

Phytoextraction of Nutrients and Heavy Metals by two Monocot Plants in Thaula Area of Small Reservoir in Anuradhapura, Sri Lanka

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ABSTRACT

Purpose: Small tanks/reservoirs are one of the major components of dry zone landscape and they were the basis of prosperity in ancient Sri Lanka. There are identified ecosystem components associated with the tanks such as upper peripheral area (thaula). It is useful to understand the role of hydrophytes in thaula area scientifically. This field study aimed to investigate the phytoextraction ability of two monocot plants, *Paspalidium punctatum* and *Cyperus rotundus* naturally grown in thaula area of Ulankulama tank located in Anuradhapura.

Research Method: The accumulation of total N, P, K, Ca, Mg, Cd, Pb and As were assessed by getting both plant and soil samples from 20 sampling points in thaula area. Total K, Ca, Mg, As, Cd, and Pb contents were measured using the Inductivity Couple Plasma Optical Emission Spectrophotometer (ICP-OES) procedure. N, P, K were assessed following standard analytical procedures.

Findings: Results showed that As and Cd were not observed in detected amount in soils of root zone of the plants. However, As and Cd were present in shoots and roots in both plant species. Both species could be considered as hyperaccumulator for K, Ca and Mg as they have biological concentration factor higher than one.

Originality/Value: *Paspalidium punctatum* and *Cyperus rotundus* could be considered as hyperaccumulator for K, Ca and Mg and bio accumulation of heavy metals in thaula area.

Keywords: Heavy metals, Nutrients, Phytoextraction, Thaula, Small tank

INTRODUCTION

Excessive use of agrochemicals and chemical use in industries lead to dispose metal containing pollutants and have accumulated in soil especially, heavy metals and plant nutrients such as phosphorus. Even in dry zone environment in Sri Lanka, use of agrochemical is still the main method of controlling pests and synthetic fertilizer is the main source of crop nutrients. The residues of agrochemicals containing metals and excess plant nutrients directly reach water bodies through the runoff as they reside in low lying area of the dry zone landscape. In addition, different kinds of industries are emerging and the use of vehicles are in increase in dry zone Sri Lanka and their chemical effluent containing different kinds of metals are very likely to ultimately dispose to water bodies. Water bodies in the dry zone are mainly manmade and are called as tanks. Of all

the small tanks in the dry zone, approximately 90 percent is clustered into the cascades (Wijesundara *et al.*, 2012).

“A ‘tank cascade’ is a connected series of tanks organized within a meso catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet” (Madduma Bandara, 1985). As this system is adapted agricultural system managed with time tested

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indigenous techniques, FAO (2018) recognized this system as a Globally Important Agricultural Heritage System. In this system, water discharged from the upper tank to the command area, flood water of the upper tank and water draining from the paddy fields in the upstream command area are captured by the tank at downstream which flow through *thaulla* area (Abeysingha *et al.*, 2018). This micro-land region of the tank is partially covered with water but only completely flooded mostly during the rainy season particularly, during the North East monsoon season. However, this area is comparatively dry during the dry season (May to September) especially, in tanks located in North Central Province where there is no *Mahaweli* water diversions. Mahatantila *et al.*, (2008) suggested that most of the water pollutant draining into tank can be effectively controlled by the *thaulla* taking *Malagane* tank as an example. Abeysingha *et al.* (2016) showed that Mg, Na, and Ca in a decreasing concentration in soils of *thaulla* area towards the water spread area in *Ulankulama* tank at *Maradankadawala* in *Anuradhapura* and also shown that metal concentration is higher in *thaulla* area when compared to the normal values of the surrounding soils (Gunapala and Abeysingha, 2019). These results suggest that *thaulla*, can act approximately as an active 'constructed wetland' which efficiently removes pollutants in order to sustain the system. *Thaulla* area along with a small tank environment can be considered as a special wetland system (Gunapala and Abeysingha, 2019).

