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A PILOT STUDY OF REMOVAL OF HEAVY METALS FROM POLLUTED SOIL THROUGH PHYTOSEQUESTRATION

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Abstract

Wastewater has a significant capacity to bind a variety of harmful chemicals, making it a key repository for pollutants. These substances can be found in a variety of forms in wastewater and in the growth forces of different crops. Studying these interactions is crucial because the form in which chemicals are found in the environment may have a significant impact on how dangerous they are. Additionally, crop variability in certain environmental aspects may alter the soil and result in the leaching of trace hazardous substances. Because of their negative direct and indirect impacts on human health, metals linked to urban wastewater and some crop species are a major concern. The major goals of this phytoremediation study conducted in the municipal wastewater irrigated zones of Mysuru city were to identify heavy metals with harmful environmental loads and determine the effects of those heavy metals on the environment (Cd, Cu, Fe, Ni, and Zn). This study's objective was to offer data on the concentration of heavy metals in specific crops. The heavy metal speciation in crops research revealed that all metals were mostly connected with the oxidizable and residual fraction, allowing us to forecast their mobility within the crop.

Key words: Phytosequestration, Wastewater, Toxicity, Fractions, Heavy Metals,

Introduction

Phytosequestration is the ability of plants to sequester certain contaminants in root zone. This is accomplished through several of the plant's physiological mechanisms. Phytochemicals extruded in the root zone can immobilize or precipitation of the target contaminant. Some techniques, like soil cleaning, have a negative impact on soil fertility, structure, and biological activity. Others are expensive from an engineering standpoint. Therefore, the low-tech, in-situ approach to Phytosequestration is wise because it provides site reinstatement, partial decontamination, maintenance of the biological activity and physical structure of soils, and is possibly affordable, aesthetically unobtrusive, and there is the possibility of

recovering heavy metals (Baker et al., 1991, 1994). The high expense of many existing soil remediation techniques and the need to adopt an environmentally friendly, sustainable procedure are the main factors driving the development of Phytosequestration.

These plants have strong metal sequestration mechanisms and can have higher internal requirements for metals (Shen et al., 1997). Unlike non-hyperaccumulating species, some species may be able to mobilise metals from less soluble soil fractions (Mc Grath et al., 1997). Hyperaccumulators typically have higher metal concentrations in their shoots than their roots. The numerous benefits that make Phytosequestration a suitable and effective method give practitioners a worthwhile remediation alternative. The USEPA estimates that it is 50–80% less expensive than the alternatives for various applications of Phytosequestration, which is its main benefit (EPA, 2000). Both organic and heavy metal removal can be done with it. According to Clemens (2001), Suresh and Ravishankar (2004), Le Duc and Terry (2005), Chehregani and Malayeri (2007), Odjegba and Fasidi (2007), Turan and Esringu (2007), Lone et al. (2008), Kawahigashi (2009), and Vithanage et al. (2012), it is a novel, cost-effective, efficient, environment- and eco-friendly, in situ applicable, and The majority of the time, plants manage the toxins without harming the topsoil, preserving its usefulness and fertility. With the addition of organic matter, they might increase the soil fertility (Mench et al., 2009). Metals' multiple forms cannot be determined from the total concentration of the metals. As a result, it is crucial to identify and keep track of specific chemical forms of heavy metals in environmental samples such water, soil, biological material, and airborne particles.

One of the most difficult issues that environmental chemists currently face is the development of analytical techniques to accurately detect the quantities of the various chemical forms (speciation) of trace metals in an environmental sample like silt. In the past 20 years, speciation methods have been extensively employed to identify heavy metals in sediments (T.M. Florence, 1982); (G.E. Batley, 1989). Because the chemical form of the metal in the crops determines its mobilisation capacity and behaviour in the environment, determining the total metal in crops may provide information about potential pollution levels, but often there are not enough details to estimate their biological impacts.

Selective sequential extraction approaches are a typical experimental strategy for examining the mobility, transport, and bioavailability of metals in crops (Mc Laren and Clucas, 2001). We can predict metals' mobility in the soil sample based on heavy metal speciation, which showed that metals were primarily connected with the oxidizable and residual fraction. While only a tiny portion of heavy metals (Fe, Cu, Cr, Zn, and Ni) are extracted in soluble fractions, exchangeable fractions, and carbonate fractions, the residual fraction contains the highest percentage of heavy metals. The low bioavailability index is shown by this. Heavy metals' mobility and availability through sequential extraction have shown to be quite important in providing useful information (Doddaiah Shivakumar, 2012). In operationally defined speciation, the fraction obtained is determined by the physical or chemical fractionation method used on the sample. In sequential multiple extraction techniques, numerous chemical extractants are sequentially given to the sample of sediment, soil, and crops, with each subsequent treatment having a more dramatic chemical action or being distinct in nature from the one before it. These techniques have been applied to a variety of materials, including atmospheric particulates (Walter et al., 1989), street dust and roadside soils (Harrison et al., 1981), biosolids (Pérez-Cid et al., 1996), incinerated sludge ash (Fraser and Lum, 1983), and sediments (Gonzalez et al., 1995), among others (Rauret et al. 1989b)

