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Uptake of Heavy Metals from Urban Wastewater Contaminated Soils by Using Selected Crop Species of Mysuru City, India

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ABSTRACT

Heavy metals are among the most important sorts of pollutant in the environment. Numerous methods already used to clean up the environment from these kinds of contaminants, but most of them are costly and difficult to get optimum results. Factors influencing heavy metal uptake by Crops were studied by pot and field experiments in Mysuru City, India. Results concern with soils is contaminated with Urban Wastewater. In this paper demonstrated effects on the heavy metal content of eight cultivated crop species, in three wastewater contaminated sites of Mysuru City. Interaction between ecological factors and crop characters was demonstrated, as well as results of pot and field studies were compared. Tested plant species were grouped on the basis of their accumulation capability and susceptibility of heavy metals.

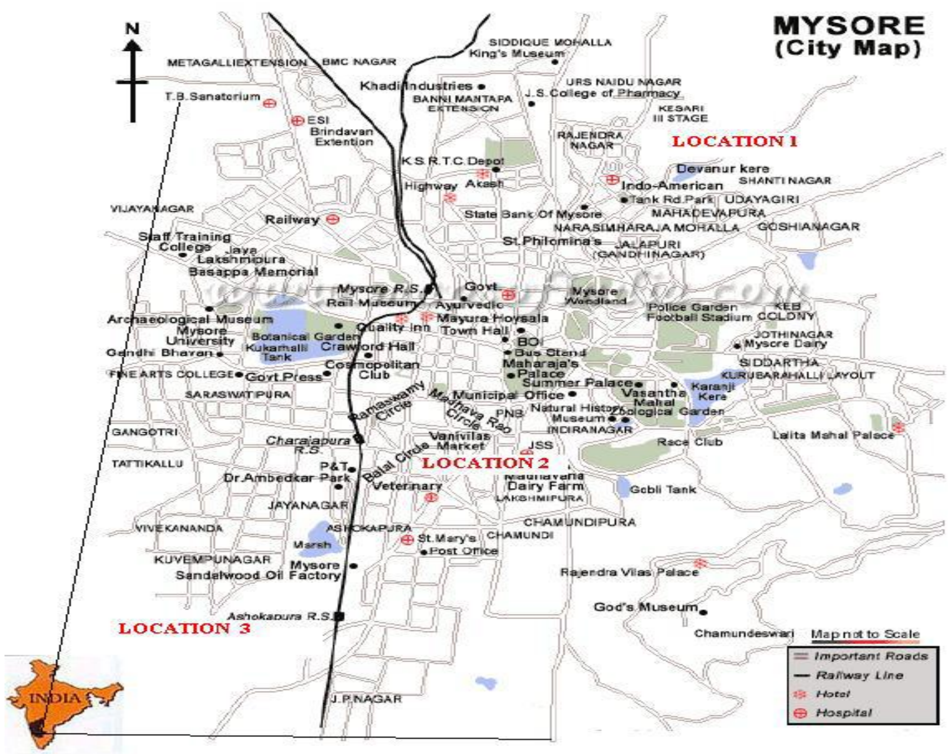
Key words: heavy metal, Uptake, Mysuru, Crop and Urban Wastewater (UWW)

