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Heavy Metal Contamination of Dumpyard Soils and its Phytoremediation with Vetiver Grass (*Chrysopogon zizaniodes*)

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ABSTRACT

A study was conducted to find out the distribution of heavy metals and the pollution status of a major dumping site in Laloor, Thrissur, Kerala and also the effectiveness of vetiver in phytoremediation of contaminated soils. The total heavy metal content of the dumping sites was higher than the non dumping sites. The average content of total Pb was recorded as 82.84 mg kg^{-1} in the soils of Laloor. Monitoring the Co content of the soil, irrespective of different intervals and the sites of study, it was found that the average content was 7.79 mg kg^{-1} at Laloor. The average total Ni content registered at Laloor was 35.54 mg kg^{-1}. The Hg content of the soil was 0.42 mg kg^{-1} at Laloor. The average content of Cr was found to be 115.67 mg kg^{-1} in Laloor soil. The result of heavy metal analysis was added to the GIS layers created for the different sites of the location and the major pollution indices were represented in the map. The highest polluted site was identified in the Laloor dump site. The soil along with waste material collected from Laloor was used for phytoremediation study with vetiver grass. Phytoremediation with vetiver showed that it has good phytoremediation potential with a bio concentration factor of more than two for metals like Ni, Cr and Hg. Vetiver is a good translocator of Cr and most of the other heavy metals were stabilized in the root. On the basis of removal ratio, it removed heavy metals in the order Cr > Ni > Co > Pb.

INTRODUCTION

Municipal waste dumping sites are designated places set aside for waste disposal. As there are a variety of wastes at the dumping site, it pollutes the natural resource of the area due to the production of toxic chemicals and pollutants like heavy metal. Most of the cities lack solid waste management regulations and facilities for disposal of harmful waste like infectious, toxic heavy metals or radioactive substances. The issues of waste dumping yards in Kerala are also not different. The waste dumping yards in different cities were undergoing serious agitation from the local residents due to health threats. With this view, a study was undertaken in the soils of Laloor area, which was the major waste dump yard of the Thrissur Corporation up to 2009-2010. And the major objective of the study was (a) to find out the distribution of heavy metals and the pollution status of the area due to heavy metals, (b) to find out the effectiveness of vetiver in phytoremediation of contaminated soils.

MATERIALS AND METHODS

The study area was located at the major waste dumping sites in Laloor in Thrissur district (Fig. 1) located at 10°30' N latitude and 76°11' E longitude is a residential area at a distance 5 km from the city.

Soil sampling was done from August 2011 to November 2012 at an interval of three months. Soils were sampled along different directions within a radial distance of 1 m from the centre of dumpsite to 10 to 15 cm depth. Soil samples were mixed to form composite surface soil samples in triplicates in each direction and the centre of dumpsite was taken as the GPS point. The same procedure was followed for sample collection from the non dumpsites.

The bulky inorganic objects like cloth, plastic, rubber, metal, plastic, medical syringes, bulbs had been sorted out manually, the samples were air dried and ground to pass through a 2 mm sieve and the soil samples were kept in polythene bag for further analysis. Total heavy metal content of the soil samples was estimated by digesting the soil samples with diacid mixture extractant (nitric acid and perchloric acid in the ratio 2:1) and analysed using ICP_OES (Optima 8000).

The location of Laloor was identified in high resolution images using the GPS points taken during the ground sur-

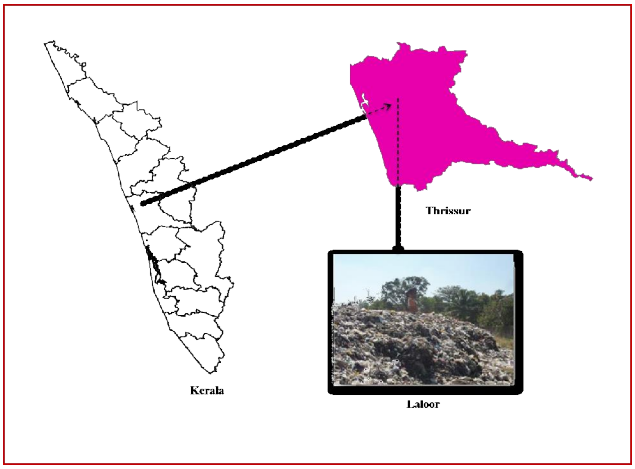

Fig. 1: Location of the study area showing Laloor dump yard.

vey. The images were digitized and geo referenced to make it into GIS layers. The result of heavy metal analysis was added to the GIS layers created for the different sites of the location, and the different maps were generated. After generation of the maps, the major pollution indices were represented in the map and the details are as follows:

Index of geo accumulation (Igeo): It is used to evaluate the degree of metal contamination in comparison to the background contents (Prasanth et al. 2012).

$$Igeo = \log_2 Cn/1.5\ Bn$$

Where, Cn = concentration of the examined element in the examined environment.

Bn = geochemical background of a given element in a reference environment.

