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Bioindicators: Study on Uptake and Accumulation of Heavy Metals in Plant Leaves of State Highway Road, Bagalkot, India

N. M. Rolli[1*], S. B. Gadi[2] and T. P. Giraddi[1]

[1]BLDEA's Degree College, Jamkhandi, 587301, Karnataka, India.
[2]Department of Botany, JSS College, Dharwad, 580004, Karnataka, India.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this study, Caesalpinia (*Caesalpinia pulcherrima*) and grass (*Cyndon dactylon*) was evaluated as the bioindicators of heavy metals such as the Lead (Pb), Copper (Cu), Cadmium (Cd), Manganese (Mn), Zinc (Zn), Chromium (Cr) and Nickel (Ni) contaminated in Bagalkot and along the state high way upto Mudhol. The soil samples at depth (0-20 cm) and caesalpinia and grass leaves were taken from different sampling stations namely Navnagar bypass road (S_1), Gaddanakeri cross (S_2), Tulasigeri (S_3), Kaladagi (S_4), Lokapur (S_5), Chichakhandi (S_6) and Mudhol (S_7). The concentrations of Pb, Cu, Cd, Mn, Zn, Cr and Ni were measured using GBC- 932 plus Atomic Absorption Spectrophotometer (Austrelia). The results of the study shows that the concentrations of heavy metals in caesalpinia ranged from Pb 20.36 to 29.39 µg/gmm, Cu 3.92 – 5.94 µg/gm, Zn 24.40 to 35.7 µg/gm, Cd 1.01 to 1.78 µg/gm, Mn 27.01 to 69.10 µg/gm, Cr 1.20 to 7.8 µg/gm and Ni 7.9 to 13.1 µg/gm. In grass heavy metal ranges between for Pb 20.16 to 28.01, Cu 3.95 to 5.76

**Corresponding author: E-mail: drnmrolli@rediffmail.com;*

µg/gm, Zn 24.50 to 35.8 µg/gm, Cd 1.15 to 1.52 µg/gm, Mn 28.91 to 72.51 µg/gm, Cr 1.28 to 8.0 µg/gm, Ni 8.1 to 15.1 µg/gm. Similarly in roadside soil heavy metal ranges between Pb 81.91 to 139.8 µg/gm, Cu 39.54 to 58.58 µg/gm, Zn 32.29 to 381.54 µg/gm, Cd 1.51 to 2.08 µg/gm, Mn 1257.9 to 2051 µg/gm, Cr 131.9 to 951.2 µg/gm and Ni 69.53 to 108.6 µg/gm. According to these results the concentration of heavy metals in grass was found high as compared to caesalpinia. Thus, compared to the metal accumulation potential grass is said to be heavy metal accumulator. The variation in heavy metal concentrations is due to changes in traffic density and anthropogenic activities. Thus, generally it is considered that grass and caesalpinia are good bioindicators and can be used in air pollution monitoring studies.

Keywords: Heavy metals; bioindicators; accumulation; anthropogenic activities.

1. INTRODUCTION

Environment pollution with toxic metals has increased since increasing industrialization and human activities [1]. Emissions of various pollutants into the atmosphere have a lot of harmful effects on plants growth [2]. Rapid urbanization, unregulated industrialization growing transport intensity and agricultural practices have created heavy metals concentrations in serious stage [3]. Plants have a major contributions in purifying land water and environmental air. Entrance of heavy metals may occur in human and animal food chain as a result of their uptake by edible plant grown in contaminated soil [4]. The toxic and hazardous effects of some heavy metals on human health are very significant and may cause many fatal diseases.

Lead (Pb) is one of the heavy metal that is responsible for anemia, neurological disorder, hyperactivity and changes in blood enzymes in human body [5]. Cadmium (Cd) and Zn are important toxic metals and longtime exposure of which may cause renal, pulmonary, hepatic, skeletal, reproductive and many other carcinogenic effects [6,7]. It is widely recognized that the principal reasons of heavy metals (Pb, Cu and Cd) derived from traffic congestion, long-range transport and household heating [8]. The spreading of contaminants is influenced by meteorological parameters such as rainfall, wind and traffic intensity [4]. The same meteorological conditions affect the concentration of same contaminants in the roadside soil [8]. The traffic density determines the lead level in soil and vegetation [9-11].