INTRODUCTION

Heavy metal pollution causes potential ecological risk. The base of uptake by crops, a promising method for cleaning of soil and water, is pollutant uptake or bounding by plants. Initially much more interest was focused on hyper-accumulator plants than those taken in non-accumulator plants (Baker et al. 1994; Brooks 1998), Heavy metals are among the contaminants in the environment. Beside the natural activities, almost all human activities also have potential contribution to produce heavy metals as side effects. Conventionally, remediation of heavy-metal-contaminated soils involves either onsite management or excavation and subsequent disposal to a landfill site. This method of disposal solely shifts the contamination problem elsewhere along with the hazards associated with transportation of contaminated soil and migration of contaminants from landfill into an adjacent environment. Soil washing for removing contaminated soil is an alternative way to excavation and disposal to landfill. This method is very costly and produces a residue rich in heavy metals, which will require further treatment. Moreover, these physico-chemical technologies used for soil remediation render the land usage as a medium for plant growth, as they remove all biological activities (Gaur et al., 2004). Application of wastewater, sludge and excreta on land is a widespread and traditional practice in many countries around the world. Wastewater and sewage sludge have also been used by the northern European and Mediterranean civilizations; and wastewater was reused in the 14th and 15th centuries (Soulié and Tréméa, 1991). In many European and North American cities, wastewater was disposed of in agricultural fields before the introduction of wastewater treatment technologies to prevent pollution of water bodies. In Paris, for instance, the use of partially treated wastewater was common until the second part of the 1900s (Asano et al., 2007). In developing countries like China, Mexico, Peru, Egypt, Lebanon, Morocco, India and Vietnam, wastewater has been used as a source of crop nutrients over many decades (AATSE, 2004; Jiménez and Asano, 2008). Therefore, agricultural use of untreated wastewater has been associated with land application and crop production for centuries (Keraita et al., 2008). However, over the years, it has become less popular in developed countries with the improvement of treatment technologies and increased awareness of the environmental and health issues associated with the practice. Besides, in developing countries, due to a variety of factors described later, farmers use it extensively, even drawing advantages to improve their livelihoods. However, the use of diluted wastewater for irrigation (indirect use) is significantly, more frequent than direct use and occurs even more in wetter climates. In this situation, untreated or partially/insufficiently treated wastewater from urban areas is discharged into drains, small streams and other tributaries of larger water bodies where it is usually mixed with storm water and freshwater, resulting in diluted wastewater (or polluted surface water). It is then used by farmers, most of whom are traditional users of these water sources. Lack of adequate sanitation and waste disposal infrastructure in cities is one of the direct causes of such pollution and use (Jiménez and Asano, 2008, Raschid-Sally). Heavy metals in soil and plant samples, tested plant species were grouped on the basis of their accumulation capability of heavy metals. The results of this research showed that there are some hyper accumulator plants in this area that can concentrate heavy metals in their different parts thus they can be used for remediation of polluted area (Behrouz E. Malayeri, 2008).Treatment methods were developed to reduce the hazardous elements in wastewater before its use on agricultural fields. However, in many developing countries wastewater is still used without any treatment as treatment facilities are not available, people are not aware of the health and environmental hazards and the WHO guidelines are not feasible. The study area is Mysore city, whose growth rate is posed to be rapid, equipped with only primary sewage treatment plants, that treats only a part of UWW generated from the city limits. Large quantity of untreated UWW are being discharged into low lying areas and water bodies located in and around the city. Due to the scarcity of water, the untreated UWW is used for irrigation. A critical review of literature has revealed that there is scanty information available regarding the treatment and disposal of urban wastewater generated from the Mysore City limits, the assessment of metal load in treated and untreated UWW and its impacts on soil, vegetation, and water bodies. Also no study is carried on uptake of heavy metals on plants species using UWW in Mysore City.

MATERIALS AND METHODS

Mysore is a city in the Indian state of Karnataka, and the administrative seat of Mysore District, one of the largest districts in Karnataka. Mysore was the former capital of the Kingdom of Mysore. Mysore is located at 770 m above sea level at 12.18° N 76.42° E and is 135 km from Bangalore, the state capital. Mysore being one of the growing cities of Karnataka, largely due to the presence of industrial resources and a well developed communication network. In recent decades industrialization is the main cause of city’s growth. A large number of small, medium and large scale industries exists in and around the Mysore city, including engineering, chemical, pharmaceutical, food, brewery, distillery, textile, rubber, steel and metal smelting. Over the past decade Mysore has transformed itself into a destination for modern industries in the manufacturing service and Information and Technology sector.



Sampling stations

Enormous quantity of UWW generated is discharged without any treatment and due to scarcity of fresh water the UWW is utilized directly for agriculture purpose and also the untreated UWW ends up in lakes. The biosolids generated from the wastewater treatment plant are utilized as manure for agriculture. Kesare village, Sewage farm, Vidhyaranyapuram, Rayanakere and surrounding UWW irrigated area .The samplings point for urban wastewater analysis at each of the station mentioned above.

