11.58	25.24	21.34	6.50
Kaner ( <i>Nerium odoroum</i> )	17.82	26.04	19.60	20.56	3.24

Table 2: Concentration of the chromium metal in  $\mu\text{g/g}$

Plant name	Polluted area				Non polluted area
	Site 1	Site 2	Site 3	Site 4	
Ashok ( <i>Saraca indica L</i> )	25.88	10.28	7.16	2.92	0.92
Neem ( <i>Azadirachta indica</i> )	10.28	7.160	0.92	3.72	1.04
Imli ( <i>Tamarindus indica</i> )	16.52	0.920	0.92	2.64	1.72
Kaner ( <i>Nerium odoroum L</i> )	10.28	4.040	4.04	2.90	1.84

Table 3: Concentration of the cadmium metal in  $\mu\text{g/g}$

Plant name	Polluted area				Non polluted area
	Site 1	Site 2	Site 3	Site 4	
Ashok ( <i>Saraca indica L</i> )	3.80	1.66	3.64	2.84	0.20
Neem ( <i>Azadirachta indica</i> )	3.96	3.12	3.78	3.52	0.50
Imli ( <i>Tamarindus indica</i> )	2.60	3.68	3.50	2.28	0.60
Kaner ( <i>Nerium odoroum</i> )	1.94	3.68	3.90	2.84	0.50

Table 4: Concentration of the nickel metal in µg/g

Plant name	Polluted area				Non polluted area
	Site 1	Site 2	Site 3	Site 4	
Ashok ( <i>Saraca indica L</i> )	32.86	35.64	4.260	20.46	2.960
Neem ( <i>Azardirachta indica</i> )	16.26	13.52	19.02	18.42	12.14
Imli ( <i>Tamarindus indica</i> )	13.48	26.40	28.24	17.42	2.960
Kaner ( <i>Nerium odororum</i> )	27.96	4.260	8.880	26.42	2.980

Table 5: Concentration of the cobalt metal in µg/g

Plant name	Polluted area				Non polluted area
	Site 1	Site 2	Site 3	Site 4	
Ashok ( <i>Saraca indica L</i> )	2.600	11.22	17.36	19.82	5.88
Neem ( <i>Azardirachta indica</i> )	18.58	29.66	24.74	28.42	7.24
Imli ( <i>Tamarindus indica</i> )	25.96	18.58	23.50	24.26	7.24
Kaner ( <i>Nerium odororum</i> )	29.66	40.70	21.04	28.28	11.3

Table 6: Standard deviation in the different plants in the polluted studied area, ±Standard error

Plant name	Cobalt	Nickel	Chromium	Lead	Cadmium
Ashok ( <i>Saraca indica L</i> )	12.75±6.44	23.30±12.39	11.56±8.6	14.70±4.93	2.98±0.84
Neem ( <i>Azardirachta indica</i> )	25.35±4.30	16.26±2.150	5.52±3.52	20.56±5.43	3.59±0.31
Imli ( <i>Tamarindus indica</i> )	23.07±2.70	21.385±6.13	5.25±6.54	20.66±5.43	3.01±0.58
Kaner ( <i>Nerium odororum</i> )	29.93±7.02	16.88±10.45	5.31±2.90	21.00±3.06	3.09±0.77

Table 7: Percentage reduction in levels of cobalt, nickel, chromium, lead, and cadmium in the leaves of naturally growing plants collected from different polluted areas

Heavy metals	Plant's name			
	Ashok ( <i>Saraca indica L</i> )	Neem ( <i>Azardirachta indica</i> )	Imli ( <i>Tamarindus indica</i> )	Kaner ( <i>Nerium odororum</i> )
Cobalt	116.80 <sup>+</sup>	250.1 <sup>+</sup>	218.6 <sup>+</sup>	164.7 <sup>+</sup>
Nickel	687.30 <sup>+</sup>	33.93 <sup>+</sup>	622.4 <sup>+</sup>	466.4 <sup>+</sup>
Chromium	1156.5 <sup>+</sup>	430.7 <sup>+</sup>	205.2 <sup>+</sup>	188.8 <sup>+</sup>
Lead	175.30 <sup>+</sup>	292.3 <sup>+</sup>	217.9 <sup>+</sup>	547.3 <sup>+</sup>
Cadmium	1390.5 <sup>+</sup>	619.0 <sup>+</sup>	402.5 <sup>+</sup>	518.0 <sup>+</sup>

