A COMPARATIVE STUDY ON CADMIUM PHYTOREMEDIATION EFFICIENCY OF TWO AQUATIC MACROPHYTES IN ANURADHAPURA DISTRICT

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Abstract

Phytoremediation is a low-cost, eco-friendly approach where metal-accumulating plants are used for the remediation of soils and wastewaters polluted with toxic substances, which is a topic of global interest. This capability is useful in removing toxic heavy metals and trace elements from contaminated soils and waters. Cadmium (Cd) has been implicated as a causal factor contributing to the CKD, and the elevated levels of Cd were reported in waters, soils and in a range of foods commonly consumed by rural communities within the Anuradhapura district. Therefore, the aim of this study was to compare heavy metal removal potential of the native submerged rooted plant Aponogeton with that of the free floating Eichornia, to determine the Bio Concentration Factor (BCF) values of both plant types and to compare these values with the corresponding values obtained from a source at Matara district, which is a location in the CKDu non-endemic area. The sampling was done during April-May, 2016.

The sample preparation and digestion were done using standard methods. Chemical analysis for Cd was done by atomic absorption spectrometry method. Results showed that the Cd concentrations present in both plant types and the BCF did not differ significantly ($P<0.05$) between the two locations. But both soil and water samples taken from the vicinity of A. crispus plant differs significantly ($P<0.05$) between the two districts.The mean BCF values for Cd is comparatively high in both plant species in Matara district (E. crassipes 3.092, A. crispus 2.365), and E. crassipes has larger BCF values than Aponogeton crispus. It has been suggested to expand the study spatially and temporally to get more samples and hence for better results.

Key Words: Phytoremediation, BCF, CKDu, *Aponogeton crispus*, *Eichhornia crassipes*

INTRODUCTION

Heavy metals are one of the most persistent pollutants in wastewater. The discharge of high amounts of heavy metals into water bodies leads to several environmental and health impacts. Severe effects on animals may include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. The chronic kidney disease of unknown etiology (CKDu) in the Anuradhapura district in Sri Lanka is attributed to the chronic exposure and cumulative effects of elevated levels of heavy metals associated with agricultural activities (Gunatilake *et al*., 2014). A variety of remediation processes existsfor removal of heavy metals andare broadly classified into chemical and biological, although the latter is advocated in recent years (Akpor *et al.*, 2014). Developing cost effective and environmentally friendly technologies for the remediation of soil and wastewater polluted with toxic substances is a topic of global interest. A considerable part of the heavy metals that enter water bodies is added to the soil or sediments and any remediation process should consider remediating the sediments too.

Macrophytes play prominent role in nutrient and heavy metal recycling of many aquatic eco-system (Pip and Stepaniuk, 1992). Several factors must be considered in order to accomplish a high performance of remediation result and the most important is identifying a suitable plant species (Biieby*et al*., 2011). The macrophytes are of 3 types *i.e*. floating, submerged and emergent.Emergent and surface floating plants absorb heavy metals and nutrients mainly through the roots whereas in submerged rooted plants it is through roots as well as leaves(Denny 1980, 1987). Cowgill (1974) suggested that submerged rooted plants have potential from water as well as sediments. The aim of this study was to compare the heavy metal removal potential of the native submerged rooted plant *Aponogeton* with that of the free floating *Eichornia*.The specific objectives were to determine the Cd concentration in*Eichhornia crassipes* and *Aponogeton crispus* plant samples, sediments and water samples taken from the vicinity of the plants at Madawalagama in Anuradhapura district, which is a location in the CKDu endemic area, and to determine the Bio Concentration Factor (BCF) values of both plant types and to compare these values with the corresponding values obtained from a source at Matara district, which is a location in the CKDu non-endemic area.

Materials and Methods

The experiment was conducted with the collection of water hyacinth (*Eichhornia crassipes*) and water chest nut (*Aponogeton crispus*) plants, from Madawalagama (Anuradhapura District) and Akuressa (Matara District) areas. Plant, sediment and water samples, 3 replicates for each, were collected from irrigation canals in paddy lands at Madawalagama and Akuressa during April and May 2016, respectivelyjust before the harvest of the'Yala'.