In-vivo condition plots

To determine the actual uptake of heavy metal in the present study, seven plots were taken; with the size of seven square meters. Out of seven plots, size of the each plot is one square meter. One plot was used as control plot where there was no addition of heavy metals in to it. For each plot 20 kg of soil was taken and 20gm of each heavy metals were added to this [for example in plot 1 only copper (20gm) is added for 20 kg of soil].In all the seven plots selected plant species were grown, so that in each plot the uptake of heavy metal by individual plant can be determined. In urban wastewater (UWW), the uptake of heavy metals by individual plant species cannot be determined, so that the plants were grown under controlled condition to measure the uptake of heavy metals by individual plant species. In these plots 5 plant species that are regularly cultivated in UWW irrigated area was grown for 37 days in normal environmental conditions.

Sample preparation and analysis

The Crop samples were analyzed for pH and digested by using tri acid mixture and 2ml of aqua-regia has been added to preserve the digested sample and stored in 100 ml distilled container. The digested sample was analyzed for heavy metal concentration by using Inductively Coupled Plasma Atomic Emission Spectroscopy techniques (ICP-AES) using the Perkin-Elmer Optima 8000, ICP-OES.

Table.1: Crop species grown around Mysore City using UWW

Sl.no	Name of plant species Irrigated using UWW	Family of the species	UWW Irrigated areas		
			Kesare	Vidyaranyapuram	Rayanakere
01	***Amaranthus tritis* L**	*Amaranthaceae*	+	-	_
02	***Anethum graveolens* L**	*Apiaceae*	-	+	+
03	***Coriandrum sativum* L**	*Apiaceae*	+	+	+
04	***Mentha longifolia* L**	*Lamiacea*	+	_	_
05	***Oryza sativa* L**	*Poaceae*	+	+	+
06	***Spiracia oleracea* L**	*Amaranthaceae*	+	+	_
07	***Trigonella foenum graecum* L**	*Fabaceae*	+	+	+
08	***Zea mays* L**	*Poaceae*	_	+	_
09	***Pennisetum Purpureum***	*Poaceae*	+	+	+
Total number of Species			**08**	**07**	**05**

Table. 2: Heavy metal concentration in Crop species irrigated with UWW in Kesare

Sl. No.	Name of Plant species	Family	Cd	Cu	Fe	Ni	Pb	Zn
1	*Amaranthus tritis* L	*amaranthaceae*	BDL	0.1	155.9	0.83	BDL	2.67
2	*Anethum graveolens* L	*Apiaceae*	BDL	0.6	168.2	0.70	BDL	1.33
3	*Coriandrum sativum* L	*Apiaceae*	BDL	0.1	123.3	0.56	BDL	0.66
4	*Mentha langifolia* L	*Lamiacea*	BDL	0.1	151.4	0.32	BDL	0.78
5	*Oryza sativa* L	*Poaceae*	BDL	0.2	201.3	0.87	BDL	2.1
6	*Spiraciaoleracea* L	*amaranthaceae*	BDL	0.9	154.5	0.64	BDL	0.83
7	*Trigonella foenum graecum* L	*Fabaceae*	BDL	0.2	155.8	0.89	BDL	3.2
8	*P. purpureum* L	*Poaceae*	BDL	6.3	683.1	8.2	4.6	46.5

Table. 3: Heavy metal concentration in Crop species irrigated with UWW in Sewage form, Vidyaranyapuram

Sl. No.	Name of Plant species	Family	Cd	Cu	Fe	Ni	Pb	Zn
1	*Anethum graveolens* L	*Apiaceae*	BDL	0.09	140.2	0.90	BDL	0.90
2	*Coriandrum sativum* L	*Apiaceae*	BDL	0.07	119.1	0.78	BDL	0.60
3	*Oryza sativa* L	*Poaceae*	BDL	0.3	165.4	2.0	BDL	0.79
4	*Spiracia oleracea* L	*amaranthaceae*	BDL	0.06	106.9	0.81	BDL	2.3
5	*Trigonella foenum graecum* L	*Fabaceae*	BDL	0.1	116.1	0.1	BDL	1.84
6	*Zeamays* L	*Poaceae*	BDL	1.5	251.3	3.2	BDL	3.5
7	*P. purpureum*	*Poaceae*	BDL	5.0	412.2	7.8	3.6	30.2