<sup>+</sup>: Indicates the percentage increase in particular plant and metal

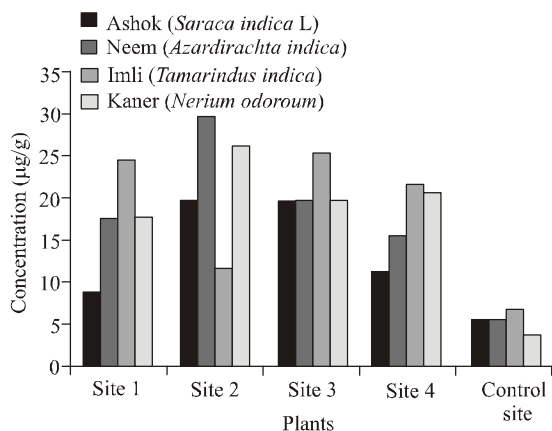


Fig. 2: Lead metal concentration in plant's leaves of studied area

than the normal limit (5-10) µg/g of lead in plants, but in control group, the range of lead is (3.24 to 6.5) µg/g which clearly indicate that in higher polluted area lead is 3 to 4 times higher than control group. Table 7 shows the percentage reduction of metals in samplings sites. There is a highest percentage reduction for Pb in *Nerium oleander L*. i.e., 547.3% + while the lowest is 175.3% + in *Saraca indica L* plant comparison to control area.

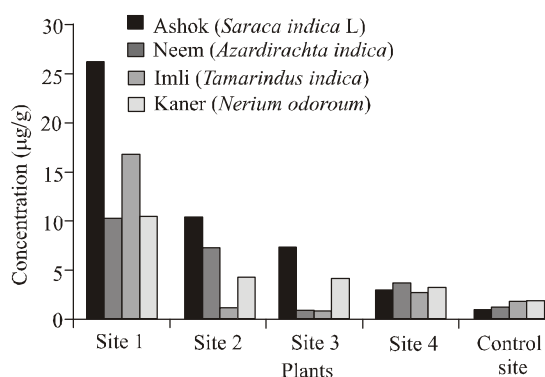


Fig. 3: Chromium metal concentration in plant's leaves of studied area

Chromium is considered as a serious environmental pollutant, due to wide industrial use (Shanker *et al.*, 2005). Leather industry is the major cause for the high influx of chromium to the biosphere (Barnhart, 1997). In India about 2000 to 32000 tons of elemental chromium annually escapes in to the environment from tanning industries. In Agra there is also a big scope of leather shoes industries which is the measure source of pollution in Agra city of chromium metal. Chromium compounds are highly toxic to plants

