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Bioaccumulation of Heavy Metal by Aquatic Macrophytes Around Ujjani Reservoir, India

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ABSTRACT

This study aimed to analyze the level of heavy metals in water and organs (stem, leaves and roots) of three aquatic macrophytes from the Ujjani reservoir. Among the studied metals (Fe, Cu, Zn and Mn) the concentration (μg/ml) of Fe (2.23) and Mn (1.52) in water were detected more than Canadian water quality guidelines. The roots of studied aquatic macrophytes plants accumulate maximum level of heavy metals than stem and leaves. The heavy metals contents (μg/g dry weight) in roots of plant species *Pistia stratiotes* L. FF were observed in the following order ; Mn (11292.7) > Fe (2637) > Zn (285.6) > Cu (92.4). Whereas order of metal contents in the roots of *Ottelia alismoides* Pers. RL observed as follows ; Fe (1340.3) > Mn (609.11) > Zn (35.8) > Cu (24.23). Moreover roots of *Eichhornia crassipes* Solms. FF accumulate maximum content of Mn (4890) followed by Fe (1731.1), Zn (48.2) and Cu (42.6). The bio-concentration factor showed that the organs of *Pistia stratiotes* L. FF and *Eichhornia crassipes* Solms. FF has more capacity to accumulate Mn. However organs of *Ottelia alismoides* Pers. RL accumulate maximum Fe. It was noticed that studied macrophyte has greater potential of bioaccumulation for metal Fe and Mn, hence can be used for their phytoremediation from contaminated water bodies.

Keywords Macrophytes, Heavy metals, Bioaccumulation.

INTRODUCTION

The Macrophytes are aquatic plants and categorized such as emergent, submerged and floating. Aquatic macrophytes live in a completely different environment even they are taxonomically closely related to terrestrial plants. They are beneficial to the aquatic ecosystem as a reason they supply food and settler for fish and aquatic invertebrates. Aquatic plants grow more vigorously where nutrient loading is high. They are consistent biological filters and play a vital role in heavy metals accumulation in aquatic ecosystem (Devlin 1967, Chung and Jeng 1974). Their uniqueness to accumulate metals make them remarkable research objects for testing and modeling ecological theories such as evolution and plant succession, nutrient and metal cycling Föstner and Whittman (1979).Large aquatic plants accumulate heavy metals in their tissues mainly through the root and leaves, which after decomposition responsible for

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increasing concentration of heavy metals in the lake sediments. These plants often concentrate essential and nonessential heavy metals higher than those of the surrounding waters. Many of the aquatic macrophytes are the potential scavengers of heavy metals from water and wetlands (Gulati et al. 1979). The uptake and subsequent release of heavy metals after decomposition of plant materials lead to the transfer of metals to higher tropic level (Sprenger and McIntosh 1989, Mudroch and Capobianco 1979).

Studies on water hyacinth (*Eichhornia crassipes*) water lettuce (*Pistia stratoites*) and duckweeds (*Lemna minor, Spirodela intermedia*), investigated that they have greater potential to absorb heavy metals in their medium (Gunathilakae et al. 2018, Daud et al. 2018). *Eichhornia crassipes* has the potential to remediating different heavy metals, total suspended solids, organic material, total dissolved solids and nutrients from the polluted water (Muthunarayanan et al. 2011). It showed high absorption rate for different organic and inorganic contaminants, tolerate an extremely polluted environment and capacity to produce large biomass (Jafari 2010). It was reported that *Eichhornia crassipes* has greater ability to remediate As, Zn, Hg, Ni, Cu and Pb from industrial and domestic wastewater streams (Dixit and Tiwari 2010). Macrophyte water lettuce (*Pistia stratiotes* L.) possesses extraordinary tolerance over an extensive range of pH and temperature. It is more prone than other aquatic vegetation and act as an excellent contender for the phytoremediation of contaminants (Forni et al. 2007). It has the capacity of reducing nutrients such as chemical oxygen demand, biological oxygen demand, dissolved oxygen, pH total Kjeldahl nitrogen, ammonia, nitrite, nitrate and phosphate from the sewage water and industrial wastewater (Yasar et al. 2017). Excessive uptake of metals (Cu, Zn, Fe, Cr and Cd and Hg) have no any harmful effect on *Pistia stratiotes* L, which makes it suitable to be used on a broad scale as a hyper accumulator's plant for the mitigation of organic and inorganic contaminants from wastewater (Skinner et al. 2007, Gonzales et al. 2019). Also *Pistia stratiotes* L is an excellent accumulator of Mg, Pb and Mn. Aquatic plant species *Ottelia alismoides* Pers. RL alismoides is an obligatory submerged dominant aquatic plant. It mainly prefers eutrophic conditions but is rarely found in brackish water *Ottelia alismoides* is used as pollution indicators due to their high enrichment capacity. It can acts as biological filters to remove metal pollutants from contaminated water (Wolverton and McDonald 1979). It gives valuable information on pollution situations where water contamination occurs periodically, so it can be used for biological monitoring of water pollution which reflect water quality over a period of time.