Table. 4: Heavy metal concentration in Crop species irrigated with UWW in Rayanakere

Sl. No.	Name of Plant species	Family	Cd	Cu	Fe	Ni	Pb	Zn
1	*Anethum graveolens* L	*apiaceae*	BDL	0.09	109.7	0.52	BDL	2.57
2	*Coriandrumsativum* L	*apiaceae*	BDL	0.07	86.2	0.39	BDL	0.8
3	*Oryza sativa* L	*poaceae*	BDL	2 .6	177.1	0.87	BDL	1.2
4	*Trigonella foenum graecum* L	*fabaceae*	BDL	0.6	100.4	0.63	BDL	0.70
5	*P. purpureum*	*poaceae*	BDL	4.9	570.3	4.9	BDL	40.3

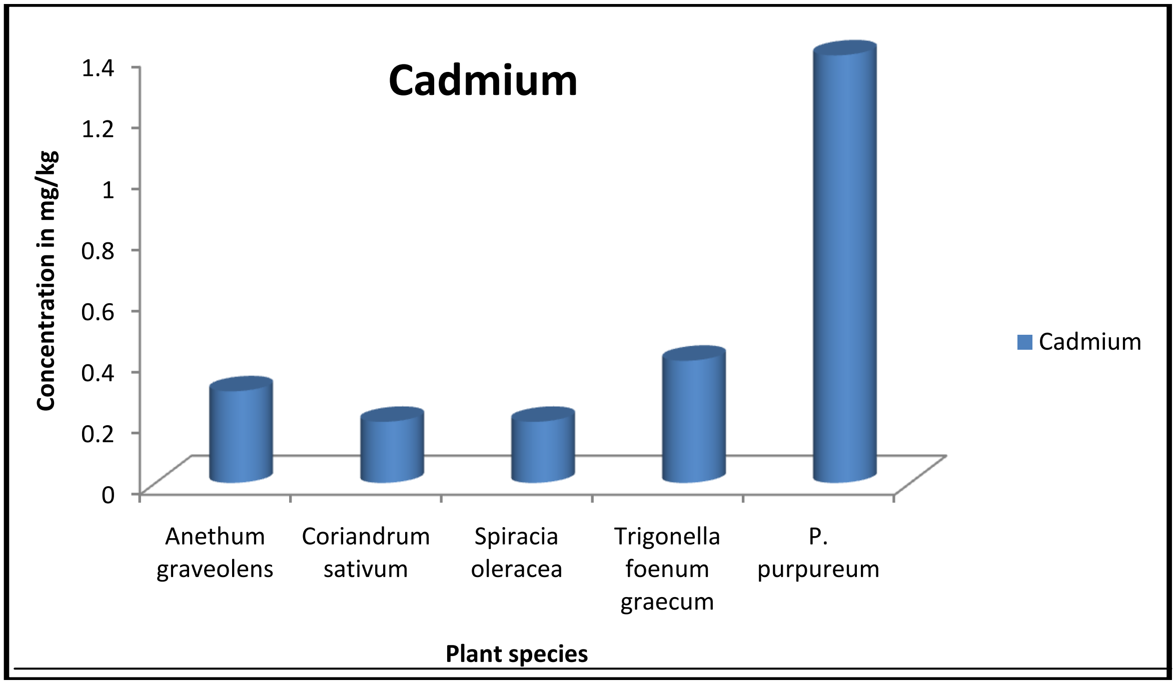
Table. 5: Uptake of Heavy metal concentration in Plant species irrigated in In-vivo condition.