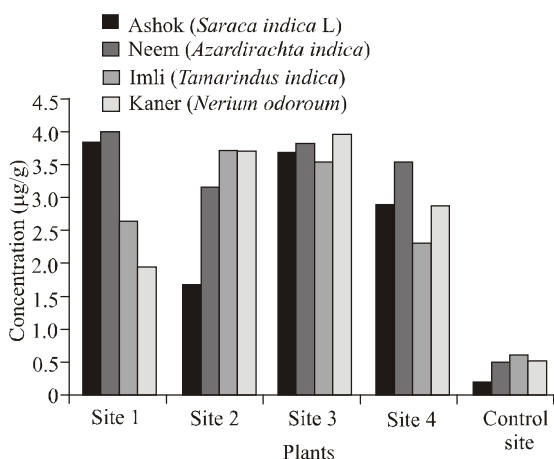


Fig. 4: Cadmium metal concentration in plant's leaves of studied area

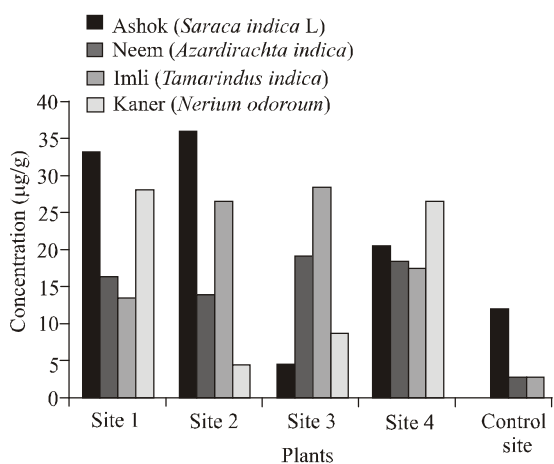


Fig. 5: Nickel metal concentration in plant's leaves of studied area

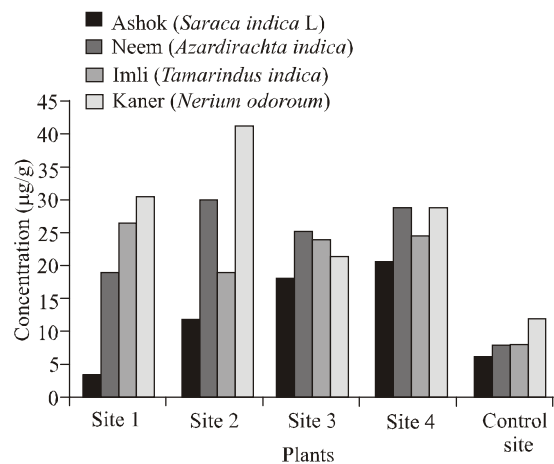


Fig. 6: Cobalt metal concentration in plant's leaves of studied area

and are detrimental to their growth and development. Significant differences in our analysis for chromium in