In wetlands, there is a close link between the aquatic flora and the soil and water conditions, being complex systems in which the exchange between soil and biota is accomplished in dilute media and sometimes in reducing environment, providing environments that differ from most soil surface horizons, which are usually under aerobic conditions (Cacador *et al.*, 2013). In addition, wetlands have an important role in the preservation of environmental quality due to their high capacity for retention and/or inactivation of harmful substances (González-Alcaraz *et al.*, 2013). Aquatic macrophytes not only assimilate pollutants directly into their tissues, but can also act as catalysts for purification reactions by increasing environmental diversity

in the rhizosphere, thereby promoting various chemical and biochemical reactions that enhance purification (Jenssen *et al.*, 1993). Approximately, similar functions can be expected in tank- *Thaulla* a partial wetland ecosystem. In this partial wetland ecosystem there are different kinds of hydrophytes. Understanding their roles is useful to conserve the *thaulla* area of tanks further in future. According to the published literature, there were no scientific studies to quantify the phytoextraction abilities of naturally grown hydrophytes in *thaulla* area. Therefore, this research study is planned to quantify the nutrients and heavy metals absorbing capabilities of most abundant two monocots plants naturally growing in *thaulla* area of a small tank.

METHODOLOGY

Study Site and Sampling Procedure

The field work was carried out in *Thaulla* area of *Ulankulama* tank, located in *Tirappane* Divisional Secretariat Division in *Anuradhapura* district, North Central Province. This tank is located about 20 km south from *Anuradhapura* city, closer to the *Anuradhapura - Maradankadawala - Kekirawa* road. It is found in the middle part of *Ulagalla* cascade which has a prominent *thaulla* area of about 0.43 km² in extent (Abeysingha *et al.*, 2016). Figure 01 shows the geographical location of the tank and sampling points.

As shown by Gunapala and Abeysingha (2019), the soil properties vary from upstream area to downstream area of *thaulla*. Therefore, sampling points were selected to represent this variation as shown in the Fig.01. In this study, only one type of dominant sedge and grass were selected and mature plants of both sedge and grass were uprooted from approximately one meter radius of the sampling points. Sampling points had to be limited to 20 sites due to limited availability of same grass and sedge. Soil samples were taken from the same place where plants are uprooted and the same root zone depth of the plants of about 0-15cm. These soil and plant samples were transferred into pre-cleaned, labeled polythene bags separately.

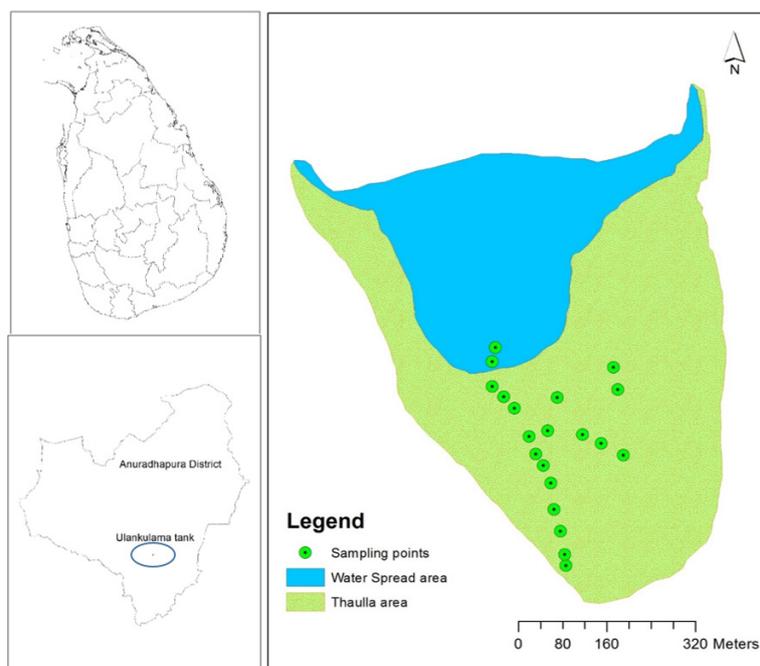


Figure 01: Ulankulama tank located in Anuradhapura District and Thaulla area and sampling points

Subsequently, samples were subjected to analysis of nutrients and heavy metals. Meanwhile, two monocot plant species i.e. sedge and grass collected were identified with the support of the National Herbarium, Peradeniya Sri Lanka. Two monocot species were identified as *Cyperus rotundus* and *Paspalidium punctatum* a sedge and grass respectively.

Analytical determinations

In the laboratory, individual plant samples were first washed thoroughly in running water to avoid any surface contamination and then rinsed with distilled water to remove any further residual materials. Then plant samples were dissected into roots and leaves and air dried for 2 to 3 days and oven dried them in 60 °C for 2 days. Plant samples were ground in an agate mortar to ensure a homogeneous element distribution in the powder. All soil samples were air-dried separately without allowing contamination with external material or among samples. Soil samples were air dried at room temperature on polythene sheet. While drying aggregates were broken by crumbling the lumps. Plant roots and stone particles were removed. Then, the collected soil samples were ground using a hammer. Then,

soil passed through a 2 mm sieve and sieved soil samples were stored in clean polythene bags after proper labeling. Then both soil and plant samples were analyzed for total N, P, K, Ca, Mg and heavy metals Cd, As and Pb. Then, pH and EC of soil samples were also tested.