Heavy metals are source of environmental pollution (Malar et al. 2016). It might be originated from natural and anthropogenic sources (El Bouraie et al. 2010). Anthropogenic sources of heavy metals are industry, atmospheric pollution, urban runoff, river dumping, shore erosion and mining. The existence of heavy metals in aquatic environments causes hazardous effect on plant and animal life (Akpor 2014). Excess metal levels in water bodies may pose a health risk to humans and to the environment. Heavy metals such as Cu, Pb, Cd, Se, As, Hg, Cr, Fe, Zn and Mn can act as environmental toxins in aquatic and terrestrial ecosystems (Påhlsson 1989, Guilizzoni 1991).

Ujjani is the largest reservoir in the state of Maharashtra. It receives water mainly from highly populated and industrialized urban areas. It was studied that water and fish fauna quality of the reservoir declining day after day (Shinde et al. 2020). The present study was carried out to determine the levels of heavy metals Fe, Cu, Zn and Mn in water and aquatic plants growing in Ujjani Reservoir. Also extent of movement of the heavy metals into the different structural and internal organs of studied plant species (*Pistia strationtes* L. FF, *Ottelia alismoides* Pers. RL and *Eichhornia crassipes* Solms. FF) were investigated.

MATERIALS AND METHODS

Study area and sample collection

Ujjani is the largest and most polluted reservoir on river Bhima in the state of Maharashtra. It receives water from highly polluted rivers such as Mula, Mutha, Ghod, and Indrayani. As the tributaries rivers of Bhima mainly passes through metropolitan cities, which are highly polluted by industrial, domestic and agricultural sewages which causes eutrophication of Ujjani reservoir. This study was carried out to assess the heavy metal levels in water and three macrophytes species around the Ujjani reservoir. In present study water and aquatic macrophyte species (*Pistia stratiotes* L. FF, *Ottelia alismoides* Pers. RL and *Eichhornia crassipes* Solms. FF) samples were collected in triplicates from the village Bhigwan during the winter season of 2020. Further collected macrophytes species samples were washed with tap water followed by distilled water. Afterward plant parts such as roots, stem and leaves were separated with the help of a plastic knife and oven-dried for 10 to 12 hours at 90–95°C in hot air oven. Furthermore, samples were powdered using pestle and mortar.

Sample preparation for analysis

Water sample collected in triplicates were initially treated with concentrated HNO_3, after 500 ml of water sample were evaporated on hot plate until volume reduced to 30 ml, latter 3 ml of HNO_3 were added and heated for 1 hour on hot plate. Finally digested water samples were filtered though watman filter paper grade 42 and diluted using distilled water to make final volume 50 ml. Similarly, powdered macrophytes plant organs (roots, stem and leaves) of each species were weighed (0.5 g) and digested with 10 ml mixture of concentrated HNO_3 / H_2O_2 (3 : 1) on hot plate, initially for 1 hour at room temperature then for 2 hour 140°C. Subsequently samples were cooled at room temperature. Later samples were diluted with distilled water to make final volume of 50 ml and filtered through watman filter paper grade 42. The concentrations of heavy metals (Fe, Cu, Mn and Zn) were determined in water and plants organs (stem and leaves and roots) by an atomic absorption spectrophotometer (Sistronics, AAS–263).

Statistical analysis

All investigations were repeated three times with three replicates. Data collected were subjected analyze Mean, Standard Deviations and Standard Errors using statistical package MS- Excel office 2007. The average values of mean and stranded errors were compared. Also, bioconcentration factor (BCF) for studied heavy metals were analyzed. It gives the ability of plants to accumulate the heavy metals with respect to the metal content in water (Adel et al. 1998). The value of BCF were calculated using following equations.

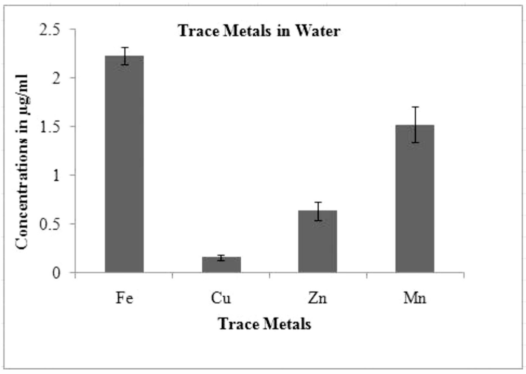

Fig. 1. Trace metal concentrations in water. Description : Heavy metal (Fe, Cu, Zn and Mn) concentrations (µg / ml) in Ujjani reservoir water.