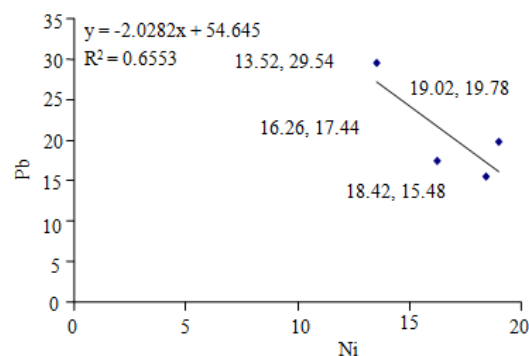


Fig. 7: Correlation between Ni and Pb in *Azadirachta indica*

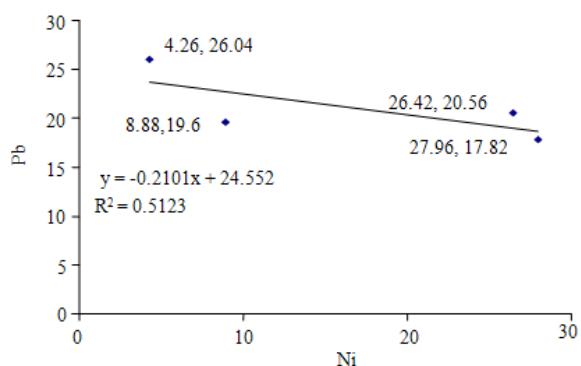


Fig. 8: Correlation between Ni and Pb in *Nerium odoroum*

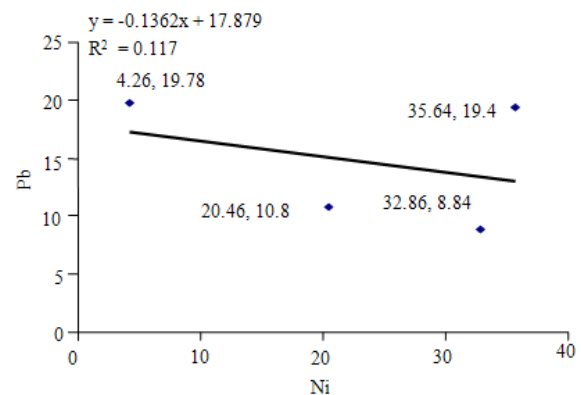


Fig. 9: Correlation between Ni and Pb in *Saraca indica*

plant samples are found. There are significant difference between polluted and control areas. From the Table 2 and Fig. 3, it is clear that the maximum chromium concentrations was measured 25.88 µg/g in *Saraca indica L* tree at first site (Bhawan cinema to civil court) and the lowest chromium concentration was measured 0.92 µg/g in both *Azadirachta indica* and *Tamarandus indica* at third site (Civil court to Sursadan) and at second and third site (Civil court to Sursadan and Sursadan to Hariparvat) respectively. The chromium contents in all the plant samples of polluted area are higher than the normal value (0.1-0.5) µg/g

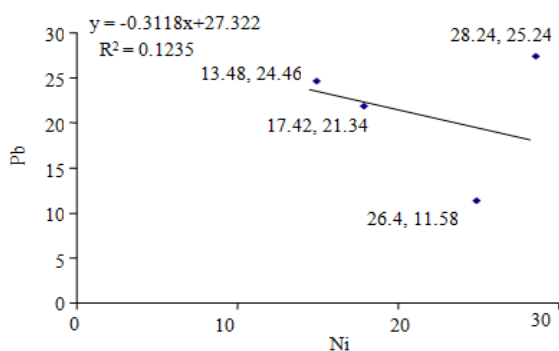


Fig. 10: Correlation between Ni and Pb in *Tamarindus indica*

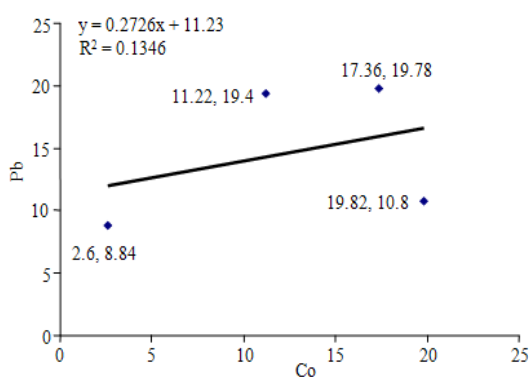


Fig. 11: Correlation between Co and Pb in *Saraca indica*

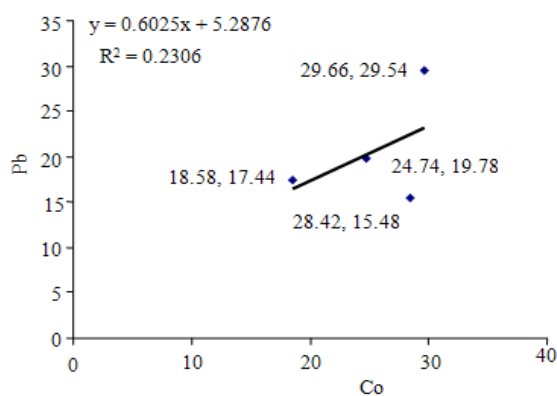


Fig. 12: Correlation between Co and Pb in *Azadirachta indica*

(Butkus and Baltrėnaitė, 2007) of chromium in plant but are in the excessive level (5-30)  $\mu\text{g/g}$  of plants. Table 6 shows that the concentration (Mean $\pm$ S.D.) of chromium metal in all the plant samples is ranging from  $5.25\pm 3.52$  to  $11.56\pm 8.67$   $\mu\text{g/g}$  which lies in the excessive level (5-30)  $\mu\text{g/g}$  (Butkus and Baltrėnaitė, 2007) of chromium in plant but in control group. The range of chromium is (0.92 to 1.84)  $\mu\text{g/g}$ , which indicates that in polluted area chromium, is 8-9 times higher than control group. Table 7 shows the percentage reduction of metals in samplings sites. There is a highest percentage reduction in *Saraca indica* L

