Metal Accumulation Profile in Roadside Soils, Grass and Caesalpinia Plant Leaves: Bioindicators

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Abstract
Heavy metals are important environmental pollutants and their toxicity in human, plants and animals have been received much more attention. A study was conducted to investigate the heavy metal pollution of roadside soil, grass and Caesalpinia species of Bagalkot city (India). The highest levels of metal concentration of Pb, Cu, Cd, Mn, Zn, Cr and Ni were found in the samples from very traffic congestion. The soil samples at a depth (0-20 cm) grass leaves and Caesalpinia leaves were taken from different sampling sites viz; S1, S2, S3, S4 and S5 on state high way with high traffic roads passing through Bagalkot (India) were determined by Atomic Absorption Spectrophotometer. Results showed that soil and both grass and Caesalpinia contained elevated levels of the metal. It was found that the primary source of the contamination occurs mainly by the vehicular exhausts. The increased circulation of the toxic metals in soils, grass and Caesalpinia may result in the inevitable build up of such xenobiotics in the food chain. The variation in heavy metal concentration is due to the changes in traffic density and anthropogenic activities. Thus, it is concluded that grass, Caesalpinia and soil samples were used as bioindicators of metal pollution in roadside.

Keywords: Bioindicators; Xenobiotics; Caesalpinia; Grass; Food chain

Introduction

Environmental pollution has increasing in tremendous rate after global industrialization that has negative impacts on human health and ecosystem services [1]. The contribution of cars and road transports to the global emission of atmospheric pollutants is regularly increasing [2]. The road transports also induce the contamination of nearer soils by a pollutant transfer via the atmospheric fallouts [3] or road runoff [3,4]. Bagalkot is one of the busiest city in Karnataka, emission from transport vehicles results in significant heavy metal accumulation in roadside soils of Bagalkot city.

Nowadays, the toxic effects of heavy metals are burning issues and been studied by many researchers [5,6]. Entrance of heavy metals may occur in human and animal food chain as a result of their uptake by edible plants grown in contaminated soil [7]. 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 [8]. Cadmium (Cd) and Zn are important toxic metals and longtime exposure of which may causes renal, pulmonary, hepatic, skeletal, reproductive and many other carcinogenic effects [9,10].

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 [2]. The spreading of contaminants is influenced by meteorological parameters such as rainfall, wind and traffic intensity [7]. The same meteorological conditions affect the concentration of same contaminants in the roadside soil [2]. The traffic density determines the lead level in soil and vegetation [11-13].

Soil samples and vegetation is the most economic and reasonable ways for assessing heavy metal status in the atmosphere [1]. Acacia [14], grass [15], other plants [16], and other organisms such as fish [17] have also been used for monitoring. In order to assess contamination by metals in the vicinity of a highway, several studies have been carried out dealing with the different 3 compartments: study of global deposits, roadside soil and vegetation [2]. Information on accumulation of heavy metal on roadside soil of this city due to highway traffic and vehicles is very limited [18]. 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.

Materials and Methods

Bagalkot is the city of Northern region of Karnataka at latitude 16°04’N to 16°21’N and longitude 75°26’E to 76°02’E. The city is suffered from high traffic density caused by vehicles. The grass, Caesalpinia and soil were collected during 2013, which were three meters away from the State Highway (Figure 1 and Table 1) passing through Navanagar. Grass and Caesalpinia samples were collected from each site at three random spots that were spaced approximately at one meter interval. The leaves were clipped with stainless steel scissors. All the samples of each site were then 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°C for 48 hr by powdered and sieved through 0.2 mm sieve. One gram sample was digested using Gerhardt digestion unit using mixed acid digestion method [19]. The digested material was diluted with double distilled water and filtered through Whatman paper 41 and made upto 100 ml.

Similarly, soil samples were dried, powdered and sieved through...
Results and Discussion

Pollution by heavy metals such as Cd, Pb, Ni, Cr etc. is a pollution of concern [1]. 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. The level of heavy metals in the plants samples collected along the roadside Figure 1. Correlation coefficient of heavy metals in roadside soil, grass and Caesalpinia plant samples are given in the Tables 2 and 3.

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 4.