Modified contamination degree (mC_d): A modified and generalized form for the calculation of the overall degree of contamination was defined as the sum of all contamination factors (CF) for a given set of pollutants divided by the number of analysed pollutants just as bellow (Abrahim & Parker 2008):

$$mC_d = {}^{i=n}\sum_{i=1} Cf^i /n$$

Where, n= number of analysed elements, i= i^{th} element, Cf^i= sum of all contamination factors (Cf) for a given set of pollutants.

Cf =Mx/Mb, where, Mx and Mb respectively, refer to the mean concentration of a pollutant in the contaminated soil samples and the baseline concentration in a reference environment, like rock in this study

The highest polluted site was identified in Laloor dump site. The soil along with waste material collected from Laloor was used for phytoremediation studies with vetiver grass. Vetiver *(Chrysopogon zizanioides)* is a perennial grass of the Poaceae family. Five concrete pots each with a capacity of 100 kg were used for the study. The soil along with the waste material from Laloor and inert sand material in the ratio 2:1 was used for filling the pot. One seedling each of vetiver was planted. Vetiver crop was harvested after one year and the harvested roots and shoots were separated, cleaned and oven dried. The ground plant material was used for plant analysis of heavy metals. The soil after phytoremediation was also analysed for heavy metals.

Based on the heavy metal accumulation in different parts of the plants, the following indices were worked out, to understand the phytoremediation potential of the crop.

Translocation factor (TF) = The metal concentration in shoots/the metal concentration in the roots.

Bio concentration factor (BCF) = the heavy metal concentration in the plant/initial concentration of metal in soil. (Subhashini et al. 2013)

Removal ratio (RCr)

RCr = (Bs×Cs+Br×Cr)/CT × Weight of initial material taken

Table 1: Heavy metal content of Laloor (mg kg^{-1}) after survey for one year at the dump and non dumpsite.

Heavy metals	Locations at Laloor		
	Dump site	Non dump site	Average
Lead	102.47	23.94	82.84
Cobalt	8.41	5.91	7.79
Nickel	38.59	26.40	35.54
Mercury	0.48	0.15	0.42
Chromium	120.30	101.75	115.67
Cadmium	0.31	0.09	0.26

Table 2: The geo accumulation index and the modified degree of contamination indices of different sites at Laloor.

Laloor	Pb	Co	Ni	Hg	Cr	Cd	mC_d
			Igeo values				
First site	2.60	-1.99	-1.25	2.55	-0.28	-0.05	3.562
Second site	2.38	-1.77	-1.34	2.67	-0.45	-0.82	3.364
Third site	0.61	-1.75	-1.58	2.83	-0.23	0.68	2.950
Fourth site	0.00	-2.34	-1.79	1.00	-0.56	-1.74	1.328

Where, B (g) is biomass, C (mg g-1) is the concentration of heavy metal, the subscript of B or C represents shoot (s), root (r) and treated soil (T).

RESULTS AND DISCUSSION

The result of the average heavy metal content at the dump site and non dumpsite for one year is represented in the Table 1.

The total heavy metal content of the dumping sites was higher than the non dump sites. The average content of total Pb was recorded as 82.84 mg kg^{-1} in the soils of Laloor. Monitoring the Co content of the soil irrespective of different intervals and the sites of study, it was found that the average content was 7.79 mg kg^{-1} at Laloor. Average total Ni content was registered at Laloor was 35.54 mg kg^{-1}. The Hg content of the soil was 0.42 mg kg^{-1} at Laloor. The average content of Cr was found to be 115.67 mg kg^{-1} in Laloor soil.

The percentage distribution of heavy metals at Laloor showed that at the first and second sites the heavy metals followed the same order of distribution as Pb>Cr> Ni> Co> Hg>Cd. At the third and fourth sites the distribution was Cr> Ni> Pb> Co> Hg. The percentage distribution of Cr ranged from 59 % at first site to 67 % at the third site. Ni content ranged from 20 % in third site to 28 % in first site. Pb content varied from 7-10%, Co ranged from 3%-4% and Hg 0.3%- 0.4 % and Cd traces-0.7 %. Pollution indices are the best indicators used to understand the degree of contamination in the soils of the area under study. The details of the geo accumulation index and modified contamination degree are given in Table 2.

The geo accumulation index calculated for the individual heavy metals at the different sites showed that Pb, Cd and Hg were pollutants at Laloor. The geo accumulation index of Pb and Hg was greater than one for all the dumping sites of Laloor (Fig. 2). The geo accumulation index of Cd was greater than one for the third dumping site of Laloor. The fourth site (non dumping site) was not contaminated with heavy metals.

Map showing the (mC_d) (modified contamination degree) of different sites is presented in Fig. 3. Modified degree of contamination values for Laloor site revealed that first, second and third site showed mC_d were contaminated and under moderate degree of contamination. The fourth site was under no to very low degree of contamination.