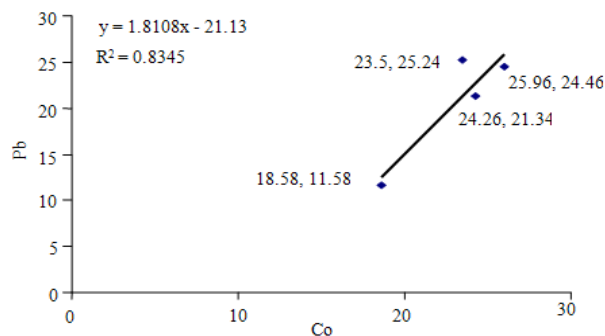


Fig. 13: Correlation between Co and Pb in *Tamarindus indica*

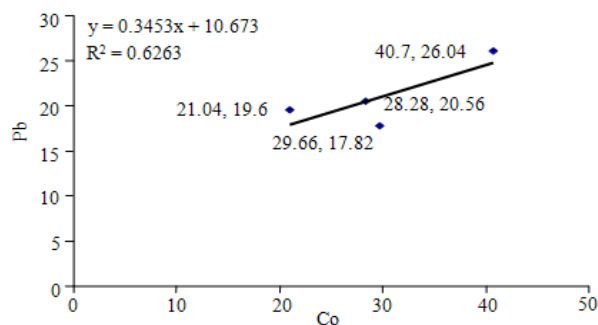


Fig. 14: Correlation between Co and Pb in *Nerium odorum*

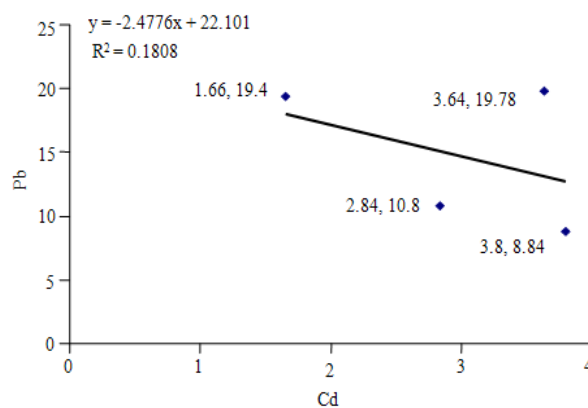


Fig. 15: Correlation between Cd and Pb in *Saraca indica*

plant 1156.5% + than the control areas while the lowest percentage reduction is 188.8% + is in *Nerium oleander* L plant. This clarifies that the investigated area (polluted area) runs a risk of chromium pollution in roadside plants in comparison to control area.

Cadmium is dispersed in natural environment through human activities as well as natural rock mineralization process thus plants can easily absorb cadmium from soil and transport in to shoot system. Cadmium induces complex changes in plants at genetically, biochemical and physiological levels: whose most obvious symptoms are: reduction of tissue, organ growth and leaf chlorosis and leaf and root necrosis. Our analyses for cadmium in the roadside plants samples showed that there are significant