Soil samples and vegetation are the most economic and reasonable ways for assessing heavy metal status in the atmosphere [12]. Acacia [13], grass [14], plants [15], and other organisms such as fish [16] have also have been used for monitoring. In order to assess contamination by metals in the vicinity of a highway, several studies have been carried out with the different compartments: Study of global deposits, roadside soil and vegetation [8]. Information on accumulation of heavy metal on roadside soil of this city due to highway traffic and vehicles is very limited [17], but this could be the new threat for agriculture. Determination of heavy metal accumulation in roadside soil may be an index of the environmental pollution of Bagalkot city. Keeping this view in mind, the research was conducted to know the heavy metal accumulation of roadside soil, grass and caesalpinia of Bagalkot city and along the state highway from Bagalkot to Mudhol.

2. MATERIALS AND METHODS

Bagalkot is the city of Northern region of Karnataka at latitude $16^{\circ} 04^{1}$ N to $16^{\circ} 21^{1}$ North and longitude $75^{\circ} 26^{1}$ E to $76^{\circ} 02^{1}$ Eastern. The city is suffered from high traffic density caused by vehicles. Grass, caesalpinia and soil were collected during 2013, which were three meters away from the State High way (Fig. 1 and Table 1) passing through Navanagar. Grass and caesalpinia samples were collected from each site at three random spots those were spaced approximately at one meter interval. The leaves were clipped with stainless steel scissors. All the samples of each site were combined to give composite samples of about 300 to 500 gm. The leaves of Grass (*Cyndon dactylon*) and Caesalpinia *(Caesalpinia pulcherrima*) samples were dried at 80℃ for 48 hrs fine by powdered and sieved through 0.2 mm sieve. One gram sample was digested using Gerhardt digestion unit using mixed acid digestion method [18]. The digested material was diluted with double distilled water and filtered through Whattman paper 41 and made upto 100 ml.

Table 1. Sampling stations

Station no.	Sampling station	Nature of stations
Control	**Navanagar (Bagalkot)**	**Unpolluted urban area- vehicular movement is negligible, unpolluted area with less disturbance**
1	Navanagar Bypass road	Vehicular movement is high
2	Gaddankeri cross	Vehicular movement is high. Agricultural fields on either side of the road
3	Tulasigeri	Bricks factories around the Gaddankeri cross, vehicular traffic is high
4	Kaladagi	Vehicular movement is high. Agricultural fields on either side of the road
5	Lokapur	Vehicular movement is high. Agricultural fields on either side of the road
6	Chichakhandi	Vehicular movement is high. Agricultural fields on either side of the road
7	Mudhol	Vehicular movement is high. Agricultural fields on either side of the road