Lead is one of the major heavy metal and considered as an environmental pollutant [20]. Lead is considered as a general protoplasmic poison which is accumulate and slow acting. The main source of Pb is exhaust fumes of automobiles, chimneys of factory, roadside vehicles pollution [21]. The results of our analysis show that there are significant differences for lead between sampling sites in control and polluted area. The results shows that soil tends to accumulate more Pb than the grass and Caesalpinia leaves and the highest Pb level found in the roadside soil was 141.8 µg/gm, while the Caesalpinia it was found that 29.39 µg/gm. Similarly, in grass it was 29.39 µg/gm. The mean soil Pb level of 95.71 µg/gm indicated considerable contamination of metal in the roadside environment, whereas, control soil has a baseline level of 70.50 µg/gm Pb much of the lead is rapidly washed onto the soil by rain water from the surface and also by the death and decomposition of the plant. The Pb deposited in soils and vegetation can also cause enhanced levels of lead in soil microorganisms [22,23].

Road side soil gave higher ‘Cu’ concentration due to industrial pollution near to the sampling location. The source of ‘Cu’ being due to corrosion of metallic parts of cars derived from engine wear, brushing and bearing metals [24]. The mean Cu level in roadside soil (49.71µg/gm) was found to be much higher than the grass (4.87 µg/gm) and Caesalpinia (4.70 µg/gm).

The source of Zn in relation to automobile traffic is: wearing of break lining, loses of oil and cooling liquid [25]. Arithmetic mean of Zn of the roadside soil of around Bagalkot shows a relatively high level of 188.31 µg/gm with a range of 32.29- 390.54 µg/gm. The range of Zn 24.40-35.70 µg/gm found in the Caesalpinia and grass 24.50-34.81 µg/gm (roadside) is not much higher. This can be attributed to the fact that Zn as an essential element is normally present in uncontaminated plants up to 100 µg/gm [26].

Cadmium is dispersed in natural environment through human activities as well as natural rock mineralization process thus plants can easily absorb Cd from soil and transport to the shoot system. Cadmium induces complex changes in plants genetically, biochemical and physiological levels. Our analysis for Cd in the roadside plants and soil showed that there significant differences between polluted and control area. Cadmium level in roadside soil averaged about 2.0 µg/gm and was the lowest among the seven metals examined. The mean Cd in Caesalpinia- 1.41 µg/gm and in grass 1.571 µg/gm. The findings are in confirmation with the findings of [26].

The soil, grass and Caesalpinia contained much higher levels of Mn than other metals examined. Roadside soil, grass and Caesalpinia had average 1528.34 µg/gm, 56.606 µg/gm and 56.10 µg/gm of Mn respectively. High Mn content of the roadside soil may be attributed to the lithogenic factor apart from the vehicular pollution as indicated by the high values of Mn of control soil. Chromium is considered as a serious pollutant due to wide industrial use [27]. Chromium compounds are highly toxic to plants and are detrimental to their growth and development. Significant differences in our analysis for Cr in soil and in plant samples are found. Chromium level too was very high in roadside soil (315.54 µg/gm) against the control value of 118.41 µg/gm. In grass it was 10.51 µg/gm and in Caesalpinia, it was found that 9.10 µg/gm against control (zero). Ni level was considerable and was the lowest among the seven metals examined. The mean Ni in Caesalpinia- 4.61µg/gm and in grass 9.10 µg/gm.

Simple linear regression between the metals (Pb, Cu, Ni, Mn, Fe, Zn and Cd) present in the soil, grass and Caesalpinia were calculated and are given in the Tables 3 and 4.

According to simple linear regression between the metal levels in roadside soil and the Caesalpinia were found in Zn, Cd and Ni are significant at 5% level (p<0.05). It may be indicating the bioconcentration of these metals in the Caesalpinia, in addition to aerial deposition. This may be attributed to the favorable root environment.
The order of increment of heavy metals in roadside soil is as follows: Mn>Cr>Zn>Pb>Ni>Cu>Cd, whereas in roadside grass, Caesalpinia it 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, Zn, Ni, Cu and Cr from the traffic area is an indicative of anthropogenic pollution. 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 showed that are highly translocated from soil to plant leaves in all the sampling sites. According to our study grass shows 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 around Bagalkot indicates the need for pollution control in around city environment. 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 bio indicators.

