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Bioremediation Potential Of Macrophytes In Jakkur Wetland

P. Sudarshan[1,2], **M.K. Mahesh**[2] and **T.V. Ramachandra**[1,3,4]

1. *Indian Institute of Science, Energy and Wetlands Research Group, Centre for Ecological Sciences, Bangalore-560 012*
2. *Yuvaraja's College, Department of Botany, Mysore - 570 005*
3. *Indian Institute of Science, Centre for Sustainable Technologies (ASTRA), Bangalore*
4. *Indian Institute of Science, Centre for Infrastructure, Sustainable Transportation and Urban Planning (CiSTUP), Bangalore*

Aquatic macrophytes are important components of wetland ecosystems as they help in the uptake of nutrients and hence help in maintaining the chemical integrity of the respective ecosystem. These plants mobilize mineral elements from the bottom sediments and provide shelter to aquatic macro invertebrates and fishes. The current study investigates the diversity, biomass, nutrient and metal uptake potential following the standard protocol. *Polygonum glabrum* and *Typha angustata* had higher biomass at both inlet and outlets. Carbon content was higher in *Typha angustata*, nitrogen and phosphorus was highest in *Spirodela polyrhiza* in the outlet. Cadmium concentration was within normal range with *Alternanthera philoxeroides* and *Pistia stratiotes* accumulating highest in inlet and outlet. *Typha angustata* in inlet had copper concentration in critical range whereas in outlet all species had normal range with *Ludwigia sp* the highest. Lead, zinc, nickel and chromium were in higher concentration in *Typha angustata*than other species in inlet. Nickel was above normal range in *Typha angustata* in inlet and in all species in outlet. In the outlet *Typha angustata* (lead), *Pistia stratiotes* (zinc and nickel) and *Alternanthera philoxeroides* (chromium) had higher concentrations. Thus the study highlighted the remediation potential of macrophytes from Jakkur lake.

KEYWORDS

Macrophytes, Bengaluru, Jakkur lake, Heavy metal

1. INTRODUCTION

Aquatic plants (macrophytes) are vascular plants growing in wetlands or on a substrate, that is where soils are flooded or saturated long enough for anaerobic conditions to develop in the root zone and these plants have evolved to adapt to an anaerobic environment [1,2]. The aquatic macrophytes occur mainly in the shallow region of lakes, ponds, pools, marshes streams and rivers, etc. Macrophytes are of considerable ecological and economic importance as they help in the uptake of nutrients and hence help in maintaining the chemical integrity of the respective ecosystem. They contribute significantly to the productivity of water bodies, mobilize mineral elements from the bottom sediments and provide shelter to aquatic macro invertebrates and fishes. Aquatic macrophytes aid in bioremediation and hence wetlands are aptly known as 'kidneys of the landscape'. They also respond to changes in water quality and have been used as indicators of pollution and are known as 'bio-indicators'. When there is enough room for colonization and abundant availability of nutrients, macrophytes show a high growth rate. They assimilate nutrients directly into their tissues. Due to these, they were used to solve eutrophic problems of freshwater bodies and to remove pollutants [3]. Macrophytes influence water quality by taking up nutrients, releasing dissolved organic matter and increasing sedimentation by absorbing turbulent energy [4]. A considerable portion of the nutrient is stored by macrophytes and transferred to the next level (consumers) in the food chain and thus regulate the biogeochemical cycle of nutrients. However, species composition and distribution depend on environmental parameters, such as light, water temperature, substrate composition, disturbance and quality [5,6].

Macrophytes strongly influence water chemistry, acting as both nutrient sinks through uptake and also aid in moving compounds from the sediment to the water column. They improve water quality through the uptake of nutrients, trace elements and other contaminants [7,8,9]. Aquatic macrophytes are excellent indicators of the ecological state of water bodies because they integrate environmental changes over periods of a few years and reflect the cumulative effects of successive disturbances [10]. Due to their relatively high levels of species richness, rapid growth rates and direct response to environmental changes, they are used as phyto-indicators or bioindicators of the status of water bodies [11]. Macrophytes have no mechanisms regulating uptake of nutrients, hence their impact on the environment is through a process of biochemical concentration and excretion and increased nutrient concentration in their tissues is the result of nutrient rich aquatic environment [12].