The five-stage systems created by (Tessier et al. 1979) or its adaptations, which form the foundation of many of these schemes (Rauret et al. 1989 a, b). The exchangeable, carbonate, reducible (hydrous Fe/Mn oxides), oxidizable (sulphides and organic phases), and residual (mineral) fractions are distinguished by these sequences. The exchangeable, carbonate, reducible (hydrous Fe/Mn oxides), oxidizable (sulphides and organic phases), and residual (mineral) fractions

are distinguished by these sequences. The main substances that limit the use of crops on agricultural land are zinc, copper, nickel, and chromium. Both human health and the ecosystem are at risk due to their potential accumulation in human tissues and biomagnification in the food chain. These factors are often dependent on the biosolid's overall heavy metal content. The estimation of the total elements does not, it is now well acknowledged, provide a reliable indication of the potential environmental impact. This is true because it is becoming clear that the chemical form of heavy metals has a significant impact on both their bioavailability and their toxicity (Alvarez et al. 2002). The primary goal of the current study is to employ the extractant used at each step to transform the metals bound in the sediment phases into soluble forms.

It is possible to study the speciation of cadmium, copper, iron, nickel, lead, and zinc in crops grown using municipal wastewater by using sequential extraction procedure proposed by Tessier method. This is done by using a series of single reagents to extract defined phases from the sediment in a defined sequence. The crop species used in this study were gathered from irrigated agricultural areas in Mysore, Karnataka, India.

MATERIALS AND METHODS

Study area

Mysuru is a city in the Indian state of Karnataka, and the administrative seat of Mysuru District, one of the largest districts in Karnataka. Mysuru was the former capital of the Kingdom of Mysuru. Mysuru is located at 770 m above sea level at 12.18° N 76.42° E and is 135 km from Bangalore, the state capital. Mysuru 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. Many small, medium and large-scale industries exists in and around the Mysuru 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.

Multi-step sequential extraction of crop biomass

The sequential extraction procedure used in this study is Tessier et al. (1979) method. The extraction was carried out increasingly on an initial mass of 1.00 g of sample of crop biomass including the composition of (root + shoot + leaf). The samples for sequential extraction were dried in an oven at 60◦C for 24 hr to avoid, as far as possible, the transformation of some chemical forms. This procedure is having five steps fractionization.

Table.1: Crop species grown around Mysore city using Municipal Wastewater (MWW)

Name of plant species irrigated using (MWW)	Family of the species.
***Amaranthus tritis* L**	*Amaranthaceae*
***Anethum graveolens* L**	*Apiaceae*
***Coriandrum sativum* L**	*Apiaceae*
***Mentha longifolia* L**	*Lamiacea*
***Oryza sativa* L**	*Poaceae*
***Pennisetum purpureum Schumach* L**	*Poaceae*
***Spiracia oleracea* L**	*Amaranthaceae*
***Trigonella foenum graecum* L**	*Fabaceae*
***Zea mays* L**	*Poaceae*

RESULT AND DISCUSSION

The metal's bonding is very weak in the exchangeable fraction (F1), where it can be drained by water and has a better mobility from one tropic level to another. The carbonate-related fraction (F2) is extractable, can accumulate in living things, and exhibits a moderate degree of mobility in the soil and water environments. Metals are matrix-enclosed in the fractions linked to iron and manganese oxides (F3) and organic matter (F4), respectively. The metals found in the residual fraction (F5) are inert, meaning that their mobility is relatively low, and they cannot travel to higher levels. Which, depending on its arrangement, may contain metals. Under conditions typically seen in nature, these metals are not likely to be released in resolution over a reasonable time period (Stylianou et al., 2007). The P.purpureum Schumach species demonstrated the highest mobility of metals for all the tested metals in the crops species planted in the agricultural field employing MWW. All crop species have trace amounts of cadmium, indicating a low concentration and lack of availability to the plants. The increased mobility of copper in plants is indicated by its uptake in the F1 and F2 cells. F5 on the other hand demonstrated entire accumulation in the plant body, which points to its residual nature.