Plants were collected randomly and carefully without breaking off the roots, rinsed with water to remove sediment and debris and were packed in sealed polythene bags. Collected plant samples were cut in to small pieces and dried in a convection oven for 48 hours at 60 ^{o}C to ascertain the accumulation of each contaminant and avoid evaporation of Cd^{2+}. The dried plant samples were ground using mortar and pestle and then packed with small transparent polythene bags until the wet acid digestion.HNO_3/$HClO_4$ digestion (Jones, 1984) was done by adding 5.0mL of HNO_3 (70%) and 1.5ml of $HClO_4$ (60%) to 0.5 g of sample, and the solution washeated until the disappearance of any brown fumes.

It was then cooled, added 5.0ml of (1:1) diluted HCl (density 1.18 g/ml) and finally diluted with distilled water up to 25ml solution.
Water samples from the vicinity of the plants (through the water column) were collected using plastic bottles rinsed with 0.01N nitric acid and stored in deep freezer until subjected to analysis. The pH of the collected water samples were adjusted to around 2 by adding conc. HNO_3 (2 ml per liter).

The soil samples collectedaround 15 cm depth of the stream bed by scooping from using soil auger equipmentwere dried in the oven for 24 hours at 102 ^{o}C. The dried soil samples were ground by using mortar and pestle, packed in transparent polythene bags until theyget digested, according to the EPA (1996) method 3050B. Sample (1.0000 g) was transferred into a digestion flask and 10 mL of nitric acid, 1:1 (v/v), was added to the flask. Using a hot plate, the mixture was heated to ~95 ^{o}C for 15 minutes without boiling, allowed to cool, 5 mL of conc, HNO_3 was added and the solution was refluxed for 30 minutes at ~95 ºC. This step was repeated twice and the solution mixture was concentrated (~5 mL) without boiling.

Cd ion concentrations(in ppm) in each of the sample prepared,plant, sediment/soil and water samples, were analyzed using AAS and bio-concentration factor (BCF) was calculated using the equation,$BCF = (P / E)I$ where, P is the element concentrations in the plant and E is the element concentration in the external environmentZayed *et al*. (1998).

The data weresubjected to one-way ANOVA and Turkey's method at 95% confident level using the Minitab 16.1software.

Results and Discussion

The Cd content and the BCF values of both plant species did not differ significantly (P<0.05) between the two locations;however, Cd concentration of *A. crispus*was greater than that of *E. crassipes*in both districts.Of the two districts, the metal ion content in plants is higher in Matara district than in Anuradhapura district (Figure 1). As a result, Cd ion concentration in the soil near *A. crispus*is lower than that of*E. crassipes* (Figure 2). These results strengthen the claim that the prevalence of CKDu patients is more in Anuradhapura district than Matara district.

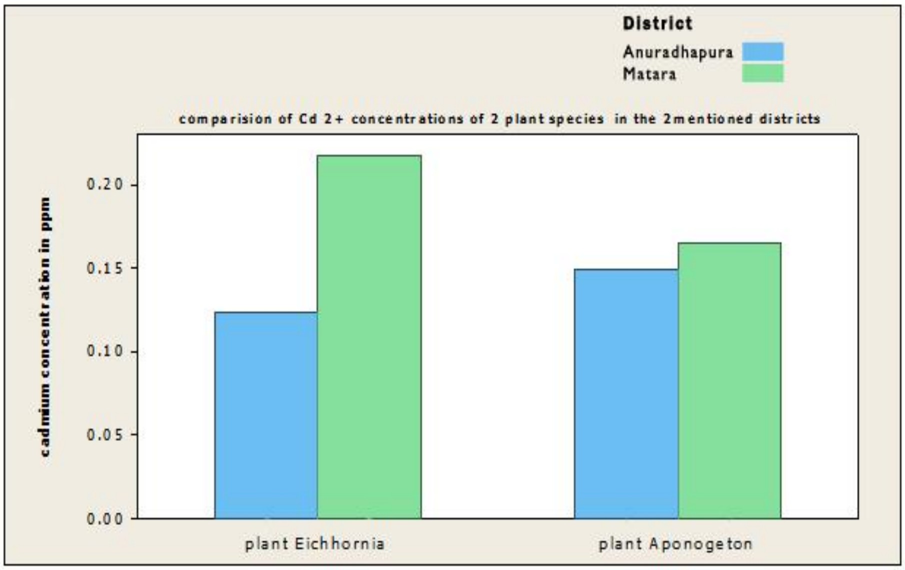

Figure 1. Comparison of Cd^{2+} concentrations of two plant species in both districts