An important physiological property of aquatic vegetation, in general, is the ability to accumulate unselectively chemical elements. Taking advantage of this property, many have attempted the water purification through aquatic vegetation to remediate nutrients, heavy metals and other pollutants [13,14,15,16]. Studies reveal that the bio-accumulation of metals in a plant species also relies upon the abiotic factors, like temperature, pH and concentration of chemical elements [17]. This also helps in characterising the water body through ecological monitoring of water quality.

Metals, when discharged into the aquatic environment, undergoes physical, chemical and biological changes and binds with the particulate matter and ultimately settles in the sediment [18]. Metal accumulation in plants varies from species to species. Plants uptake metals from soil either passively through the mass flow of water into roots or direct transport through the plasma membrane of root epidermal cells [19]. Nevertheless, abilities to take up and accumulate various trace elements in the tissues depend on plant species, evident from the several studies focussing on select species [9,20,18,21,22,23,24,25]. Some species are hyper-accumulators with higher abilities to accumulate metals in their biomass. The investigations of the role of macrophytes at the land-water interface are vital as the aquatic macrophytes are involved in many ecological and environmental processes [26]. Aquatic plants are often used as bioindicators of water quality, filters of particulate matter, trapping sediments, bioremediation (removal of nutrients and heavy metals) and improvement of water quality. Phytomonitoring of chemical composition would provide insights to the uptake of nutrients during different growth phases and also the nutritional value of the plants [27,28]. The nutrient pool assessment helps in determining the nutrients balance in the environment including uptake by primary producers [26]. The focus of the current study is to assess the phyto-diversity with the biomass and nutrient (carbon, nitrogen and phosphorus) content and to assess heavy metal (cadmium, copper, chromium, nickel, zinc and lead) uptake capability in phyto samples from Jakkur wetland, Bengaluru.

2. MATERIAL AND METHOD

2.1 Study area

Bangalore is located in the Deccan plateau, toward the south east of Karnataka state extending from 12°49'5"N to 13°8'32"N in latitude and 77°27'29" E to 77°47'2"E in longitude (Figure 1). Spatially Bangalore urban area has spatially increased from 69 km^2 (1901), 161 km^2 (1981), 221 km^2 (2001) to 741 km^2 (2006, Greater Bangalore). The undulating terrain in the region facilitated the creation of a large number of tanks in the past, providing for the traditional uses of irrigation, drinking, fishing and washing [29]. This led to Bangalore having hundreds of such water bodies through the centuries. There were 1452 water bodies in 1800 in the current spatial extent of Bangalore (741 km^2). A large number of water bodies (locally called lakes or tanks) in the city had ameliorated the local climate and maintained a good water balance in the neighbourhood. The undulating topography, featured by a series of valleys radiating from a ridge, forms three major watersheds, namely the Hebbal valley, Vrishabhavathi valley and the Koramangala and Challaghatta valleys (Figure 1). These form important drainage courses for the interconnected lake system which carries storm water beyond the city limits. Bangalore, being a part of peninsular India, had the tradition of storing this water in these man-made water bodies which were used in dry periods. Today, untreated sewage is also let into these storm water streams which progressively converge into these water bodies and results in algal bloom; proliferation of exotic aquatic weeds and macrophytes; large scale fish kill due to asphyxia (zero dissolved oxygen levels) and frothing due to phosphorus enrichment [29].

The present study was conducted at Jakkur wetland in Hebbal valley and is situated at north east of Bengaluru. It spreads across 3 villages (Jakkur, Agrahara and Sampigehalli) and covers an area of 157.8 acres. It consists of 10 MLD sewage treatment plant near the inlet followed by man-made wetland through which both treated and partially treated water enters the lake (Figure 2).