$$\text{BCF} = \frac{\text{Heavy element concentration in plant organs } (\mu g/g)}{\text{Initial concentration of the element in the external medium } (\mu g/ml)}$$

RESULTS AND DISCUSSION

This study was conducted to assess the heavy metal contents in water and macrophytes species around the Ujjani reservoir. The water and macrophytes plants samples were collected in triplicate from selected location. The metal level (Fe, Cu, Zn, Mn) in studied samples were detected by AAS. It was found that the concentration of Fe in water from Ujjani study site is maximum than the metal Cu, Zn and Mn. The hierarchical order of heavy metals concentrations (µg/ml) in water sample as follows ; Fe (2.23)>Mn (1.52) > Zn (0.63) > Cu (0.15) respectively (Fig. 1.)

The concentrations of heavy metals in the stem, leaves and roots of aquatic macrophytes were determined on the dry weight basis. The plant species *Pistia stratiotes* L. FF were investigated for concentration of heavy matals (Fe, Cu, Zn and Mn) and it was

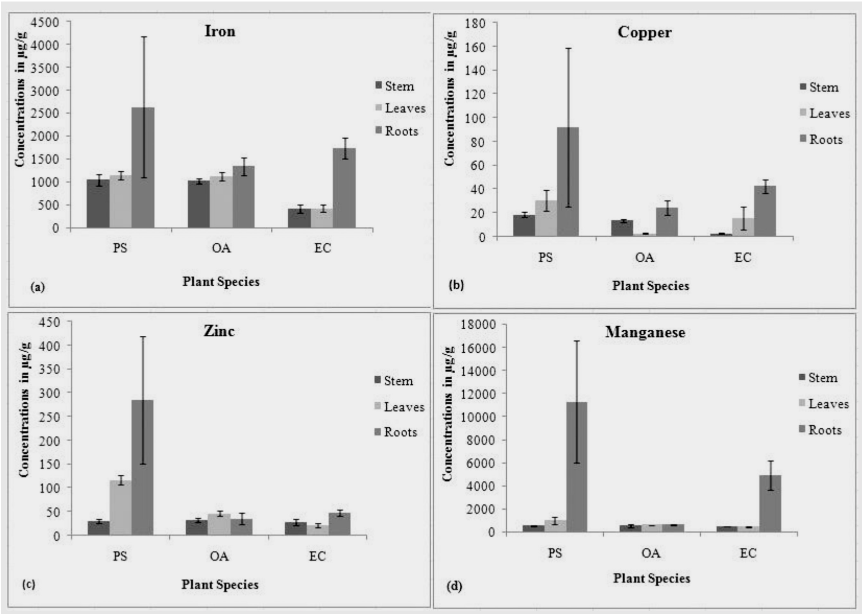

Fig. 2. Heavy metal concentrations in stem, leaves and roots of various macrophyte species around the Ujjani reservoir. Description Concentrations of Fe (a), Cu (b), Zn (c) and Mn (d) in stem, leaves and roots of macrophyte species *Pistia stratiotes* L. FF (PS), *Ottelia alismoides* Pers. RL (OA), *Eichhornia crassipes* Solms. FF (EC) respectively.

found that the roots accumulate more heavy metals than leaves stem. The stem of *Pistia stratiotes* L. FF showed more Fe (1041.7 µg/g) content, followed by Mn (536.7 µg/g), Zn (30.55 µg/g) and least accumulation of metal Cu (18.66 µg/g) were recorded. Similarly leaves of *Pistia stratiotes* L. FF showed maximum contents of Fe (1142.6 µg/g), followed by Mn (979.14 µg/g), Zn (117.4 µg/g) and Cu (30.4 µg/g). The roots of *Pistia stratiotes* L. FF showed higher accumulation of metal Mn (11292.7 µg/g) than Fe (2637 µg/g), Zn (285.6 µg/g) and Cu (92.4 µg/g) (Table 1, Fig.2). The detected content of metals indicates that the *Pistia stratiotes* L. FF accumulate more Fe in stem and leaves, whereas Mn was accumulated more in roots. Plant species *Ottelia alismoides* Pers. RL analyzed for bioaccumulation characteristics of stem, leaves and roots. The accumulation of heavy metals exhibited similar trend as of plant species *Pistia stratiotes* L. FF. Accumulation of heavy metals in the *Ottelia alismoides* Pers. RL showed order as of follows Fe> Mn>Zn>Cu. The level of Fe and Cu in the organs of *Ottelia alismoides* Pers. RL showed descending order such as ; roots>stem>leaves.Whereas the level of Mn and Zn observed in the descending order such as ; roots>leaves>stem. The stem of *Ottelia alismoides* Pers. RL accumulate more Fe (1020.6 µg/g) followed by Mn (544.3 µg/g), Zn (32.5) and Cu (13.8), whereas leaves of *Ottelia alismoides* Pers. RL accumulate heavy metals in following order ; Fe (1118 µg/g)>Mn (592.6 µg/g)>Zn (46.2 µg/g)>Cu (2.52 µg/g). It were noticed that roots of *Ottelia alismoides* Pers. RL has higher contents of metal Fe (1340.3 µg/g), Mn (609.11 µg/g), Zn (35.8 µg/g) and Cu (24.23 µg/g) than the leaves and stem (Table 1, Fig. 2). Further, the plant species *Eichhornia crassipes* Solms. FF was analyzed for the level of metals Fe, Cu, Zn and Mn in various organs. The heavy metals Fe, Cu and Mn showed order of accumulation in various organs as follows ; root>leaves>stem. Moreover Zn showed maximum accumulation in the roots afterwards in the stem and leaves. The stem of *Eichhornia crassipes* Solms. FF accumulate metals in the following orders ; Mn (470.1 µg/g) > Fe (407.6 µg/g) > Zn (28.02 µg/g). Similarly, leaves of *Eichhornia crassipes* Solms. FF exhibited metals contents in the descending order as follows ; Mn (423.41 µg/g)> Fe (422.1 µg/g). >Zn (21.9 µg/g)> Cu (15.75 µg/g). It was found that the roots *Eichhornia crasssipes* Solms. FF accumulate