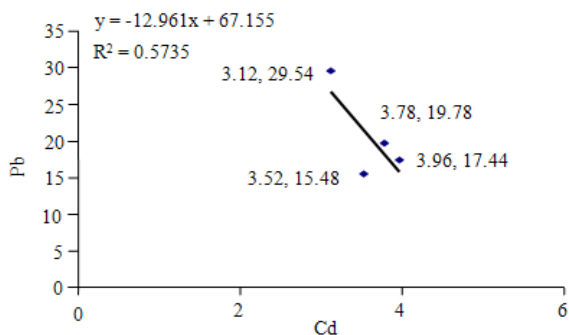


Fig. 16: Correlation between Cd and Pb in *Azadirachta indica*

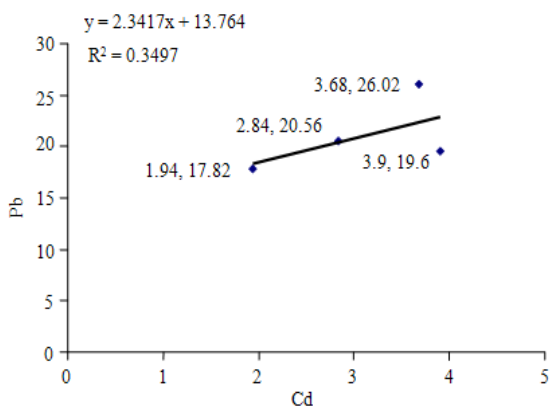


Fig. 17: Correlation between Cd and Pb in *Nerium odororum*

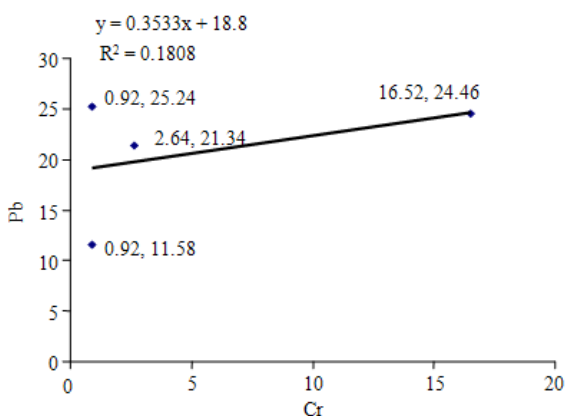


Fig. 18: Correlation between Cr and Pb in *Tamarindus indica*

differences between polluted and control area. The highest cadmium in all the samples of polluted area was found 3.96  $\mu\text{g/g}$  in *Azadirachta indica* plant at first site (Bhagwan cinema to civil court) and the lowest concentration was found 1.66  $\mu\text{g/g}$  in *Saraca indica* at second site (Civil court to Sursadan). The main sources of environmental cadmium pollution are vehicle wheels, mineral oils and usage of waste mud and these increase cadmium levels of plants (Gune *et al.*, 2004). The cadmium contents in all the plants samples of polluted area (Table 3 and Fig. 4) are above the maximum allowed limit 1  $\mu\text{g/g}$  in plants. Table 6 shows

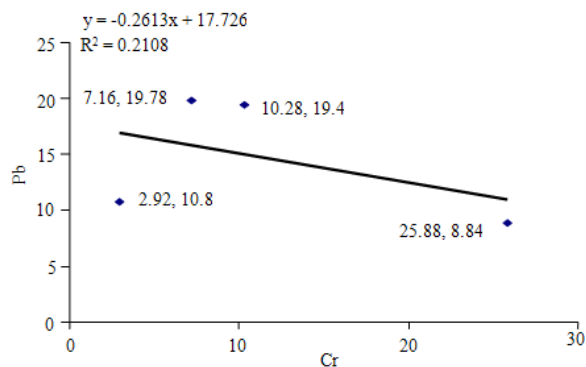


Fig. 19: Correlation between Cr and Pb in *Saraca indica*

the mean concentration of cadmium in all plant samples indicating that the range of cadmium is  $(2.98 \pm 0.84)$  to  $(3.59 \pm 0.31)$   $\mu\text{g/g}$  which is higher than the maximum allowed limit 1  $\mu\text{g/g}$ . In control group, the range of chromium is (0.20 to 0.60  $\mu\text{g/g}$ )  $\mu\text{g/g}$  which indicates that in polluted group cadmium was 10-14 times higher than control group. Table 7 shows the percentage reduction of metals in samplings sites. There is a highest percentage reduction of 1390.5% + in *Saraca indica L* than control group and lowest is 402.5% + in *Tamarindus indica* plant in comparison to control area.