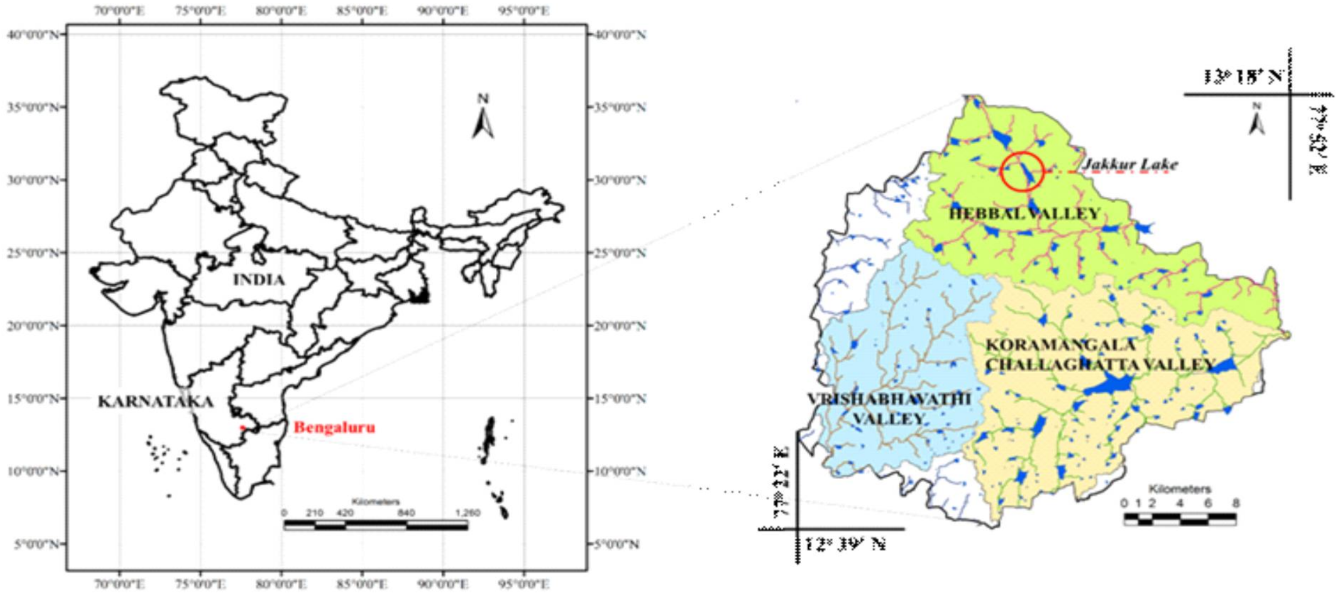

Figure 1. *Study area- Jakkur lake*

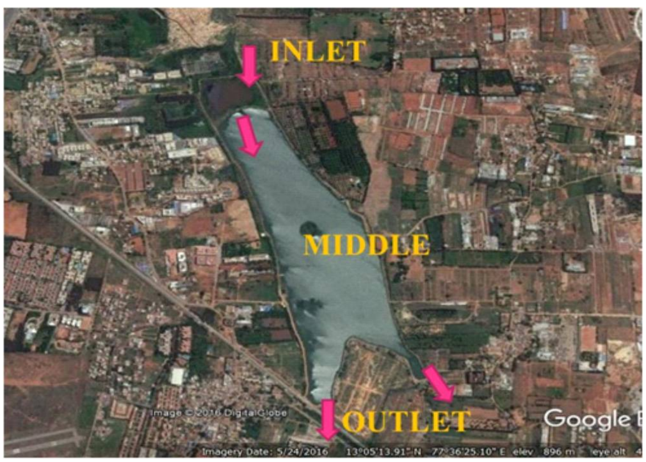

Figure 2. *Sampling locations in the Jakkur wetlands*

2.2 Bio-monitoring

Macrophytes samples were collected from inlets and outlets of Jakkur wetlands in triplicates through quadrat sampling method (0.5 m^2 area) every week. Plant species were identified based on morphological keys using the standard taxonomic literature and were stored in polyethene bags [30]. These samples were washed with distilled water to remove periphyton and sediments and later samples were dried at $60^{0}C$ until constant weight. The dry weights of samples were noted and biomass is expressed as kg/dry weight.