Total K, Ca, Mg, As, Cd, and Pb contents were measured using the Inductivity Couple Plasma Optical Emission Spectrophotometer (ICP-OES) procedure after acid digestion of soil samples and dry ashing of plant samples (SERAS, 2006). pH and EC of soil samples were determined using the multi-parameter analyzer (HATCH, Sension 156) with the 1: 2.5 soil-water suspension method (Rowell 1994) and 1: 5 soil-water suspension method (Chapman and Pratt 1961) respectively. Total N content of soil samples were determined through the Kjeldahl procedure (Bremmer and Muloaney 1982). Total P in soil was measured by wet oxidation method (Akinremi *et al.*, 2003) and P in plant samples were determined after dry ashing of plant samples.

Bio concentration/ Biological accumulation and translocation factors were determined to assess element mobility in the studied species. The values obtained were based on the following

$$\text{BAF} = \text{NC shoot} : \text{NC soil}$$

BTF = NC shoot : NC root

BCF = NC root : NC soil

BAF- Biological accumulation factor

BTF- Biological translocation factor

BCF- Biological concentration factor. (Yoon and Li, 2007)

To test the significant differences between mean values of different elements in both soil and plant and ratios (BAF, BTF and BCF), data were subjected to one-way analysis of variance ($p < 0.05$) with a mean separation of least significant difference (LSD) value.

RESULTS AND DISCUSSION

Different plants species have different capacities to accumulate the nutrients and toxic heavy metals from various wet environments which is an indicator of their potential phytoremediation action. This study tested accumulation of few nutrients and heavy metals in *Paspalidium punctatum* and *Cyperus rotundus* which were abundant in meadow of tank *Ulankulama*.

Results indicated that N content was significantly higher in shoots than the roots in both the monocot plant species *Paspalidium punctatum*, and

Cyperus rotundus. However, N content in both roots and shoots was not significantly different between two plant species (Table 01). Also, soil N content was not significantly different from places where the plants were uprooted (Table 02). These results infer that both grass and sedge tested has approximately same capacity to accumulate nitrogen and more nitrogen is located in shoots than roots. Soil nitrogen content varies from 0.132 to 0.146 % at the root zone area and these values are lower than the general soil in the area of Anuradhapura district' soil which is Reddish Brown Earth (RBE) and it is associated with Low Humic Glay (LHG) soil and N content varies from 11.6 % to 23.22 % (Nandasena 2002). N is the most limiting nutrient in wetland system (Reddy and D'Angeolo, 1997) and *thaula* area was also observed with limited nitrogen compared to the reference soil. N. Gunapala and Abeysingha (2019) also observed the lower N contents (0.073%) in the entire *Thaulla* area of the same tank, *Ulankulama*. Wetland plants have special physiological processes such as cluster roots to accumulate essential nutrients such as N and P (Zedler, 2010). *Thaulla* in small tanks can be considered approximately as a wetland (Abeysingha *et al.*, 2018). Lower concentration of N reported in the present study also supports the hypothesis that the *Thaulla* can act partially as a wetland.

Table 01: Nutrient and heavy metal content of *Paspalidium punctatum* and *Cyperus rotundus*

Parameter	<i>Paspalidium punctatum</i>		<i>Cyperus rotundus</i>	
	Shoot	Root	Shoot	Root
N%	0.09* ± 0.04	0.05 ± 0.03	0.07* ± 0.02	0.04 ± 0.01
P (mg/kg)	33.83 ± 14.27	23.13 ± 8.46	36.91 ± 14.25	22.84 ± 5.03
K (mg/kg)	186.19 ± 133.66	125.12 ± 104.57	207.50 ± 41.33	141.08 ± 49.50
Ca (mg/kg)	37.02 ± 7.66	34.83 ± 10.99	41.94 ± 5.77	39.04 ± 7.62
Mg (mg/kg)	25.08 ± 6.55	21.33 ± 7.94	28.91 ± 9.1	22.61 ± 7.2
Heavy metal				
Cd (µg/kg)	0.001 ± 0.001	0.002 ± 0.001	0.002 ± 0.001	0.002 ± 0.001
As (µg/kg)	0.808 ± 0.20	1.158 ± 0.38	0.820 ± 0.16	1.286 ± 0.36
Pb (µg/kg)	0.18 ± 0.05	0.25* ± 0.06	0.141 ± 0.03	0.170 ± 0.06