The primary ingredient for plant growth is iron. The main source of iron is the rusting of pipes and trash, which is linked to the soil as a nutrient and MWW and plays a crucial role in both uptake and uptake rate. As a result, the plant species frequently absorbs a lot of iron. P. purpureum Schumach, Oryza sativa L, Trigonella foenum graecum L, Zeamays L, and Amaranthus tritis L species all have nickel bound to F1. It shown that by collecting greater concentrations, it may travel into the next tropic level and remain mobile. Except for P. purpureum Schumach, the lead concentration was once more BDL in all fractions.

Table 2: Total content of Cadmium and its distribution among fractions in crops

Cadmium (Cd)						
Crops	**Plants grown by using MWW (mg/L)**					
	F1	**F2**	**F3**	**F4**	**F5**	**Total**
***Amaranthus tritis* L**	BDL	BDL	BDL	BDL	0.12	0.12
***Anethum graveolens* L**	BDL	0.21	BDL	BDL	0.1	0.31
***Coriandrum sativum* L**	BDL	BDL	BDL	BDL	BDL	BDL
***Mentha langifolia* L**	BDL	0.11	BDL	BDL	BDL	0.11
***Oryza sativa* L**	BDL	BDL	BDL	BDL	BDL	BDL
P.purpureum Schumach	0.21	BDL	0.32	BDL	0.11	0.64
***Spiracia oleracea* L**	BDL	BDL	BDL	BDL	BDL	BDL
***Trigonella foenum graecum* L**	BDL	BDL	BDL	0.22	BDL	0.22
***Zeamays* L**	BDL	0.12	BDL	BDL	0.2	0.32

Table 3: Total content of Copper and its distribution among fractions in crops

Copper (Cu)						
Crops	**Plants grown by using MWW(mg/L)**					
	F1	**F2**	**F3**	**F4**	**F5**	**Total**
***Amaranthus tritis* L**	0.1	BDL	0.22	BDL	0.14	0.46
***Anethum graveolens* L**	0.12	0.11	BDL	0.1	0.12	0.45
***Coriandrum sativum* L**	BDL	BDL	BDL	BDL	0.13	0.13

***Mentha langifolia* L**	BDL	BDL	BDL	BDL	0.12	0.12
***Oryza sativa* L**	BDL	BDL	BDL	BDL	0.24	0.24
P.purpureum Schumach	0.2	0.9	0.9	0.3	0.21	1.61
***Spiracia oleracea* L**	0.3	0.2	BDL	BDL	0.46	0.96
***Trigonella foenum graecum* L**	BDL	BDL	BDL	BDL	0.3	0.3
***Zeamays* L**	0.2	0.4	0.2	BDL	0.9	1.7

Table 4: Total content of Iron and its distribution among fractions in crops

Iron (Fe)						
Crops	**Plants grown by using MWW (mg/L)**					
	F1	**F2**	**F3**	**F4**	**F5**	**Total**
***Amaranthus tritis* L**	7.9	28	35	47.2	37.4	155.5
***Anethum graveolens* L**	7.0	14.9	18.9	46.8	80.6	168.2
***Coriandrum sativum* L**	3.0	13.8	15.3	46.2	45.0	123.3
***Mentha langifolia* L**	7	18	37	31	62	155
***Oryza sativa* L**	10.3	39.1	79.1	46	26	200.5
P.purpureum Schumach	26.0	69.3	144	265.1	168	672.4
***Spiracia oleracea* L**	5.0	21.2	47.8	19.7	61.8	155.5
***Trigonella foenum graecum* L**	2.2	19.4	33.4	32.5	68	155.5
***Zeamays* L**	9.7	23.3	44.1	97.6	66.6	241.3

Table5: Total content of Nickel and its distribution among fractions in crops

Nickel (Ni)						
Crops	**Plants grown by using MWW (mg/L)**					
	F1	**F2**	**F3**	**F4**	**F5**	**Total**
***Amaranthus tritis* L**	0.1	0.4	0.2	BDL	0.24	0.94
***Anethum graveolens* L**	BDL	BDL	0.23	0.21	0.3	0.74
***Coriandrum sativum* L**	BDL	BDL	BDL	0.25	0.46	0.71
***Mentha langifolia* L**	BDL	BDL	BDL	0.12	0.26	0.38
***Oryza sativa* L**	0.12	0.12	0.23	0.35	0.14	0.76
P.purpureum Schumach	1.12	2.4	1.8	1.2	1.8	8.32
***Spiracia oleracea* L**	BDL	BDL	0.12	0.24	0.3	0.66
***Trigonella foenum graecum* L**	0.1	0.12	0.27	0.12	0.31	0.92
***Zeamays* L**	0.4	0.6	0.6	0.5	1.1	3.2