2.3 Assessment of remediation potential

Dried plant samples were pulverised using mortar and pestle, sieved (1 mm) to get fine powders and labelled properly. Later 0.5 g of samples were acid digested and analysed for six heavy metals, namely cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) with reagent blanks and suitable standards using atomic absorption spectrophotometer (GBC Avanta version 1.31) [31]. Elemental carbon (C) and nitrogen (N) were estimated using CHN analyser. Total phosphorus was analyzed according to the standard protocol after digesting samples using HNO_3:H_2SO_4:$HClO_4$ [32].

3. RESULT AND DISCUSSION

3.1 Phytodiversity in Jakkur wetlands

Macrophyte distribution is related to several environmental and anthropogenic factors, such as climate, hydrology, geomorphology, nutrient availability, biological interactions and the extent of anthropogenic activities [33,34,35]. Table 1 lists 9 species of macrophytes (4 floating and 5 emergent types) belonging to 8 families (5 species from inlet and 6 species from outlet) with life forms. *Typha angustata* was the dominant species followed by *Alternanthera philoxeroides*. The percentage composition of macrophytes was given in figure 3.

3.2 Estimation of biomass

Tables 2 and 3 lists species-wise biomass and C, N and P of macrophytes samples at inlet and outlets. *Polygonum* species had higher biomass at inlet whereas *Typha angustata* had higher biomass than

Table 1. *Macrophyte species with the life form and family details.*

Species	Life form	Family
Typha angustata	Emergent	Typhaceae
Alternanthera philoxeroides	Emergent	Amaranthaceae
Polygonum glabrum	Emergent	Polygonaceae
Ludwigia sp	Emergent	Onagraceae
Cyperus sp	Emergent	Cyperaceae
Pistia stratiotes	Free floating	Araceae
Spirodela polyrhiza	Free floating	Lemnaceae
Lemna sp	Free floating	Araceae
Eichhornia crassipes	Free floating	Pontederiaceae

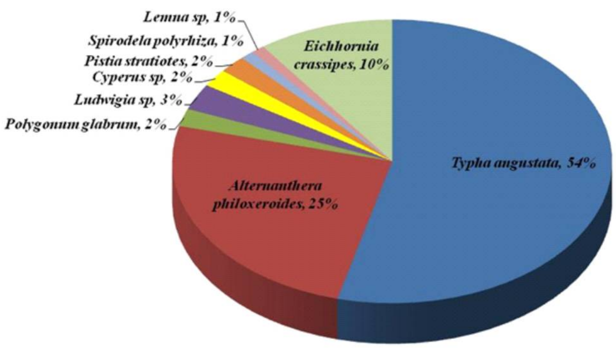

Figure 3. *Species-wise distribution of macrophyte in Jakkur wetland*

other species at the outlet. The biomass range was 0.15-0.412 kg/dw (*Cyperus sp. - Polygonum glabrum*) at inlet and 0.03-1.04 kg/dw (*Lemna sp - Typha angustata*) at the outlet. Among all, *Typha angustata* had higher biomass compared to others during the study period. Variations in biomass and plant zonation are due to varied growth rates among species depending on the nutrient availability and water level [36,37,38,39]. The biomass changes are low in the aquatic environment with minimal variations of water level during seasons [39].

3.3 Nutrient concentrations in macrophytes

Carbon (C), nitrogen (N) and phosphorus (P) are the most vital elements for plant morphogenesis, support a variety of cell physiological functions and their absorption and allocation are prove to be essential for all organisms [40]. These nutrients limit primary production especially in freshwater ecosystems [41]. All these species vary in their nutrient concentration and their distribution depends on nutrient availability. Plant nutrient concentration varies among sites and seasons and each species have specific ability to concentrate the nutrients.