Table 1. Concentrations (µg/g dry weight) of the heavy metals in organs (Stem, leaves and roots) of macrophyte species. Mean and Standard Error (Mean ± SE) are compared (n = 3).

Macrophyte species	Plant organs	Fe	Cu	Zn	Mn
Pistia stratiotes	Stem	1041.7 ± 122.66	18.66 ± 2.33	30.55 ± 4.11	536.7 ± 44.6
L. FF	Leaves	1142.6 ± 84.36	30.4 ± 8.7	117.4 ± 10.5	979.14 ± 337.7
	Root	2637 ± 1535.6	92.4 ± 66.8	285.6 ± 134.1	11292.7 ± 5320.5
Ottelia alismo-	Stem	1020.6 ± 63.726	13.8 ± 1.274	32.5 ± 4.8	544.3 ± 126.6
ides Pers. RL	Leaves	1118 ± 88.935	2.52 ± 0.41	46.2 ± 5.1	592.6 ± 17.1
	Root	1340.3 ± 191.05	24.23 ± 6.19	35.8 ± 13.1	609.11 ± 42.71
Eichhornia cras-	Stem	407.6 ± 93.9	2.76 ± 0.6	28.02 ± 6.3	470.1 ± 29.38
sipes Solms FF	Leaves	422.1 ± 90.02	15.75 ± 9.91	21.9 ± 4.9	423.41 ± 62.16
	Root	1731.1 ± 226.9	42.6 ± 5.8	48.2 ± 7.13	4890 ±1274.8

several fold higher level of metal Mn (4890 µg/g), than the Fe (1731.1 µg/g) Zn (48.2 µg/g) and Cu (42.6 µg/g) in the roots (Table 1, Fig. 2).

Bioconcentration factor was assessed to examine metal accumulation potential of macrophytes organs (stem leaves and roots). It was noticed that roots of *Pistia stratiotes* L. FF has more BCF value. The order of BCF values examined for studied metals in stem, leaves and roots of *Pistia stratiotes* L. FF as follows Mn>Fe> Cu>Zn (Table 2). Similarly in case of *Ottelia alismoides* Pers. RL the value of BCF was found more in roots than stem and leaves. The order of BCF values for various metals observed were similar to the *Pistis stratiotes* L. FF. It was observed that *Ottelia alismoides* Pers. RL has low bioaccumulation potential than *Pistia stratiotes* L. FF. Moreover *Eichhornia crassipes* Solms. FF showed significantly higher bioaccumulation of Mn in roots than stem and leaves (Table 2). The roots of *Eichhornia crassipes* Solms. FF accumulates maximum Mn followed by Fe Cu and Zn. Overall bioconcentration factor indicates that the *Pistia stratiotes* L. FF has more capacity to concentrate metals followed by *Eichhornia crassipes* Solms. FF and least for *Ottelia alismoides* Pens. RL.

The heavy metals concentration in the water of Ujjani reservoir was evaluated. It was found that heavy metals levels were several folds higher than the normative requirements. Among the metals Fe and Mn contents were much higher than maximum permissible concentrations in water proposed by Canadian water quality guidelines (CWQGs) for the protection of aquatic life (CCME 2007). According to CWQGs guideline maximum permissible concentrations (µg/ml) of metals Fe, Cu, Zn and Mn in water

Table 2. Bioconcentration Factor in various plant organs (stem, leaves and roots) of studied macrophyte species *Pistia stratiotes* L. FF, *Ottelia alismoides* Pers. RL, *Eichhornia crassipes* Solms. FF.