Table 6: Total content of Lead and its distribution among fractions in crops

Lead (Pb)						
Crops	**Plants grown by using MWW (mg/L)**					
	F1	**F2**	**F3**	**F4**	**F5**	**Total**
***Amaranthus tritis* L**	BDL	BDL	0.12	BDL	BDL	0.12
***Anethum graveolens* L**	0.11	BDL	BDL	BDL	BDL	0.11

***Coriandrum sativum* L**	BDL	BDL	BDL	BDL	BDL	BDL
***Mentha langifolia* L**	BDL	BDL	0.26	BDL	BDL	0.26
***Oryza sativa* L**	BDL	BDL	BDL	BDL	BDL	BDL
P.purpureum Schumach	0.8	0.8	1.2	0.9	1.9	5.6
***Spiracia oleracea* L**	0.23	BDL	BDL	BDL	BDL	0.23
***Trigonella foenum graecum* L**	BDL	BDL	BDL	BDL	BDL	BDL
***Zeamays* L**	BDL	0.2	BDL	BDL	0.4	0.6

Table 9: Total content of Zinc and its distribution among fractions in crops

Zinc (Zn)						
Crops	**Plants grown by using MWW (mg/L)**					
	F1	**F2**	**F3**	**F4**	**F5**	**Total**
***Amaranthus tritis* L**	0.2	0.3	0.3	0.4	1.3	2.5
***Anethum graveolens* L**	0.1	0.1	0.2	0.2	0.73	1.3
***Coriandrum sativum* L**	BDL	BDL	BDL	0.2	0.4	0.6
***Mentha langifolia* L**	BDL	BDL	0.2	0.3	0.3	0.8
***Oryza sativa* L**	0.2	0.3	0.2	0.3	0.9	1.9
P.purpureum Schumach	2.9	4.2	14.1	13.9	13.4	48.5
***Spiracia oleracea* L**	0.1	0.2	0.2	0.2	0.28	0.98
***Trigonella foenum graecum* L**	0.6	0.7	0.3	0.9	0.6	3.1
***Zeamays* L**	0.4	0.8	0.9	0.3	1.2	3.6

For each fraction, the zinc concentration was recorded, and its level was monitored. BDL has been seen in Coriandrum sativum L and Mentha langifolia L species. According to the speciation investigation, most of the cadmium discovered in various crop species' crops was bonded to carbonates. Cadmium in the study samples would not be transportable because its concentration in exchangeable fractions is below the detection threshold. Because copper is bonded by organic matter much more firmly than nickel, it is significantly less likely to be moved by the hydroxylamine hydrochloride reagent. McLaren and Clucas report comparable outcomes (2001). Crops do not contain copper in ionic forms, which lessens its toxicity.

All metal concentrations in the exchangeable fraction, except for iron, are below the detection limit. A small component of the overall metal content is represented by the metals that were released in the carbonate fraction.

Iron has modest amounts in this fraction, and the levels of copper, chromium, and zinc are below the detection threshold. Nickel, iron, and zinc concentrations are relatively high in the fractions linked to hydrated iron and manganese oxides. These metal concentrations would release under declining circumstances. The metal concentrations in the percentage of organic matter are relatively high and make up a significant portion of the total metal concentrations. Because these quantities of metals are discharged into soil under highly oxidising circumstances, this fraction represents a significant source of potentially accessible trace metals. Most of the investigated metals, particularly iron, were related to the residual fraction.

CONCLUSION

The findings of the current study's heavy metal speciation in crop sample showed that all metals were often associated with the residual and oxidizable fraction, allowing us to anticipate the mobility of each metal in the crop sample. While only a tiny portion of heavy metals are recovered from soluble fractions, exchangeable fractions, and carbonate fractions, the residual fraction contains the highest percentage of heavy metals. The low bioavailability index is shown by this. The study makes it abundantly evident that, given the toxicity of heavy metals in certain crops in Mysuru city, the mobility and availability of heavy metals by sequential extraction have been proven to be of major value in delivering valuable information. Additionally, regular availability and use of MWW for irrigation may increase the toxicity of heavy metals and result in major issues with bioaccumulation and biomagnification in both crops and the environment. These studies shed new information on the use of sequential extraction techniques for identifying the species of heavy metals in crops cultivated with municipal wastewater and offer an assessment of the true mobility of these substances.

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