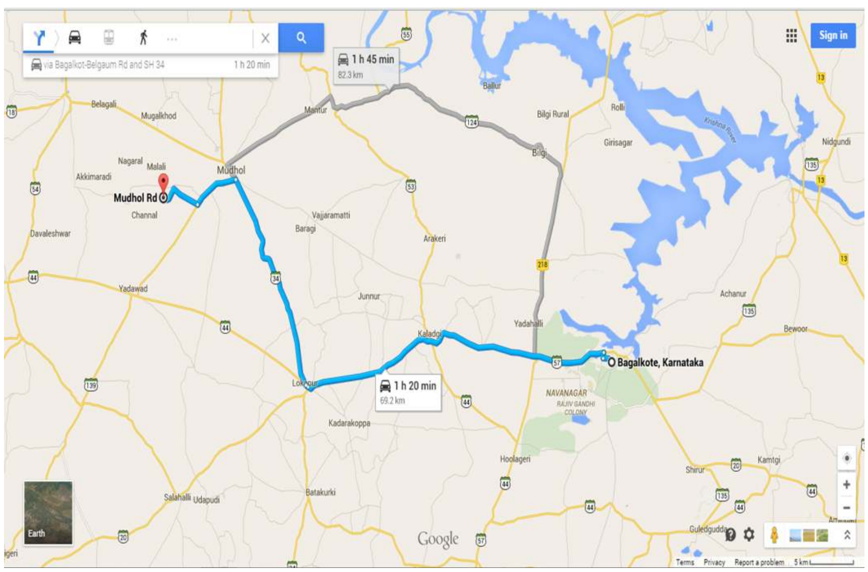

Fig. 1. Map showing the state highway of Bagalkot

Similarly, soil samples were dried, powdered and sieved through 0.2 mm sieve. One gram of sample was digested Gerhardt digestion unit according to Allen et al. [18] method (mixed acid digestion method. The results were in triplicates. The resulting extracts were diluted and filtered through Whattman No 41 paper and made upto 100 ml using double distilled water and analyzed for heavy metals viz Pb (Lead), Cd (Cadmium), Cu (Copper), Zn (Zinc), Mn (Manganese), Ni (Nickel) and Cr (Chromium) with GBC-932 plus Atomic Absorption Spectrophotometer (AAS) (Austrelia)with an air / acetylene flame and metal hollow cathode lamps. Respective wavelengths were used for the estimation of solutions for heavy metals were purchased from Siscochemical Laboratory Bombay (1000 mg/l). For Cd 228.8 nm, Pb 217.0 nm, Ni 232.0 nm, Cu 324.7 nm, Zn 213.9 nm, Mn 279.5 nm and Cr 221.8 nm filters have been used for the estimation using AAS. The working standards were prepared by serial dilution of standard stock solutions and were used for the calibration of the instrument [18].

3. RESULTS AND DISCUSSION

Environmental pollution with toxic metals has increased dramatically since the increasing of vehicular exhausts [19]. The pollution by heavy metals such as Lead, Cadmium, Nickel, Chromium etc is a problem of concern [20]. So it is now necessary to conduct this study and to determine the kinds of environmental pollution and how for these exhibit and act as an efficient bioindicator in reducing the degree of pollution in the environment. The samples were collected along the state highway between Bagalkot to Mudhol for the estimation of heavy metals (Fig. 1). Correlation coefficient of heavy metals in roadside soil, grass and caesalpinia plant samples are given in the Tables 3 and 4. The analysis showed high levels of heavy metals in the leaves of caesalpinia and grass collected from the polluted as compared to less polluted sites of the city (Control).

The ranges and arithmetic mean of heavy metal concentration of soil, grass and caesalpinia samples of state high-way and control sites are presented in the Table 2.

Lead is one of the major heavy metal and is considered as an environmental toxic pollutant [21]. Lead is considered as more toxic pollutant which brings about many physiological disorders. The main sources of lead are exhaust fumes of automobiles, chimneys of factory, roadside vehicles pollution [22]. The results shows that soils tend to accumulate more Pb then grass and caesalpinia leaves. The highest Pb level found in the soil (roadside) was 139.8 µg/gm, in grass it was 28.01 µg/gm, similarly in caesalpinia leaves it was found that 29.39 µg/gm. The mean soil Pb level was 95.71 µg/gm indicated considerable contamination of metal in the roadside environment; however, the control soil has a baseline level of 70.50 µg/gm. The results of our analysis represents, there should be significant differences for lead between sampling sites in control and polluted areas. The lead is rapidly washed onto the soil by rain water from the surface also by the death and decomposition of the plant [23,24]. Many literatures have notified the contents of heavy metals were higher in plant samples collected along the roadside of highways [8].

Copper is also one of the major heavy metal considered as an environmental pollutant. Copper is a micronutrient but toxic when it is in excess concentration. The source of copper being due to corrosion of metallic parts of cars derived from engine wear, brushing and bearing metals [25]. The mean Cu level in roadside soil (49.71 µg/gm) found to be much higher than the grass (4.87 µg/gm) and caesalpinia (4.70 µg/gm).