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Table 1: Sampling stations along State Highway of Bagalkot.

| S. No. | Sampling stations      | Nature of stations                                                |
|-------|------------------------|-------------------------------------------------------------------|
| 1     | Navanagar (Bagalkot)   | Unpolluted urban area- vehicular movement is negligible, unpolluted area with less disturbance |
| 2     | Near Simikeri          | Vehicular movement is high. Agricultural fields on either side of the road |
| 3     | Gaddankeri cross       | Bricks factories around the Gaddankeri cross, vehicular traffic is high |
| 4     | Tulasigeri             | Vehicular movement is high. Agricultural fields on either side of the road |
| 5     | Kaladagi               | Vehicular movement is high. Agricultural fields on either side of the road |
| 6     | Lokapur                | Vehicular movement is high. Agricultural fields on either side of the road |

Table 2: Correlation coefficient of heavy metals in roadside soil and grass. *Significant at 5% level (p<0.05).

| S. No. | Metal | r value |
|-------|-------|---------|
| 1     | Lead  | 0.627   |
| 2     | Copper| 0.481   |
| 3     | Zinc  | 0.829   |
| 4     | Cadmium | 0.748 |
| 5     | Manganese | 0.529 |
| 6     | Nickel | 0.331   |
| 7     | Chromium | 0.210  |

Table 3: Correlation coefficient of heavy metals in roadside soil and Caesalpinia. *Significant at 5% level (p<0.05).

| S. No. | Heavy metals | Control Group (µg g⁻¹ dry wt.) | Roadside | Caesalpinia | Roadside grass | 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 | 20.46-29.39 | 23.73 ± 1.84 | 70.50                        | 82.91-141.8 | 95.71 ± 8.71 |
| 2     | Copper       | 2.15                         | 3.92-5.74  | 4.70 ± 0.35 | 3.95-7.76   | 4.87 ± 0.35 | 34.91                        | 39.54-59.29 | 49.71 ± 3.51 |
| 3     | Zinc         | 16.19                        | 24.40-35.7 | 32.84 ± 3.10 | 24.50-34.8 | 32.87 ± 3.11 | 29.84                        | 32.29-390.54 | 188.3 ± 54.28 |
| 4     | Cadmium      | 0.82                         | 1.10-1.79  | 1.41 ± 0.08 | 1.20-1.82 | 1.571 ± 0.082 | 2.16                        | 1.75-2.91 | 2.0 ± 0.19 |
| 5     | Manganese    | 15.72                        | 28.01-70.10 | 56.10 ± 7.30 | 28.91-72.24 | 56.60 ± 7.30 | 1254.1                      | 1257.9-2057.5 | 1528.3 ± 26.5 |
| 6     | Chromium     | ND                           | 1.20-8.4  | 4.61 ± 2.20 | 1.30-9.00 | 4.90 ± 2.23 | 110.41                       | 131.9-958.2 | 315.54 ± 2.46 |
| 7     | Nickel       | 6.70                         | 8.1-14.9  | 9.10 ± 1.40 | 8.8-15.1 | 10.51 ± 1.411 | 69.38                       | 70.53-109.6 | 85.91 ± 5.91 |

Table 4: Heavy metal accumulation profile in Caesalpinia grass and soil. ND: Not detectable.

[28] i.e., soil conditions might have favored their absorption.

Simple linear regression in case of chromium, nickel, manganese and copper contents between soil, grass and Caesalpinia are not at significant at 5% level, were low due to low bioavailability of these metals owing to unfavorable root environment. Whatever excess content of these metals found in soil, grass and Caesalpinia was presumed to be due to the heavy deposition contributed by motor vehicles.

The results of our study indicate that the concentration of heavy metals such as Pb, Cd, Mn, Zn, Ni, Cu and Cr from the traffic area is an indicative of anthropogenic pollution. 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 showed that are highly translocated from soil to plant leaves in all the sampling sites. According to our study grass shows 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 around Bagalkot indicates the need for pollution control in around city environment. 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 bio indicators.

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