The soils of Laloor were taken for phytoremediation study with vetiver and the heavy metal content of the soil after phytoremediation with vetiver is given in Table 3, and the heavy metal concentration of the different parts of vetiver is represented in the Fig. 4.

The results showed that Pb content in soil after phytoremediation was 93.88 mg kg^{-1} in soils phytoremediated with vetiver. Cobalt content of the soil before treatment was 11 mg kg-1 and the soil phytoremediated with vetiver showed a Co content of 8.78 mg kg^{-1}. After phytoremediation the soils showed reduction in Ni content which was 32.62 mg kg^{-1} in soil planted with vetiver. The initial content of chromium in the soils was 105 mg kg^{-1} and after phytoremediation it ranged from 49.6 mg kg^{-1} in soils grown with vetiver. The soils treated with vetiver had a mercury content of 0.34 mg kg^{-1}.

On comparison of the concentration of heavy metals in the root and shoot of vetiver, it was found that the concentration of most of the heavy metals under study (Pb 13.6 mg

Fig. 2: Map showing the geo accumulation index for the different sites of Laloor.

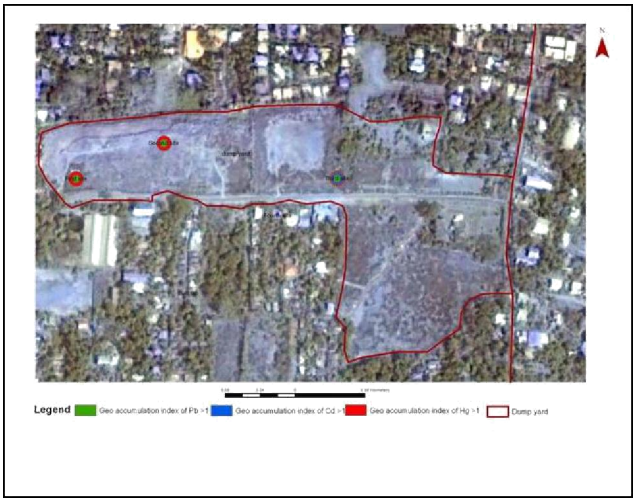

Fig. 3: Map showing the modified contamination degree for the different sites at Laloor.

Table 3: Heavy metal content of the soil (mg kg^{-1}) after phytoremediation with vetiver.

Soil after the growth of vetiver	Pb	Co	Ni	Cr	Hg
	93.88	8.78	32.62	49.6	0.34

Table 4: Different phytoremediation indices worked out for vetiver.

Heavy metals	Translocation factor	Bioconcentration factor	Removal ratio
Pb	0.5	0.35	1.10
Co	0.4	0.73	1.30
Ni	0.6	2.10	5.44
Cr	1.1	3.21	10.01
Hg	0.5	2.94	0.65
Pb	0.5	0.35	1.10

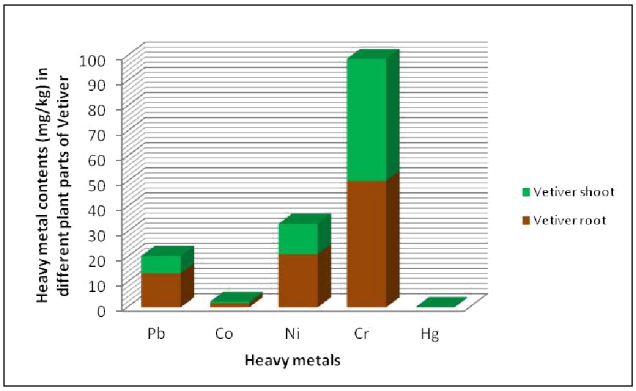

Fig. 4: Heavy metal concentration in the root and shoot of vetiver after phytoremediation.

kg^{-1}, Co 1.67 mg kg^{-1}, Ni 21.2 mg kg^{-1} and Hg 0.12 mg kg^{-1}). The Cr content was higher in shoot (54.95 mg kg^{-1}) compared to root (50.38 mg kg^{-1}).

The three main factors considered in assessing the phytoremediation potential of the different crops are translocation factor, bio concentration factor and removal ratio (Table 4). This factor was calculated based on total plant uptake/ pot basis. On the basis of removal ratio the removal of heavy metals by vetiver was as per the order Cr>Ni> Co> Pb.

As the total biomass of vetiver was higher, the content of heavy metals in Laloor soil was decreased to the least extent, due to phytoremediation using vetiver.

CONCLUSIONS

The study provided the spatial extent of pollution at the various sites, which is very essential to understand the degree of contamination at the sites. Phytoremediation with vetiver showed that it has good phytoremediation potential with a bioconcentration factor more than two for metals like Ni, Cr and Hg. Vetiver is a good translocator of Cr and most of the other heavy metals were stabilized in the root. On the basis of removal ratio it removed heavy metals in the order Cr> Ni> Co> Pb. The study revealed that the large scale phytoremediation of vetiver at dumpsites is a viable option in removing toxic metals and the soil of the dumpsites could be cultivated again with the addition of needed nutrients.

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