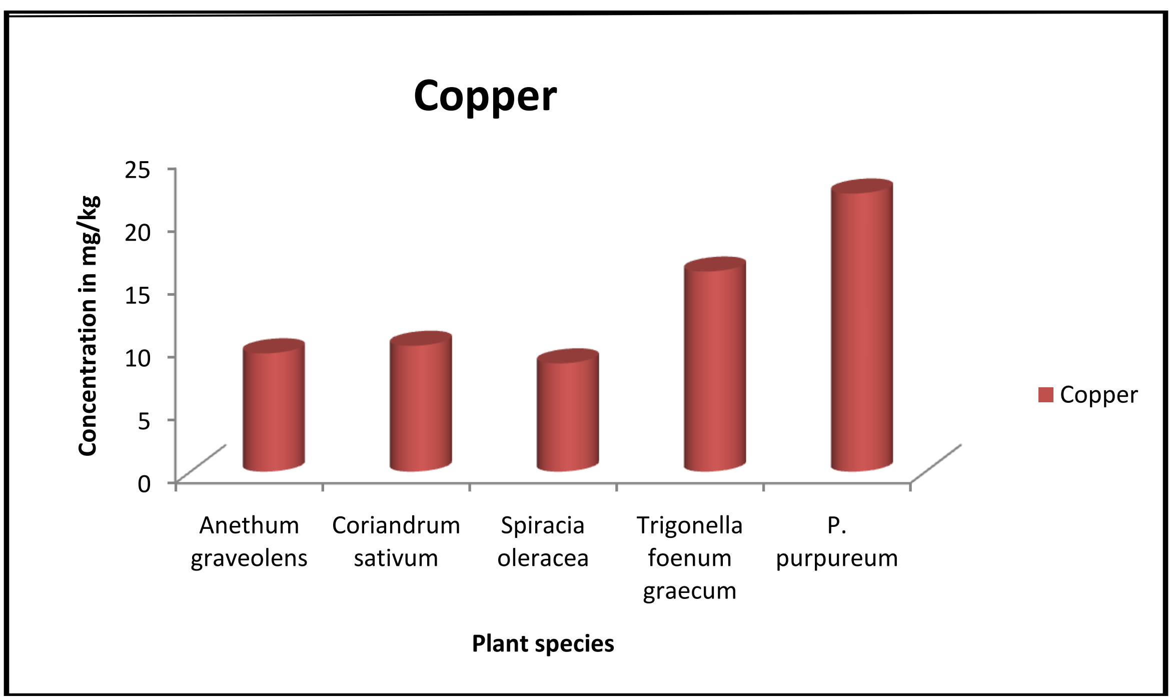
Sl. No.	Name of Plant species	Family	Cd	Cu	Fe	Ni	Pb	Zn
1	*Anethum graveolens* L	*apiaceae*	0.3	9.4	287.6	1.2	0.60	1.6
2	*Coriandrum sativum* L	*apiaceae*	0.2	10.0	184.3	0.9	0.45	0.84
3	*Spiracia oleracea* L	*amaranthaceae*	0.2	8.6	347.8	2.2	0.32	2.4
4	*Trigonella foenum graecum* L	*fabaceae*	0.4	15.9	436.5	2.6	0.78	1.8
5	*P. purpureum*	*poaceae*	1.4	22.1	698.1	3.9	1.6	2.7