Macrophyte species	Plant organs	Fe	Cu	Zn	Mn
Pistia stratiotes L. FF	Stem	466.4328	120.3871	48.23684	353.0921
	Leaves	511.6119	196.129	185.3684	644.1711
	Root	1180.746	596.129	450.9474	7429.408
Ottelia alismoides					
Pers. RL	Stem	456.9851	89.03226	51.31579	358.0921
	Leaves	500.597	16.25806	72.94737	389.8684
	Root	600.1343	156.3226	56.52632	400.7303
Eichhornia crassipes					
Solms. FF	Stem	182.5075	17.80645	44.24211	309.2763
	Leaves	189	101.6129	34.57895	278.5592
	Root	775.1194	274.8387	76.10526	3217.105

are, 0.3, 0.004, 0.03 and 0.05 respectively (CCME 2007). Whereas recorded contents in Ujjani reservoir water were far more for studied metals. It indicates that studied water body has large impact of pollution and it may be toxic to fish and other aquatic fauna of the Ujjani reservoir.

The metals contents and its distribution pattern in various organs of three aquatic macrophytes plants were investigated. Uptake of metal Fe is vital for the metabolism of mitochondria and chloroplast. Mostly Fe exists in the less soluble ferric oxides forms, which is readily converted soluble form for the plants to uptake (Walker and Connolly 2008). It was observed that the metal Fe accumulation was observed highest in stem and roots of *Pistia stratiotes* L. FF than the *Ottelia alismoides* Pers. RL and *Eichhornia crassipes* Solms. FF. Whereas Fe accumulation in leaves of *Ottelia alismoides* Pers. RL has higher value than leaves of *Pistia stratiotes* L. FF and *Eichhornia crassipes* Solms. FF. The concentrations of Fe obtained in present study were compared with literature. Bai et al. (2018) recorded contents of Fe in leaves (427.0 μg/g) and stem (456.0 μg/g) of *Eichhornia crassipes* Solms. FF, leaves (5207 μg/g) and stem (3334 μg/g) of *Potamogeton malaianus*, leaves (841.0 μg/g) and stem (1209 μg/g) of *Nymphoides peltata* and (4427 μg/g) and stem (4409 μg/g) of *Hydrilla verticillata*. The concentration of Fe found in present study was lower in leaves and stem than reported in previous study on *Eichhornia crassipes* Solms. FF, whereas roots of *Eichhornia crassipes* Solms. FF has more Fe contents. Overall, Fe accumulation in macrophyte species under study showed order such as ; *Pistia stratiotes* L. FF > *Ottelia alismoides* Pers. RL > *Eichhornia crassipes* Solms. FF. Whereas roots of studied plant showed order of Fe accumulation as follows ; *Pistia stratiotes* L. FF > *Eichhornia crassipes* Solms. FF > *Ottelia alismoides* Pers. RL. It was noticed that the *Pistia stratiotes* L. FF and *Ottelia alismoides* Pers. RL has more tendency to accumulate metal Fe than *Eichhornia crassipes* Solms. FF in stem leaves and roots.

Further we investigated level of metal copper. Copper is an essential micronutrient and plays a fundamental role in the growth and development of plants (Mateos-Naranjo et al. 2015). Plants control the intercellular copper concentration by rectifying its uptake and declining the free intercellular copper concentrations with the help of metallo-chaperones. Metallo chaperones are copper binding soluble proteins which transport copper to the plant cells where they are needed (O'Halloran and Culotta 2000). The accumulation of metal Cu was observed lowest than the Fe, Zn and Mn in all plant species under study. Stem and leaves and roots of *Pistia stratiotes* L. FF showed maximum Cu content than stem, leaves and roots of the *Ottelia alismoides* Pers. RL and *Eichhornia crassipes* Solms. FF. Here we found that contents of Cu were observed lower in stem and leaves than normally found in aquatic plants. Bai et al. (2018) investigated various macrophytes for level of Cu accumulation and recorded concentration of Cu in the leaves (11.2 μg/g) and stem (9.9 μg/g) of *Potamogeton malaianus*, leaves (10.7 μg/g) and stem (5.7 μg/g) of *Eichhornia crassipes*, leaves (4.4 μg/g) and stem (4.9 μg/g) of *Nymphoides peltata*, and leaves (5.5 μg/g) stem (6.3 μg/g) of *Hydrilla verticillata* respectively. Macrophytes under study showed order of Cu accumulation such as *Pistia stratiotes* L. FF > *Ottelia alismoides* Pers. RL > *Eichhornia crassipes* Solms. FF. Moreover the contents of Cu studied species showed higher accumulation in roots of *Pistia stratiotes* L. FF which was far more than normal content (5-30 μg/g) found in aquatic plants (Bai et al. 2018).