3.3.1 Carbon: The carbon concentration ranged from 28.5-44.3% at the inlet with *Polygonum* species having higher carbon (40.7-44.3%) (Table 2). The range of carbon in the outlet was 20.5-42% with *Typha angustata* having higher carbon (37.9-42%) (Table 3).

3.3.2 Nitrogen: The concentration of nitrogen was in the range of 0.98-3.98% in the inlet (Table 2) and 1.53-4.42% (Table 3) at the outlet. *Alternanthera philoxeroides* (1.64-3.98 %) at the inlet and *Spirodela* sp. (3.5-4.42%) at the oulet had higher nitrogen. The uptake potential varies widely depending on plant species and age, growing season, type of applied wastewater, environmental conditions, etc., and is related to its net productivity and the concentration in the tissues [42,43]. Nitrogen deposition increases the N:P ratio in the plants of terrestrial and freshwater ecosystems while reducing soil and water nitrogen fixation capacity and ecosystem species diversity [40].

3.3.3 Phosphorus: The concentration of phosphorus varied from 0.3-2.22% at the inlet (Table 2) and 0.95-3.52% (Table 3) at the outlet with the higher concentrations in *Typha angustata* (0.97-2.22%) at the inlet and *Spirodela* sp. (1.07-3.52%) at the outlet.

3.4 Heavy metal concentrations in macrophytes

Metal uptake by plants depends on the bioavailability of the metal in the water phase, which in turn depends on the retention time of the metal as well as the interaction with other elements and substances in water. The pH, redox potential and organic matter content in the surrounding environment of the metal bound soil or sediment will affect the tendency of the metal to exist in ionic and plant available form [44].

Table 2. *Biomass and nutrient content of macrophytes at the inlet of Jakkur wetland*

	Typha angustata		*Alternanthera philoxeroides*		*Polygonum glabrum*		*Eichhornia crassipes*		*Cyperus sp*	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Biomass (kg/dw)	0.184-0.412	0.29	0.16-0.276	0.2	0.22-0.45	0.33	0.18-0.29	0.256	0.15-0.16	0.157
C (%)	37.1-43.3	40.27	28.5-36.9	32.29	40.7-44.3	43.03	37-39.2	38.6	38.2-43.6	41.3
N (%)	1.52-2.84	2.08	1.64-3.98	2.85	2.58-3.12	2.85	2.15-2.5	2.2	0.98-1.46	1.25
P (%)	0.97-2.84	1.64	0.98-1.31	1.09	0.97-1.55	1.20	0.8-1.42	1.1	0.3-0.65	0.55

Table 3. *Biomass and nutrient content of macrophytes at the outlet*

	Typha angustata	*Alternanthera philoxeroides*	*Ludwigia adscendens*	*Pistia stratiotes*	*Spirodela polyrhiza*	*Lemna sp*
Biomass (kg/dw)	0.14-1.04 0.36	0.16-0.39 0.23	0.14-0.22 0.2	0.08-0.22 0.17	0.04-0.22 0.11	0.03-0.2 0.1
C (%)	37.9-42 40.6	20.5-39.7 35.17	35.6-37.2 36.08	33.7-33.8 33.73	25.7-37.1 32.97	30.2-33.4 31.5
N (%)	1.53-2.7 1.85	1.78-4.24 3.7	2.68-3.44 3.05	2.63-3.42 3.16	3.5-4.42 4.07	3-4.1 3.86
P (%)	0.95-2.29 1.31	0.96-1.4 1.06	1.06-1.34 1.2	1.09-1.19 1.12	1.07-3.52 1.12	0.98-2.56 1.6