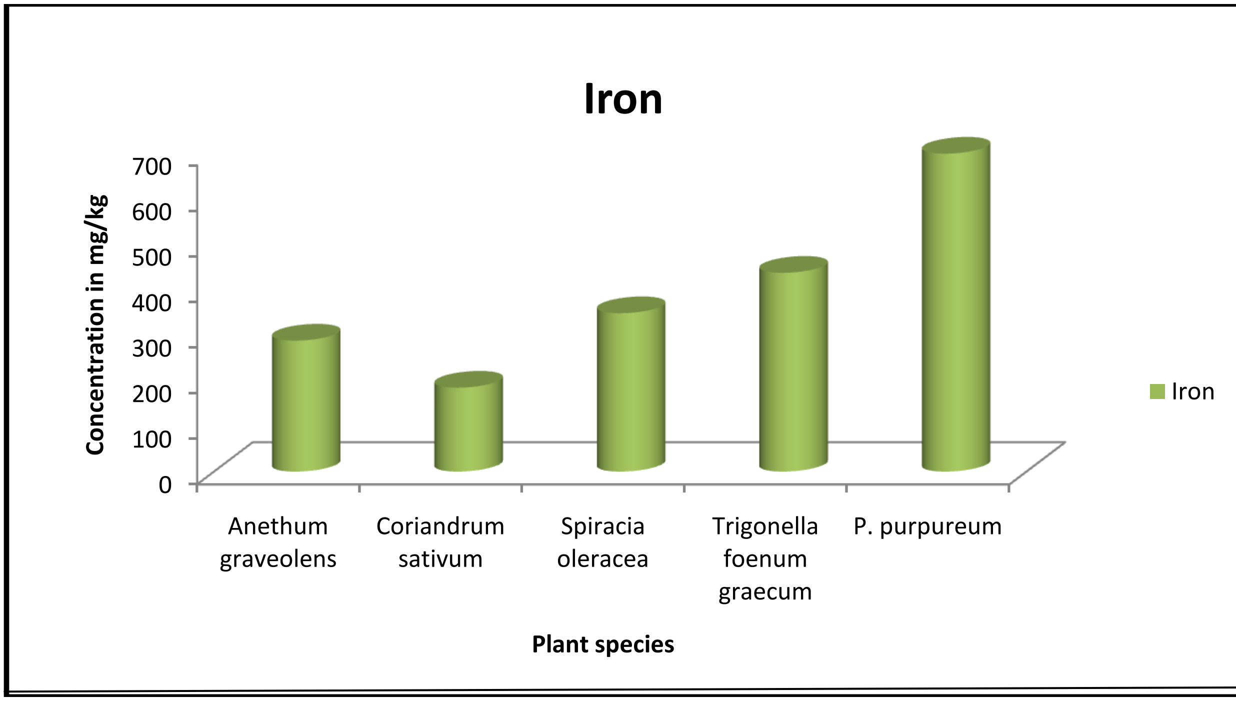
Note: All the Heavy metals expressed in mg/kg