Further we have detected metal Zn contents. Zinc is a crucial element which plays a significant role in the growth and development of plants. It is most commonly found element in several enzymes such as polyphenol oxides, cytochrome oxides and ascorbic acid oxides (Lesage et al. 2007, Vymazal et al. 2007). After absorption of Zn by plants, it is transformed from insoluble to soluble state (Zn2+) and eventually enhances the ability of the aquatic plant to accumulate higher amount in their body parts (Mcgrath et al. 1997). It was noticed that Zn accumulation did not show significant variations in stem of studied macrophytes. The range Zn contents in stem of studied aquatic plant species was observed between 28.2–32.5 μg/g. Zinc accumulation in leaves and roots indicates that *Pistia stratiotes* L. FF contains more Zn than *Ottelia alismoides* Pers. RL and *Eichhornia crassipes* Solms. FF.Accumulation of Zn in leaves (46.7 μg/g) and stem (35.9 μg/g) of plant species *Potamogeton malaianus*, leaves (59.5 μg/g) and stem (54 μg/g) of *Eichhornia crassipes*, leaves (28.8 μg/g) and stem (26.5 μg/g) of *Nymphoides peltata* and leaves (28.8 μg/g) and stem (32.5 μg/g) of *Hydrilla verticillata* were reported in literature (Bai et al. 2018). The values of Zn accumulation in roots of *Pistia stratiotes* L. FF were observed more than normal range (27-150 μg/g) found in plants (Bai et al. 2018).

The metal Mn was observed higher than Cu and Zn in all plant species under study. It was recorded that stem of *Ottelia alismoides* Pers. RL contains more Mn than the stem of *Pistia stratiotes* L. FF and *Eichhornia crassipes* Solms. FF. Whereas leaves and roots of *Pistia stratiotes* L. FF exhibit more Mn than leaves of *Ottelia alismoides* Pers. RL and *Eichhornia crassipes* Solms. FF. Bai et al. (2018) also reported contents of Mn in leaves (561.0 μg/g) of *Potamogeton malaianus*, leaves (474.0 μg/g) and stem (220 μg/g) of *Eichhornia crassipes*, leaves (1904 μg/g) and stem (167.0 μg/g) of *Nymphoides peltata* and leaves (1268 μg/g) and stem (2040 μg/g) of *Hydrilla verticillata*. Here we noticed that Mn contents in the stem and leaves of macrophytes are in excess than normally (30–300 μg/g) found in aquatic plants (Bai et al. 2018). The accumulation of metals in stem and leaves of studied plants showed order such as Fe > Mn > Zn > Cu. The accumulation of materials in plant reflects similar pattern as seen in the water body. It was noticed that roots have more capacity to accumulate metals followed by leaves and least in stem. A hairy root system of aquatic plants plays a vital part in the phytoremediation of pollutants from the wastewater (Majumder et al. 2018). Further we have noticed that *Pistia stratiotes* L. FF has more capacity to accumulate metals followed by *Ottelia alismoides* Pers. RL and least for *Eichhornia crassipes* Solms FF. Recent study on Water hyacinth (*Eichhornia crassipes*), Water lettuce (*Pistia stratiotes* L. FF) and Duck weed (*Lemna minor*) showed they are major metal accumulator plants for the remediation of heavy-metal polluted water. Aquatic plants *Pistia stratiotes* L. FF stratiotes, *Azolla pinnata*, and *Salvinia molesta* were found very proficient for the removal of Fe, Cu and Mn at 25% concentration of the textile effluents (Manjunath and Kousar 2016). Present study indicates that even plant species collected from same study site it shows differences in heavy metal accumulation potentials. It was noticed that the accumulation of heavy metals in macrophyte species depends on type of plant species. Also within same macrophyte species accumulation of heavy metals in various organs differ significantly ; indicating that metal accumulation, its transports distribution within plant organs depends on properties of individual metals and plant cell.

To compare accumulative potential of macrophytes species, the bio-concentration factor (BCF) was determined. The value of BCF > 1 indicates that transfer of metal ions from water medium to aerial parts of the plant (Usman et al. 2019). Bioconcentration factor calculated indicates that roots of *Pistia stratiotes* L. FF (7429.44) and *Eichhornia crassipes* Solms. FF (3217) has maximum capacity to accumulate metal Mn than Fe, Cu and Zn. Moreover roots of plant species *Ottelia alismoides* Pers. RL showed maximum BCF value for metal Fe than the metals Mn, Cu and Zn. According to previous studies, different floating aquatic plants demonstrated much higher accumulation for these heavy metals with higher bioconcentration factor. Roots of *Eichhornia crassipes* and *Pistia stratiotes* showed much better metal accumulation potential as compared to the upper parts of the plants (Victor et al. 2016). Physiological demand of plant organs for certain heavy metals and their accumulation kinetics directly or indirectly affects their absorption from the growth medium (Verma and Suthar 2015). The value of BCF more than 1 indicates the suitability of studied aquatic plants for phytoextraction of heavy metals.