*Significantly different at $P < 0.05$; mean values (\pm SD)

Table 02: Nutrient and heavy metal content of root zone soil under *Paspalidium punctatum* and *Cyperus rotundus*

Parameter	<i>Paspalidium punctatum</i>	<i>Cyperus rotundus</i>
N %	0.132 ± 0.08	0.146 ± 0.05
P (mg/kg)	47.314 ± 17.24	35.575 ± 10.14
K (mg/kg)	9.357 ± 1.90	8.432 ± 1.76
Ca (mg/kg)	17.176 ± 4.75	23.03* ± 2.60
Mg (mg/kg)	14.12 ± 3.33	21.66* ± 3.46
Cd(ppb)	ND	ND
As(ppb)	ND	ND
Pb (ppb)	33.75± 13.81	27.9 ± 9.33
pH	6.34 ± 0.56	6.34 ± 0.48
EC (µS/cm)	151.99 ± 49.64	158.00 ± 43.81

Note: mean values (± SD)

P and K contents of studied plants were also higher in shoots of both the plants and they were not significantly different between both plant species. Though both Ca and Mg contents were higher in shoots than those of roots, they were not statistically different in both the plant species and between both two plants. Out of the nutrients parameters tested, K absorbed by both plants more than other elements. However, the most abundant nutrient in the *thaulla* area was P (Table 02). The total P concentration of RBE soils in *Anuradhapura* district varied from 1.6 to 20 mg/kg (Karunadasa and Duminda, 2013). This study observed the P accumulation (35 to 47 mg/kg) in soils in the root zone area of part of *thaulla* area probably due to higher use of P fertilizer in the tank catchment area. Contents of other nutrients in soil are shown in Table 02 and these values are not significantly different under two plant types except Ca and Mg. Ca and Mg concentration was higher in soil associated with the sedge (*Cyperus rotundas*) and it may be due to root exudates of the sedge or the inherent soil properties. Moreover, Ca and Mg contents are higher in both the shoots and roots of sedge than the grass though the values are not statistically significant.

Wetland can effectively remove heavy metals and metalloids in water by acting as a matrix,

facilitating interaction between microbes and plant/animal communities and performing functions such as filtration, adsorption, precipitation, ionic exchange, microbiological degradation, and biological uptake (Malaviya and Singh, 2012). Cd and As in root zone area of *Thaulla* soil were not detected while, Pb was detected in higher quantities (Table 02) in soils associated with root zone area of both the plant species. Bioaccumulation of metals is determined by pH of the substrate, plant type, climatic conditions, and form and state of available metals in the substrate (Maiti and Jaiswal, 2008). It is observed that a higher release rate of heavy metals exists in the sediment-water system at lower pH than higher pH (Li *et al.*, 2013). pH of the studied *thaulla* soil was slightly acidic (Table 02) and that may result in higher release of heavy metals from the soil system. Three heavy metals tested were observed in both plants and present in both shoots and roots. Though As and Cd were not present in detected amount (ICP-OES method) in soils, presence of As and Cd in shoots and roots may be due to higher release rate of the soil and their bio accumulation in plants. Concentration of As was higher than the Pb and Cd both in roots and shoots. As and Pb contents are higher in roots than those of shoots in both the species. Only Pb is significantly higher in roots than those of shoots in grass. Greater accumulation of

trace element in underground organ is a common pattern as a defensive mechanism to protect the species against harmful toxic effects (Bonanno, 2013; Phillips *et al.*, 2015).

Biological translocation, Biological concentration and Biological accumulation factors of nutrient and heavy metals are shown in Table 03. Biological translocation Factor (BTF) is a measure of the internal mobility of a given element across plant organs (Deng *et al.*, 2004). The highest BTF recorded element is N for *Paspalidium punctatum* and K for *Cyperus rotundus*. Variation of BTF for the tested elements was narrow for *Cyperus rotundus* and the range was 0.68 to 1.86 whereas it was in the range of 0.67 to 2.23 for *Paspalidium punctatum*. For both the species, N, P, K, Ca, Mg can be considered as more mobile elements compared to tested heavy metals. For Cd, As and Pb, comparatively higher translocations were observed in *Cyperus rotundus* than those of *Paspalidium punctatum* though the results were not statistically significant.