The main source of Zn on the roadside is because of automobile traffic i.e break lining looses of oil and cooling liquid [26]. Arithmetic mean of Zn of the roadside soil from Bagalkot to Mudhol state highway owes relatively high level of 188.31 µg/gm with a range of 32.29 – 381.54 µg/gm. the range of Zn 24.40 – 35.70 µg/gm in caesalpinia and grass 24.50 – 35.8 µg/gm. however, the Zn content in the test plant samples of polluted area are below the allowed limit (15 – 100 µg/gm) [18].

The main sources of environmental cadmium pollution are vehicle wheels, mineral oils increases Cd levels of environment and plants [27]. Cd dispersed in the natural environment through anthropogenic activities as well as natural rock mineralization process and thus, plants can easily absorbs Cd from the soil and also transport to the shoot levels. Cadmium induces complex changes in plants genetical, physiological and biochemical levels. The values were found little higher than allowed limit (1 µg/gm) in plants, i.e the Cd level in roadside soil averaged about 2.0 µg/gm and was observed that Cd was the lowest among the seven metals tested. The mean Cd in caesalpinia was 1.41 µg/gm and in grass, it is found to be 1.57 µg/gm. These findings were in confirmation with Shafia et al. [28].

From the results it was found that the soil, grass and caesalpinia contained high level of Manganese than other limits. Roadside soil, grass and caesalpinia had average 1528.34 µg/gm, 56.606 µg/gm and 56.10 µg/gm respectively. The attribution of Mn content is the lithogenic factor apart from vehicular pollution [29].

Chromium is considered as a serious concern with respect to health of biotics particularly in detrimental to plant growth and development. Cement, limestone industries are the major causes for the high influx of chromium into the atmosphere [29]. Significant differences in our analysis for chromium in soil and in plant samples are found. Chromium level was too high in roadside soil (315.54 µg/gm against control 110.41 µg/gm. In caesalpinia it was found to be 4.61 µg/gm, in grass it is found that 4.90 µg/gm against control (zero). Thus, the Cr content in soil and test plant samples of polluted area are above the maximum allowed limit (soil- 10-200 µg/gm, plant- 0.05-0.5 µg/gm).

Table 2. Metal accumulation profile in caesalpinia, grass and soil

S. no	Heavy metals	Control (µg g-1 dry wt.)	Roadside Caesalpinia (µg g-1 dry wt.)		Roadside grass (µg g-1 dry wt.)		Control (µg g-1 dry wt.)	Roadside soil (µg g-1 dry wt.)	
			Range	Mean ± SE	Range	Mean±SE		Range	Mean± SE
1	Lead	18.46	20.36-29.39	23.73±1.84	20.16-28.01	23.736±1.84	70.50	81.91-139.8	95.71±8.71
2	Copper	2.15	3.92-5.94	4.70±0.35	3.95-5.76	4.87±0.35	34.91	39.54-58.58	49.71±3.51
3	Zinc	16.19	24.40-35.7	32.84±3.10	24.50-35.8	32.87±3.11	29.84	32.29-381.54	188.3±54.28
4	Cadmium	0.82	1.01-1.78	1.41±0.08	1.15-1.52	1.571±0.082	2.16	1.51-2.08	2.0±0.19
5	Manganese	15.72	27.01-69.10	56.10±7.30	28.91-72.51	56.606±7.36	1254.1	1257.9-2051.5	1528.3±26.5
6	Chromium	N.D	1.20-7.8	4.61±2.20	1.28-8.00	4.90±2.23	110.41	131.9-951.2	315.54±2.46
7	Nickel	6.70	7.9-13.1	9.10±1.40	8.1-15.1	10.51±1.411	69.38	69.53-108.6	85.91±5.91

ND- Not detectable; Mean values ± standard error

Table 3. Correlation coefficient of heavy metals in roadside soil and grass

S. no.	Metal	r. value
1	Lead	0.628*
2	Copper	0.481*
3	Zinc	0.829*
4	Cadmium	0.748*
5	Manganese	0.529*
6	Nickel	0.331*
7	Chromium	0.215*

r= 0.60 and above have significant correlation

Table 4. Correlation coefficient of heavy metals in roadside soil and caesalpinia

S. no.	Metal	r. value
1	Lead	0.627*
2	Copper	0.480*
3	Zinc	0.824*
4	Cadmium	0.740*
5	Manganese	0.520*
6	Nickel	0.321*
7	Chromium	0.210*

r= 0.60 and above have significant correlation

Nickel is a micronutrient required at very low concentration by the plants normally in Ni^{+2} state, at high concentration Ni inhibits plant growth. The maximum Ni content was found 10.5 µg/gm in grass than caesalpinia with 9.10 µg/gm. Generally it is concluded that Ni content in test plant samples of polluted area are higher than the normal values (0.1 – 5.0 µg/gm) in plants [18].