Nickel is a micronutrient required at very low concentration by plants, mostly in  $\text{Ni}^{2+}$  state, at high concentration nickel inhibits plant growth but in addition to other heavy metals which may be found in industrial wastes i.e., zinc, copper, chromium, nickel etc. are the element most likely to damage plants with some reinforcement. Nickel phytotoxicity varies with the concentration of nickel in soil solution as well as with the plant species. Studies in different countries show nickel contents in soil on a wide scale from 0.2 to 450 ppm that explain that nickel is absorbed easily and rapidly by plants. The results of our analysis show that there are significant differences between sampling sites in control and polluted area. Maximum nickel content was found 35.64  $\mu\text{g/g}$  in *Saraca indica L* plant at second site (civil court to sursadan) and the lowest concentration 4.26  $\mu\text{g/g}$  were found in *Nerium odororum* at second site (civil court to sursadan) and in *Saraca indica L* at third site (Sursadan to Hariparvat). The nickel contents in all the plants samples of polluted area (Table 4 and Fig. 5) are higher than the normal values (0.1-5)  $\mu\text{g/g}$  (Butkus and Baltrėnaitė, 2007) in plants. Table 6 shows the concentrations (Mean $\pm$ S.D.) of nickel metal in all plants samples. The range of nickel is  $(23.3 \pm 12.39)$  to  $(16.26 \pm 2.15)$   $\mu\text{g/g}$  which lies in the excessive level (10-100)  $\mu\text{g/g}$  (Butkus and Baltrėnaitė, 2007) but in control group the range of nickel was found (2.96 to 12.14)  $\mu\text{g/g}$  indicates that in polluted area nickel is 7-10 times higher than control area. Table 7 shows the percentage reduction of metals in samplings sites. There is a highest percentage reduction of 687.3% + in *Saraca indica L* and lowest 33.93% + in *Azadirachta indica* plants comparison to control area.