The Biological concentration Factor (BCF) is generally defined as the metal concentration ratio in root to soil. However, this study tested the BCF of nutrient parameters also in relation to tested plant species. The highest BCF was recorded for K by both the plants. Similarly, BAF which is the ratio of concentration of given element in

shoot to soil, was also the highest for K in both plant species. Ca also had a considerable higher value of BCF and BAF in both plant species. A BCF value higher than one may indicate that a plant species could act as a hyperaccumulator (Bonanno and Cirelli, 2017). Therefore, both species could be considered as hyperaccumulator for K, Ca and Mg. A plant species that has both BCF and BTF > 1 has the potential of being use in phytoextraction (Yoon *et al.*, 2006). Hence, this study showed phytoextraction ability of two species *Paspalidium punctatum* and *Cyperus rotundus* considering the tested elements K, Ca, Mg and their BCF and BTF.

Rather than these two species, effective accumulator of N and P may also be present in *thaula* area and identification of their effectiveness in accumulating nutrients may be useful. Kao *et al.*, (2003) showed different capabilities of retention of N and P of different wetland plant species. This study used only two abundant plant species, and it is suggested to use other available plant species in the natural habitat to evaluate the nutrients and also toxic heavy metal retention capabilities so that water resources planner can encourage growing of those aquatic plants with high capacities to accumulate agricultural pollutants in *thaula* area. In addition, these plant species can be used as plants in constructed wetlands locally.

Table 03: Biological translocation factor, Biological concentration factor, Biological accumulation factor of Nutrient and heavy metal content of under *Paspalidium punctatum* and *Cyperus rotundus*

Parameter	<i>Paspalidium punctatum</i>			<i>Cyperus rotundus</i>		
	Shoot:Root (BTF)	Root: Soil (BCF)	Shoot: Soil (BAF)	Shoot:Root (BTF)	Root: Soil (BCF)	Shoot: Soil (BAF)
N%	2.23 ± 1.47	0.54 ± 0.56	1.57 ± 2.73	1.53 ± 1.24	0.49 ± 0.55	0.72 ± 2.96
P (mg/kg)	1.52 ± 0.63	0.53 ± 0.18	0.76 ± 0.16	1.67 ± 0.76	0.69 ± 0.23	1.07 ± 0.37
K (mg/kg)	1.96 ± 0.95	14.41 ± 9.94	22.34 ± 11.1	1.86 ± 1.35	15.18 ± 7.57	24.16 ± 8.50
Ca (mg/kg)	1.24 ± 0.37	2.52 ± 1.02	2.42 ± 1.05	1.17 ± 0.48	1.89 ± 0.98	2.13 ± 1.11
Mg(mg/kg)	1.25 ± 0.27	1.67 ± 0.71	1.94 ± 0.58	1.31 ± 0.44	0.92 ± 0.81	1.21 ± 0.69
Heavy metal						
Cd (ppb)	0.67 ± 0.34	ND	ND	0.806 ± 0.41	ND	ND
As (ppb)	0.77 ± 0.26	ND	ND	0.681 ± 0.30	ND	ND
Pb (ppb)	0.75 ± 0.2	0.02 ± 0.02	0.01 ± 0.02	0.809 ± 0.26	0.008 ± 0.02	0.006 ± 0.01

Note: mean values (± SD)

CONCLUSION

This field study tested the nutrients and heavy metal accumulation of the most abundant two plant species *Paspalidium punctatum* and *Cyperus rotundus* in *Thaulla* area of Ulankulama tank. Results indicated that both species could be considered as hyperaccumulator for K, Ca and Mg. This study further showed that N, P, K, Ca, Mg can be considered as more mobile elements compared to tested heavy metals for both species. Moreover, As and Cd were not observed in detected amount in soils associated root zone of the plants, the presence of As and Cd in shoots

and roots may be probably due to higher release rate of these elements from the soil and their bio accumulation. This study is the first study which attempted to find the phytoextraction abilities of soil nutrients and heavy metals and metalloids in *thaulla* area of small tank. There may be better hyperaccumulator plants for all nutrients which may not be abundant in *thaulla* area. Therefore, further studies are suggested to carry out tests of nutrients and heavy metal accumulation capabilities of *thaulla* plants especially in a controlled environment and in *thaulla* area of other tanks.

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