Table 4. *Heavy metal concentrations in macrophyte samples at the inlet*

Metal	Range (mg/kg)					WHO standard	Critical range in plants [47]	Normal range in plants [47]
	Typha angustata	*Alternanthera philoxeroides*	*Polygonum glabrum*	*Eichhornia crassipes*	*Cyperus sp*			
Cd	0-0.8	0-1.8	0.2-0.8	0.1-1.8	0-0.9	0.5	5-30	0.1-2.4
Cr	5-14	0.6-10.2	8.8-12.0	3-14	0.8-10	1.3	5-30	0.03-14
Cu	0-17.2	0-2.2	0.8-1.4	0-1.5	0-1.2	40	5-30	1-5
Ni	1.4-10.4	1.4-3.2	0.2-2.4	1.5-4.1	0.1-2.1	10	10-100	0.02-5
Pb	0-9.0	0-9.8	0-5.2	0-8.5	0-4.5	2.0	30-300	0.2-20
Zn	5.2-16.4	2.8-8.6	3.2-9.0	5-14.5	1.5-8.5	60	100-400	1-400

Table 5. *Heavy metal concentrations in macrophyte samples at the outlet*

Species	Ranges of metal (mg/kg)					
	Cd	Cr	Cu	Ni	Pb	Zn
Typha angustata	0-1.4	2-13.2	0-1.8	0-8.0	3.2-13.6	3.2-23.0
Alternanthera philoxeroides	0-1.0	4.6-19.6	0-0.8	0-5.8	0-10.4	3-10.2
Ludwigia adscendens	0.2-0.6	4-10.6	0.6-3.2	0-6.2	3.6-12.2	6.4-7.8
Pistia stratiotes	0.2-1.6	7-9.6	1.2-2.6	6-6.2	5-8.2	7-8.8
Spirodela polyrhiza	0-1.0	10.6-13.6	0-0.8	0-6.8	2.8-7.6	4-8.8
Lemna sp	0-0.9	4-12.1	0-0.9	0-6.5	1.5-8.5	5-10
Critical range in plants [47]	5-30	5-30	5-30	10-100	30-300	100-400
Normal range in plants [47]	0.1-2.4	0.03-14	1-5	0.02-5	0.2-20	1-400

3.4.1 Cadmium: Cadmium a highly toxic and non-essential element affects growth, metabolism and creates water stress plants [45]. Cadmium also produces oxidative stress by releasing free radicals and reactive oxygen species which cause the death of plants by damaging membrane lipids, proteins, pigments and nucleic acids [46]. Tables 4 and 5 list species-wise cadmium concentration in plants, which range from 0-1.8 mg/kg (inlet) and 0-1.6 mg/kg (outlet), which are within the normal range and lesser than values reported earlier in macrophytes of Bangalore urban lakes [47,48,49]. *Alternanthera philoxeroides* (0-1 mg/kg) and *Pistia stratiotes* (0.2-1.6 mg/kg) accumulated higher amount of cadmium.

3.4.2 Copper: Copper at low concentration is essential for plant nutrition and is required for various enzymatic activities and are toxic at higher concentrations, leading to oxidative stress and growth inhibition [50,51]. Tables 4 and 5 list species-wise copper concen-trations of 0-17.2 mg/kg, which are higher compared to earlier studies [48]. Copper accumulation was higher in the critical range in *Typha angustata* (0-17.2 mg/kg) at the inlet. It was within the normal range in all studied species at the outlet with the highest accumulation in *Ludwigia* species (0.6-3.2 mg/kg).

3.4.3 Lead: Lead is not essential in plant organs, immobile in the soil, tends to accumulate in roots, resulting in a scarce translocation into above ground organs and is toxic [52]. Tables 4 and 5 list species-wise lead concentration, which are within the normal range, 0-9.8 mg/kg (inlet) and 0-13.6 mg/kg (outlet). Lead accumulation was higher in *Alternanthera philoxeroides* (0-9.8 mg/kg) at inlet and *Typha angustata* (3.2-13.6 mg/kg) at outlet.