CONCLUSION

Heavy metals concentrations in water were observed more than the standard value proposed Canadian water quality guidelines for protection of aquatic life (CWQGs 2007). It indicates that most of the heavy metal concentrations were represented moderate to significant contamination levels resulting from human activities in the catchment area of the Ujjani reservoir. Heavy metal detected in the aquatic plants indicates that the concentration of Mn recorded was within the critical limit in all studied aquatic plants.

Whereas concentration of Fe, Cu and Zn in stem and leaves of aquatic macrophytes were mostly within the ranges of normal concentration values for plants leaves and stem. Whereas roots of all studied macrophytes has more contents of metals than normally found in plant body. It is also confirmed that metal accumulation properties of macrophyte plant species are species and plant organ specific. Bioconcentration factor revels that the *Pistia stratiotes* L. FF and *Eichhornia crasssipes* Solms. FF has greater potential to absorb metal Mn whereas *Ottelia alismoides* Pers. RL has more tendency to accumulate metal Fe. Considering the important role that aquatic plants in the food chain of reservoir ecosystems, The relatively high levels of heavy metals in the aquatic plants documented here indicates need of further attention.

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REFERENCES

Adel Z, Suvarnalatha G, Norman T (1998) Phytoaccumulation of trace elements by wetland plants : I. Duckweed. J Environ Qual 27 : 715—721.

Akpor OB (2014) Heavy metal pollutants in wastewater effluents. Sources, effects and remediation. Adv Biosci Bioeng 2 : 37.

Bai L, Liu XL, Hu J, Li J, Wang ZL, Han G, Li SL, Liu CQ (2018) Heavy metal accumulation in common aquatic plants in rivers and lakes in the Taihu Basin. Int J Environ Res Public Hlth 15 (12) : 2—12.

CCME (2007) Canadian Council of Ministers of the Environment. Canadian Water Quality Guidelines for the Protection of Aquatic Life : Organotins – tributyltin triphenyltin, and tricyclohexyltin. In : Canadian Environmental quality Guidelines, 1999.

Chung IH, Jeng SS (1974) Heavy metal pollution of Ta-Tu River. Bull Inst Zool Acad Sin 13 : 69—73.

Daud MK, Shafaqat A, Zohaib A, Ihsan EZ, Muhammad AR, Afifa M, Afzal H, Muhammad R, Muhammad ZR, Shui J (2018) Potential of duckweed (*Lemna minor*) for the phytoremediation of landfill leachate. J Chem 2018 : 1—9.

Devlin RMR (1667) Plant physiology. New York' Reinhold 564.

Dixit S, Tiwari S (2010) Effective utilization of an aquatic weed in an eco-friendly treatment of polluted water bodies. J Appl Sci Environ Manag 11 (3) : 41—44.

El Bouraie MM, El Barbary AA, Yehia MM, Motawea EA (2010) Heavy metal concentrations in surface river water and bed sediments at Nile Delta in Egypt. Suo 61 (1) : 1—12.

Forni C, Patrizi C, Migliore C (2007) Floating aquatic macrophytes as a decontamination tool for antimicrobial drugs. Pollut Monit Prot Remediat 467—477.

Föstner U, Whittman GTW (1979) Metal pollution in the aquatic environment. Berlin Heidelberg' Springer-Verlag. 486.

Guilizzoni P (1991) The role of heavy metals and toxic materials in the physiological ecology of submersed macrophytes. Aquat Bot 41 : 87—109.

Gulati KL, Nagpaul KK, Bukhari SS (1979) Uranium, boron, nitrogen, phosphorus and potassium in leaves of mangroves. Mahasagar. Bull Nati Inst Oceanogr 12 : 183—186.

Gunathilakae N, Yapa N, Hettiarachchi R (2018) Effect of arbuscular mycorrhizal fungi on the cadmium phytoremediation potential of *Eichhornia crassipes* (Mart) Solms. Groundw Sustain Dev 7 : 477—482.

Gonzales GE, Rusiñol M, Medema G, Calvo M, Girones R (2019) Quantitative risk assessment of norovirus and adenovirus for the use of reclaimed water to irrigate lettuce in Catalonia. Water Res 153 (2018) : 91—99.

Jafari N (2010) Ecology and Socio-economic utilization of water hyacinth (*Eichhornia crassipes* Mart Solms). Appl Sci Environ Manag 14 (2018) : 43—49.