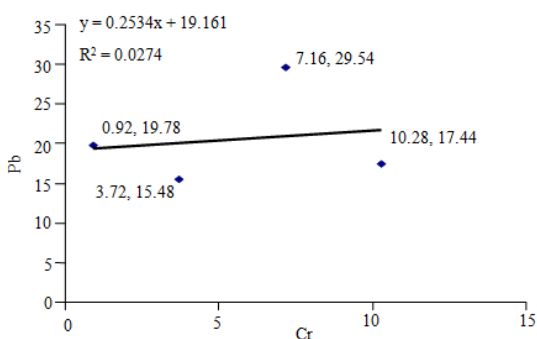


Fig. 20: Correlation between Cr and Pb in *Azadirachta indica*

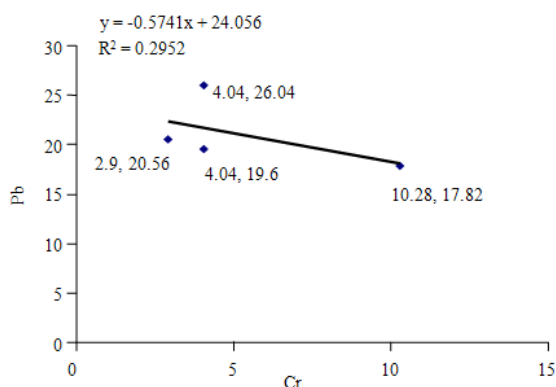


Fig. 21: Correlation between Cr and Pb in *Nerium odorum*

Metals play an integral role in life process of microorganism. Cobalt is such an essential metal which serves as micronutrients and used for redox-process to stabilize molecules through electrostatic interactions as component of various enzymes and for regulation of osmotic pressure. But at high level chromium metal damage cell membrane: alter enzyme specifically: disturb cellular function; and damage the structure of DNA. The results show that there are significant differences between sampling site in control and polluted area. Maximum cobalt content is found 40.70  $\mu\text{g/g}$  in *Nerium odorum* plant at second site (civil court to sursadan) and the lowest concentration was found 2.60  $\mu\text{g/g}$  in *Saraca indica L.* at first site. The cobalt contents in all the plants samples of polluted area (Table 5 and Fig. 6) are higher than the toxic level 10  $\mu\text{g/g}$ . Table 6 shows the mean concentrations (Mean $\pm$ S.D.) of cobalt metal in all plant samples indicate that the range of cobalt metal in all plant samples are (12.75 $\pm$ 6.44) to (29.93 $\pm$ 7.02)  $\mu\text{g/g}$  which is above the toxic level of cobalt in plants. In control group the range of cobalt was found (5.88 to 11.30)  $\mu\text{g/g}$  indicating that in polluted area cobalt is 2-3 times higher than control group. Table 7 shows the percentage reduction of metals in sampling sites. There is a highest percentage reduction of 250.1% + in *Azadirachta indica* plant and lowest 116.8% + in *Saraca indica L.* plant comparison to control area.

### Statistical analysis:

**Correlation between heavy metals in different plants:** Correlation is a statistical measurement of the relationship between two variables. Possible correlations range from +1 to -1. A zero correlation indicated that there is no relationship between the variables. A correlation of -1 indicates a perfect negative correlation, meaning that as one variable goes up, the other goes down. A correlation of +1 indicates a perfect positive correlation, meaning that both variables move in the same direction together.

Correlation between heavy metals in different plants as mean heavy metal contents of different sample places are calculated for each metal separately. There are positive correlations between heavy metals in different plants, these relations are not statically significant for all the plants and all metals but are significant for cadmium in *Azadirachta indica*, nickel in *Azadirachta indica*, nickel in *Nerium oleander L.*, cobalt in *Tamarindus indica* and cobalt in *Nerium oleander L.* (0.5735, 0.6553, 0.5123, 0.8345 and 0.6263) which concluded that the source of all the heavy metals are same i.e., roadside vehicle pollution. The highest value of correlation coefficient is found between lead and cobalt (0.8345) in *Tamarindus indica* and the lowest correlation coefficient is found between lead and nickel (0.0274) in *Azadirachta indica*. Positive correlations for metal contents between heavy metals in different plants are found in expected results, because plants take nutritional elements from the environment through soil and leaves.

According to these results of the present study cobalt and lead concentrations were far above the threshold levels, implying that these elements could be potentially harmful on local vegetation and environments in the future if the emission of pollutants is not controlled effectively. It has been reported that plants with spiny and hairy leaves accumulated more heavy metals as compared to smooth-leaved plants. High element concentrations may cause loss of plants leaves production in the future in the study area. In this study, nickel, chromium and cadmium concentrations are also far above the threshold levels which implying that these elements most likely to damage plants with some reinforcement and injures higher plants by damaging their foliage, impairing the process of photosynthesis (food making) and also weakens trees. The order of heavy metals found in this study is as follows Co>Pb>Ni>Cr>Cd. These results explain the fact that heavy metals like lead and cobalt are the results of low quality fuel and leaded petrol which are accumulated directly in the plants leaves. Overall the result reports that plants such as *Azadirachta indica*, *Tamarindus indica*, *Saraca indica L.* and *Nerium oleander L.* are good bioindicators and can be used in air pollution monitoring studies in industrial areas.

## CONCLUSION

These results explain the fact that heavy metals like lead and cobalt are the results of low quality fuel and leaded petrol which are accumulated directly in the plants leaves. Overall the result reports that plants such as *Azadirachta indica*, *Tamarindus indica*, *Saraca indica L* and *Nerium oleander L*. are good bioindicators and can be used in air pollution monitoring studies in industrial areas. Another fact that arises is that the plants having more accumulation properties can be used for removing the heavy metal toxicity in the roadside environment in an affecting and natural way.

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