3.4.4 Zinc: Zinc is a vital plant nutrient and plays a role in metabolism, plant nutrition and enzymatic activities and concentration above 500 mg/kg is phytotoxic [47]. Its toxicity in plants can lead to poor or reduced root and shoot growth as well as chlorosis of leaves [51]. Zinc was within normal range at both the sites. Tables 4 and 5 lists the values of zinc, all samples are in the range 1.5-16.4 mg/kg at inlet and 3-23 mg/kg at outlet. The concentration was higher in *Typha angustata* (5.2-16.4 mg/kg) at inlet and 3.2-23.0 mg/kg in *Typha angustata* at outlet.

3.4.5 Nickel: The range of nickel was 0.1-10.4 mg/kg in inlet (Table 4) and 0-8 mg/kg in outlet (Table 5), which are above the normal range in *Typha angustata* (at inlet) and in all species at the outlet, respectively. Nickel concentration was higher in *Typha angustata* (1.4-10.4 mg/kg at the inlet and 0-8.0 mg/kg at the outlet) and *Pistia stratiotes* (6-6.2 mg/kg at the outlet), respectively. However, these concentrations were lower compared to earlier studies [48,49].

3.4.6 Chromium: Tables 4 and 5 list species-wise chromium concentrations, which are in the range 0.6-19.6 mg/kg (0.6-14 mg/kg inlet; 2-19.6 mg/kg outlet). Chromium was within the normal range in inlet samples but in outlet, it was above normal range in *Alternanthera philoxeroides* species (4.6-19.6 mg/kg). The concentration was higher in *Typha angustata* (5-14 mg/kg), *Polygonum glabrum* (8.8-12.0 mg/kg) and *Eichhornia crassipes* (3-14 mg/kg) at the inlet and *Alternanthera philoxeroides* (4.6-19.6 mg/kg) at the outlet.

4. CONCLUSION

The current study provides an insight into the macrophytes diversity with the nutrient and heavy metal concentrations in samples collected from Jakkur wetland, Bangalore. Nine species of macrophytes are present with the domination of *Typha angustata*, *Polygonum*, *Alternanthera philoxeroides* and *Typha angustata* had a higher concentration of carbon, nitrogen and phosphorus, respectively at the inlet. Carbon content was higher in *Typha angustata* (40.6%), nitrogen (4.07%) and phosphorus (1.94%) was highest in *Spirodela polyrhiza* in the outlet of the lake. Cadmium was ranging from 0-1.8 mg/kg in inlet and 0-1.6 mg/kg in outlet macrophyte samples with the *Alternanthera philoxeroides* and *Pistia stratiotes* having higher amount at both inlet and outlet. Range of copper in the studied macrophytes was 0-17.2 mg/kg with *Typha angustata* and *Ludwigia* species having higher concentrations. The concentration of lead in studied macrophyte samples were in the range 0-9.8 mg/kg (inlet) and 0-13.6 mg/kg (outlet) with *Alternanthera philoxeroides* accumulating the higher concentration in inlet (0-9.8 mg/kg) and *Typha angustata* in outlet (3.2-13.6 mg/kg). The values of zinc was in the range 1.5-16.4 mg/kg in inlet and 3-23 mg/kg in outlet samples. The concentration was higher in *Typha angustata* in inlet (5.2-16.4 mg/kg) and in outlet (3.2-23.0 mg/kg) samples. The range of nickel was 0.1-10.4 mg/kg in inlet and 0-8 mg/kg in outlet, respectively. Nickel concentration was higher in *Typha angustata* in both inlet (1.4-10.4 mg/kg) and outlet (0-8 mg/kg). The range of Chromium was 0.6-19.6 mg/kg (0.6-14 mg/kg inlet; 2-19.6 mg/kg outlet). *Typha angustata* (5-14 mg/kg at inlet) and *Alternanthera philoxeroides* (4.6-19.6 mg/kg at outlet) had a higher concentration of chromium. These results confirm bioaccumulation of heavy metals and uptake of nutrients by the macrophytes from wetlands.

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