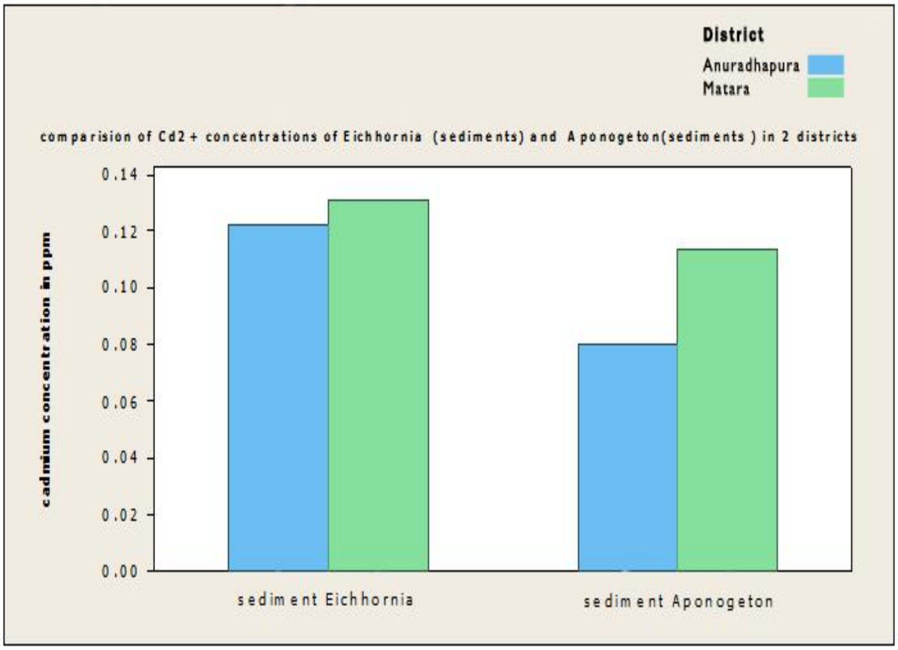

Figure 2. Comparison of Cd^{2+} concentrations of sediment samples taken from the vicinity of two plant species in both districts

Although not significant, the BCF of both species were considerably higher in Akuressa compared to Anuradhapura (Figure 4) though the Cd concentration in water did not differmuch (Figure 3). The ambient metal concentration in water is the major factor influencing the metal uptake efficiency (Cain *et al*, 1980). In general, when the metal concentration in water increases, the amount of metal accumulation in plants increases; whereas the BCF value decreases (Wang and Lewis, 1997). Therefore, this could be probably due to some environmental factors in Akuressa are favorable for more Cd absorption.

The Cd uptake and BCF though did not differ between species in Anuradhapura and it was considerably higher in *E. crassipes* compared to *A. crispus* in Akuressa. Despite *A. crispus* absorbing metals possibly through both roots and leaves the reason for lower Cd content could be its less efficiency or the low bio-availability of Cd in sediment. This could also be due to the concentration of the metal in the environment as has been reported by Elankumaran *et al*. (2003) established a comparative study between *Hydrilla verticillata* and *Salvinia* sp. and concluded that removal efficiency of *Hydrilla verticillata* is higher in lower concentration of (at 5 ppm) compared to *Salvinia*, but in higher concentration removal efficiency of *Salvinia* is more. Cd present in soils may be in different forms, whether or not water soluble. So the bio-availability of elements in soils needs to be determined before making any conclusions. The impact of metal (Cd) uptakemay be influenced by many soil factors such as the pH, Redox potential and organic matter levels, type of clay and cation exchange capacity.

The plant density of *A. crispus* was very low compared to the plant density of *E. crassipes* in both locations. One of the reasons could be less light penetration due to the dense growth of floating weedy macrophytes. The growth rate of *Eichornia* too is much higher. Its population can double in as little as 6 days as reported by (Mitchell, 1976). Thus in terms of phytoremediation *E. crassipes* an efficient candidate compared to *A. crassipes*. However, *E. crassipes* is a highly invasive problematic weed and for phytoremediation of water bodies which are not infested with such weeds. The plant density of native macrophytes like *Aponogeton* in such water bodies would be higher due to lack of weeds and hence can play a crucial role in phytoremediation of such water bodies.