Lesage E, Rousseau DPL, Meers E, Tack FMG, De Pauw N (2007) Accumulation of metals in a horizontal subsurface flow constructed wetland treating domestic wastewater in Flanders, Belgium. Sci Total Environ 380 (380) : 102—115.

Majumder A, Ray S, Jha S (2018) Hairy roots and phytoremediation. Biol Process Pl Syst 549—572.

Malar S, Shivendra Vikram SJC, Favas P., Perumal, V (2016) Lead heavy metal toxicity induced changes on growth and antioxidative enzymes level in water hyacinths [*Eichhornia crassipes* (Mart.)]. Bot Stud 55 (1) : 1—11.

Manjunath S, Kousar H (2016) Phytoremediation of textile industry effluent using free floating macrophyte Azolla pinnata. Int J Environ Sci 5 : 68—71.

Massaquoi LD, Ma H, Liu XH, Han PY, Zuo SM, Hua ZX, Liu DW (2015) Heavy metal accumulation in soils, plants and hair samples : An assessment of heavy metal exposure risks from the consumption of vegetables grown on soils previously irrigated with wastewater. Environ Sci Pollut Res 22 (23) : 18456—18468.

Mateos-Naranjo E, Gallé A, Florez-Sarasa I, Perdomo JA, Galmés J, Ribas-Carbó M, Flexas J (2015) Assessment of the role of silicon in the Cu-tolerance of the C4 grass *Spartina densiflora*. J Pl Physiol 178 (2015) : 74—83.

Mcgrath SP, Shen ZG, Zhao FJ (1997) Heavy metal uptake and chemical changes in the rhizosphere of *Thlaspi caer-ulescens* and *Thlaspi ochroleucum* grown in contaminated soils. Pl and Soil 188 (1) : 153—159.

Mudroch A, Capobianco JA (1979) Effects of mine effluent on uptake of Co, Ni, Cu, As Zn, Cd, Cr and Pb by aquatic macrophytes. Hydrobiologia 64 (3) : 223—231.

Muthunarayanan V, Santhiya M, Swabna V, Geetha A (2011) Phytodegradation of textile dyes by water hyacinth (*Eichhornia crassipes*) from aqueous dye solutions. Int J Environ Scil (7) : 1702—1717.

O'Halloran TV, Culotta VC (2000) Metallochaperones, an intracellular shuttle service for metal ions. J Biol Chem 275 (33) : 25057—25060.

Påhlsson AMB (1989) Toxicity of heavy metals (Zn, Cu, Cd, Pb) to vascular plants–A literature review. Water Air Soil Pollut 47 : 287—319.

Shinde D, Kamble P, Mahajan DM, Devkar V, Chakane S (2020) Analysis of accumulated heavy metal concentrations in various body parts of Chillapi (*Oreochromis mossambicus*) fish from Ujjani reservoir. Adv Bot Zool 8 (2) : 37—44.

Skinner K, Wright N, Porter-Goff E (2007) Mercury uptake and accumulation by four species of aquatic plants. Environ Pollut 145 (1) : 234—237.

Sprenger M, McIntosh A (1989) Relationship between concentrations of aluminum, cadmium, lead and zinc in water, sediments and aquatic macrophytes in six acidic lakes. Arch Environ Contam Toxicol 18 (1—2) : 225—231.

Usman K, Al-Ghouti MA, Abu-Dieyeh MH (2019) The assessment of cadmium, chromium, copper and nickel tolerance and bioaccumulation by shrub plant *Tetraena qataranse*. Sci Rep 9 (1) : 1—11.

Verma R, Suthar S (2015) Lead and cadmium removal from water using duckweed–*Lemna gibba* L. : Impact of pH and initial metal load. Alexandria Engg J 54 (4) : 1297—1304.

Victor KK< Ladji M, Adjiri AO, Cyrille YDA, Sanogo TA (2016) Bioaccumulation of heavy metals from wastewaters (Pb, Zn, Cd, Cu and Cr) in water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). Int J Chem Tech Res 9 (2) : 189—195.

Vymazal J, Švehla J, Kröpfelová L, Chrastný V (2007) Trace metals in *Phragmites australis* and *Phalaris arundinacea* growing in constructed and natural wetlands. Sci Total Environ 380 (1–3) : 154—162.

Walker EL, Conolly EL (2008) Time to pump iron : Iron-deficiency-signaling mechanisms of higher plants. Curr Opin Pl Biol 11 (5) 530—535.

Wolverton BC, McDonald RC (1979) Water hyacinth (*Eichhornia crassipes*) productivity and harvesting studies. Econ Econ Bot 33 (1) : 1—10.

Yasar A, Zaheer A, Tabinda AB, Khan M, Mahfooz Y, Rani S, Siddiqua A (2017) Comparison of Reed and Water Lettuce in constructed wetlands for wastewater treatment. Water Environ Res 90 (2) : 129—135.