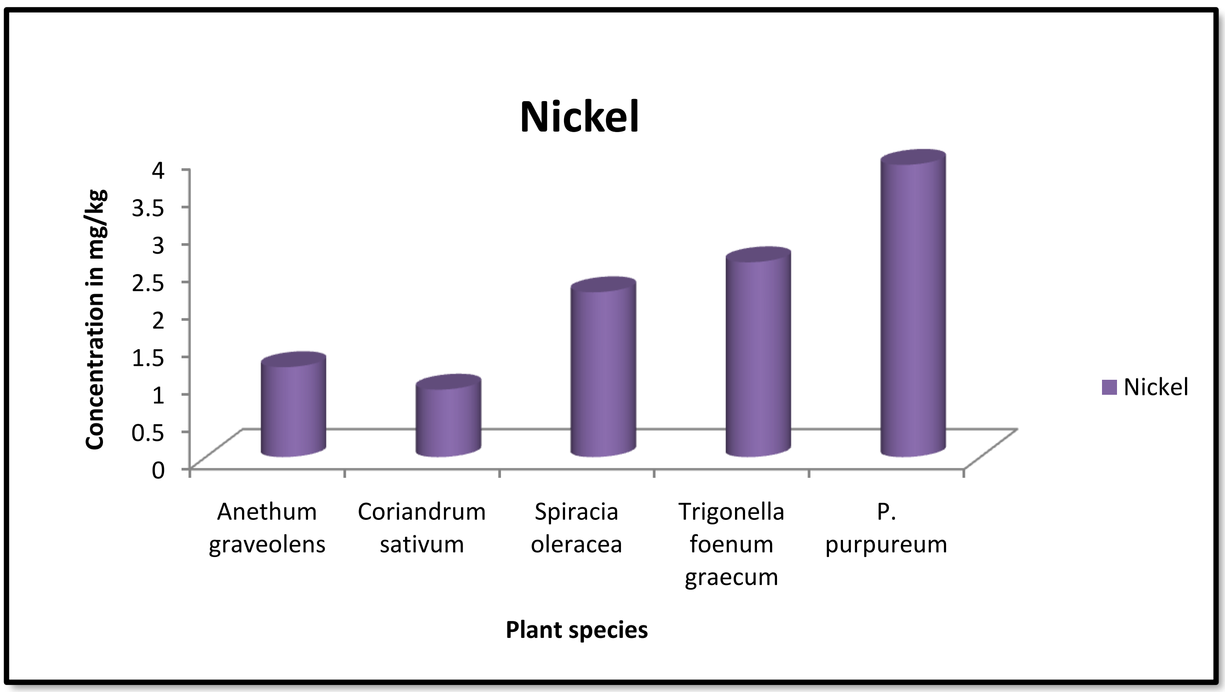
The heavy metal which enters in to the ecosystem may lead to geo-accumulation, bio-accumulation, and bio-magnifications and may have possibilities for environmental transformation into a toxic form. The bioavailability of metals in plants is a dynamic process that depends on specific combinations of chemical, biological and environmental parameters. These toxic heavy metals entering aquatic environment are adsorbed onto particulate matter, although they can form free metal ions and soluble complexes that are available for uptake by plants and biological organisms. Heavy metals are potentially toxic for plants, phyto-toxicity results in chlorosis, weak plant growth, yield depression and may even be accompanied by reducing the nutrient uptake, disorder in plant metabolism and in leguminous plants reducing the ability to fixate molecular nitrogen. The bioavailability of metals is directly related to the chemical characteristics of the UWW, biosolids and of the Soil. Soils receiving sewage irrigation for 10 years exhibited significant increase in Zn, Fe, Ni and Pb, while on Fe in the soils was positively affected by sewage irrigation for 5 years (Rattan, 2005). The consumption of plants containing high levels of heavy metals might pose a serious risk to human health (Turkdogan*et.al.*,2003; Wang *et.al.*, 2003). Selected plant species were grown in-vivo condition using irrigated with urban wastewater in Mysore City. Those plants were grown under controlled condition where there was no presence of heavy metals in the water used for the growth of plant species and the soil which contains naturally occurring heavy metals like copper, iron, nickel, lead and zinc were detected. Cadmium was found BDL (Below Detectable Limit) when compare to other heavy metals. The concentration of Cu, Zn, Fe, Pb and Ni in the soil was found to be 4.9, 69.3, 222.0, 2.0 and 4.6 mg/kg, respectively, and these were the concentrations present in the soil. In each plot the uptake of heavy metals by plants were observed, and the uptake concentration was more compared to plants which was using urban wastewater in irrigation areas in Kesare, Vidyaranyapuram and Rayanakere. In controlled condition, 20 grams of heavy metals were added to each plot, so that the uptake of heavy metal by plants was more than in irrigation land which was irrigated using UWW. Heavy metals uptake was carried out in the study area. Nine plant species have been identified during thestudy period and the ***P.purpureum Schumach*** is considered as highest heavymetals accumulated crop among all the crops which were grown in the UWW contaminate area. The uptake study identifies the mobility of the metals among the different fraction. The ***P.purpureum Schumach*** species significantly having the higher mobility for all the analyzed heavy metals. The comparative study clearly shown that, crops grown in in-vivo condition accumulates huge heavy metal to compare UWW irrigated crops because of simultaneous availability of heavy metal.