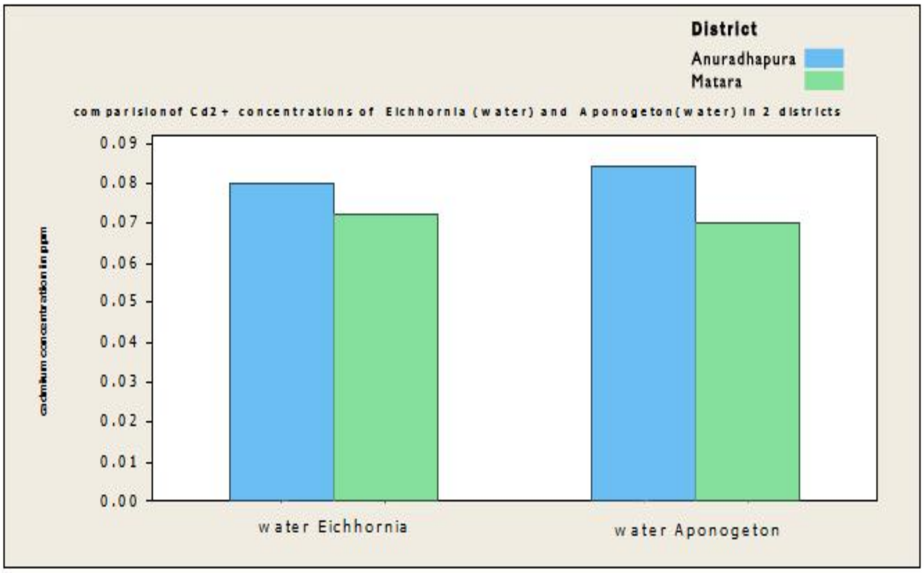

Figure 3. Comparison of Cd^{2+} concentrations of water samples taken from the vicinity of two plant species in both districts

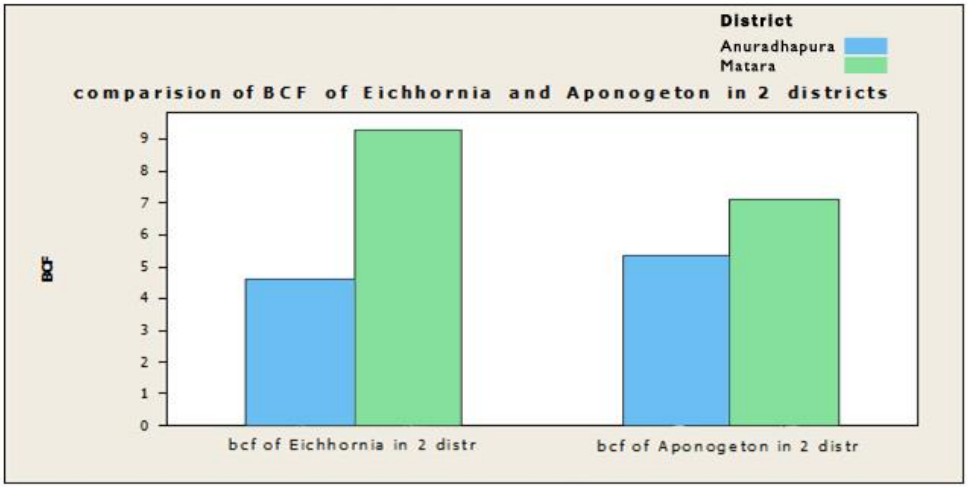

Figure 4.Comparison of BCF of two plant species in both districts

Conclusion

The Cd concentration present in both type of plant samples were high in Matara district compared to that of Anuradhapura district. The heavy metal removal potential of the native submerged rooted plant *Aponogeton*is higher than that of the free floating *Eichornia*at one place and it is reverse at the other place, hence environmental factors of the locality influence the heavy metal removal potential of the plants concerned.

The results endorse that the Cd content in the soil is less when the plant uptake is more.Further, the Cd concentration in water is slightly higher in Anuradhapura district suggests its influence on the CKDu and higher prevalence of the disease in the district. The BCF for Cd is comparatively high in both plant species in Matara district, irrespective of the plant type. Environment of the locality influences in this regard as well.

Acknowledgements

Authors are grateful to the South Eastern Universityof Sri Lanka for the financial support provided to carry out this researchand to the University of Colombo for sample analysis.

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