Simple correlations (r > 0.60) between the metal Pb, Cu, Ni, Mn, Fe, Zn and Cd were calculated and are given in the Tables 3 and 4. Significant correlations between the metal levels in roadside soil, caesalpinia and grass were found in Zn, Cd and Ni (r > 0.06). It may be indicating the bioconcentration of these metals in soil, grass and caesalpinia, in addition to aerial deposition. This may attributed to the favorable root environment [30] i.e soil conditions might have favored their absorption. Correlations in case of chromium, nickel, manganese and copper contents between soil, grass and caesalpinia were low due to low bioavailability of these metals owing to unfavorable root environment. Whatever excess content of these metals found in grass and caesalpinia was presumed to be due to the aerial decomposition contributed by motor vehicles.

Thus, the order of increment of heavy metals in roadside soil is as follows: Mn > Cr > Zn > Pb > Ni > Cu > Cd, whereas in grass: Mn> Zn> Pb> Ni> Cr> Cu> Cd and in caesalpinia: Mn>Zn > Pb> Ni> Cu> Cr > Cd. The elevated levels of heavy metals in the roadside soil, grass and caesalpinia is an evidence of airborne pollutants of roadside environment along the state high way of Bagalkot to Mudhol. Soils due to their cation exchange capacity (CEC), complexing organic substances, oxides and carbonates, have high retention capacity for the heavy metals [31]. Thus, contamination levels increase continuously as long as the nearby sources remain active. During the last decade, the Bagalakot to Mudhol state high way has witnessed sharp increase in vehicle number due to urbanization. Similar observation in Caesalpinia in Madhurai city of southern region of Tamil Nadu [32].

In soil, the lesser mobility of metals and its accumulation on a long-term basis, leads to overall higher contamination level of metals; whereas, in roadside grass, caesalpinia it represents more accumulation due to turnover of plant materials (like new growths, the senescence followed by abscission of old parts) and meteorological influences [33]. Thus, the study of metal concentration of both roadside soil, grass and caesalpinia reflects the extent of aerial contamination of the roadside environment. The penetration of heavy metals into the food chains due to vehicular emissions may cause a long- range ecological and health hazard.

The results of our study indicate that the concentration of heavy metals such as Pb, Cd, Mn, Ni, Cu and Cr from the traffic area is an indicative of anthropogenic pollution.

4. CONCLUSION

It was concluded that with an increase in the amount of heavy metals in soil and their uptake by plants also increase. The mobility of heavy metals are highly translocated from soil to plant leaves in all the sampling sites. According to our study grass shows slight greater accumulation potentiality than caesalpinia. High metal concentrations in plants are contained in urban and highway roadsides due to the anthropogenic activities in addition to the traffic density. The heavy metal concentration was maximum in the study area along the roadside of Bagalkot to Mudhol. Caesalpinia is widely distributed at Bagalkot (Navanagar) is used as roadside ornamental plant and the grass is the good food for grazing animals. In accordance with the data presented here grass and caesalpinia possess all characteristics and are selected as bioindicators.

There is also a need for enforcement of regulations to control environmental pollution. Public participation, non-governmental organization and civic agencies of the government required collective approach towards the solution. Continuous air monitoring for one or more pollutants is an absolute necessity for completing a diagnosis of pollutant level in the air, water and soil environment. Most importantly, a network of monitoring stations throughout the country would be helpful to measure the current pollutant level. Accumulation of air monitoring data will provide the criteria needed for establishing air quality standards.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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