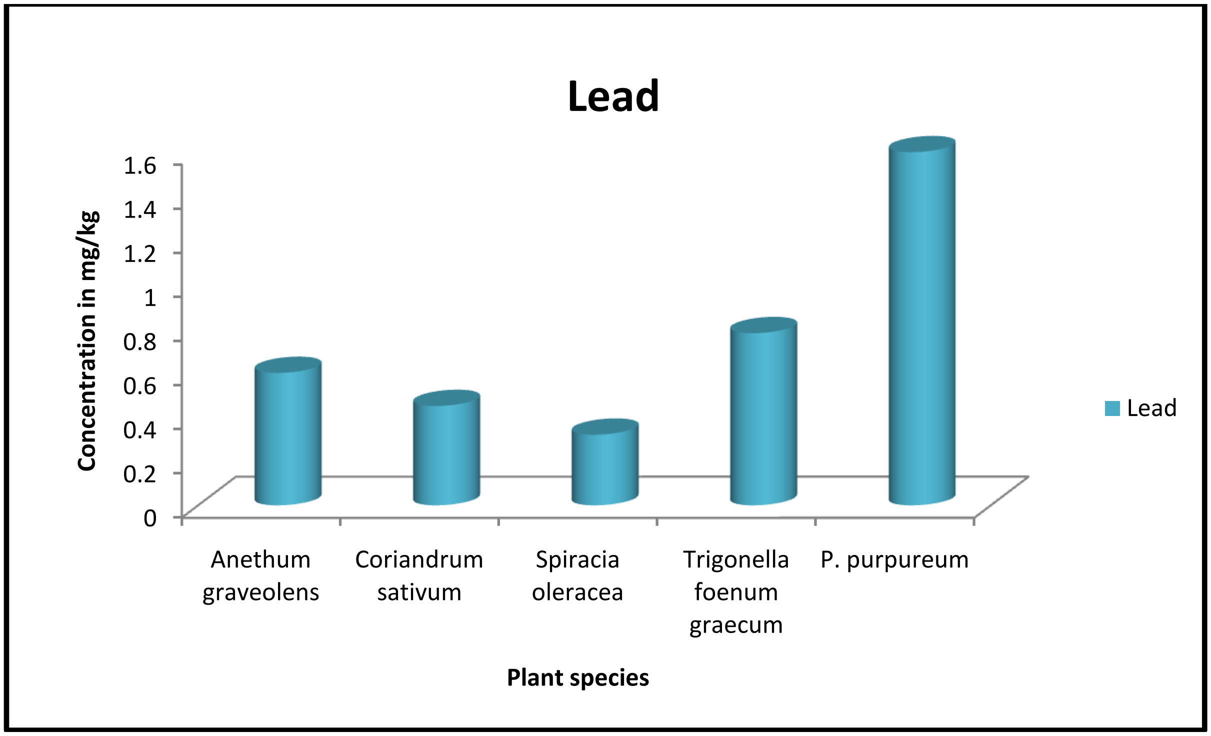
Graphical representation of Uptake of Heavy metal by plant species in In-vivo condition






Iron
Concentration in mg/kg
700
600
500
400
300
200
100
0
Anethum graveolens
Coriandrum sativum
Spiracia oleracea
Trigonella foenum graecum
P. purpureum
Plant species
Iron


Nickel
Concentration in mg/kg
4
3.5
3
2.5
2
1.5
1
0.5
0
Anethum graveolens
Coriandrum sativum
Spiracia oleracea
Trigonella foenum graecum
P. purpureum
Plant species
Nickel



RESULTS AND DISCUSSION

Due to anthropogenic activity, the concentrations of heavy metals were not constant in urban wastewater which was used for irrigation purposes. Each heavy metal concentration varied when the samples were collected for the analysis of heavy metal content in the soil, urban wastewater and plant species. In the experimental plot condition the heavy metals uptake was significantly high where compare to UWW used for irrigation in areas. In the UWW used for irrigation the heavy metal concentration would have more concentration than that of experimental condition. But the concentration of heavy metals uptake varied even with the same plant species grow in both the condition. The concentration distribution in UWW used for irrigation was observed along with biosolids, agriculture soil and plants. But in the experimental condition the distribution of heavy metals was observed only among the experimental plot soil and plants. There is no other diversification of heavy metal concentration in the experimental plot. The added source of heavy metals has to be remaining either with plants body or in the receiving soil. But when UWW is used for irrigation the concentration of heavy metals gets diluted when the UWW receives more domestic and industrial waste. Obviously in the experimental plot condition the heavy metal was uptake by plants have been observed in higher concentration than UWW irrigated areas because of availability of heavy metal in in-vivo plot is more and freely available to uptake of plant species.

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