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Phytoremediation potential of *Bacopa monnieri* in the removal of heavy metals

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Abstract

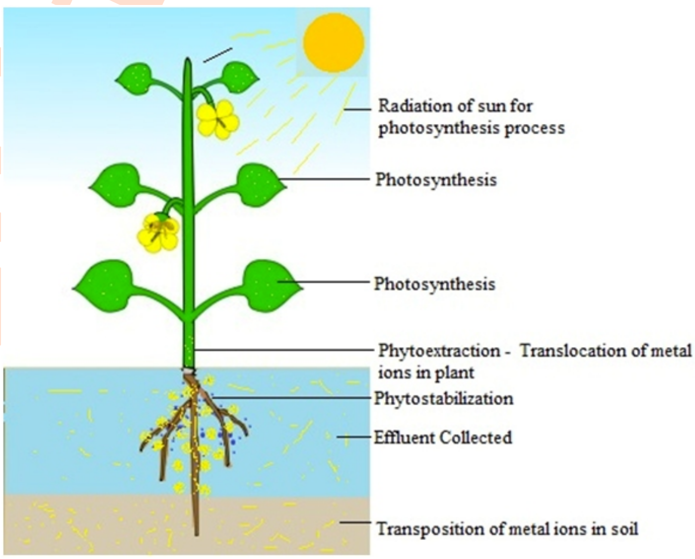
Aim: The present study aimed to investigate the bioaccumulation of heavy metals from the effluent of battery industry by an aquatic plant, *Bacopa monnieri.*

Methodology: Experiment was carried for 25 days and heavy metal concentrations were analyzed in plant parts (roots and shoots), soil and effluent using atomic absorption spectroscopy (AAS) for 5 days each. Parameters such as Translocation Factor (TF), Bioconcentration Factor (BCF) and Transposition Factor (TrF) were calculated to analyze heavy metal interaction between plant, soil and effluents.

Results : Zn and Mg were found to be high in TF, BCF and TrF, but Cr had a TF value higher than Zn as it translocates high amount of ions to plant parts. TrF values of contaminants increased constantly in the following order: Mg > Zn > Cd > Pb > Cr. TF and BCF values were not > 1 for toxic metals (Pb, Cr and Cd).

Interpretation : *B. Monnieri* can be used as a phytoextractor in removing contaminants from aquatic bodies.

Key words: Aquatic plant, *Bacopa monnieri*, Heavy metals, Phytoremediation, Transposition factor



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Introduction

Increase in industrialization, production of a variety of chemical compounds and their discharge in the effluent are the important cause of environmental pollution. A continuous discharge of industrial wastes into the environment considerably reduces the environmental quality and raises the ecological risk to living organisms (Galal *et al*., 2017; Salama *et al*., 2017). Studies have also shown that heavy metal pollution in aquatic environment is the major cause of ecological degradation (Maine *et al.,* 2016). Presence of heavy metals in the environment and in food chain is serious problem to humans as it enters food chain (Kaur *et al*., 2017).

Essential elements such as copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) are required for various biochemical and physiological functions of plants, while metals such as cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), arsenic (As) and antimony (Sb) are highly toxic (Mustapha, van Bruggen and Lens, 2018) to the plants and plays no significant role in the growth of plants. Various studies have been studied to neutralize/reduce the environmental pollution by heavy metal but it turns out to be more complex than simple. Several water treatment technologies such as physical (Hatami, Kariman and Ghorbanpour, 2016; Gupta, Sinha and Chandra, 1994), chemical (Jampeetong and Brix, 2009) and biological (Pirzadah *et al*., 2017; Prasad *et al*., 2010) are employed for the treatment of heavy metal pollution. Among all biological treatment method is found to be more promising, inexpensive and eliminates the negative impact of heavy metals (Maka *et al*., 2014; Mishra *et al*., 2006). Phytoremediation is an environmental friendly and economical method to remediate heavy metal contamination in soil and water (Muszyńska *et al*., 2016). Among the phytoremediation techniques, phytoextraction refers to the removal of heavy metals from the environment through plant uptake into harvestable parts of the plant (Suman *et al.,* 2018). Stabilizing metals in roots and shoots and plant biomass are the major hurdle in phytoextraction process. Non-hyperaccumulating plants tend to restrict soil–root and root–shoot transfer and on the other hand hyperaccumulators have the capacity to uptake and translocate metals into different parts of the plant (Maine *et al*., 2016; Mercado-Borrayo *et al*., 2015).

Phytoremediation is a process of using plants to remove or reduce pollutants from the ecosystem (García-Mercadoa *et al*., 2017). Current technologies of effluent treatment hold a disadvantage compared to phytoremediation due to its eco-friendly technique and cost-effective. *B. monneri*, is an important plant used in Ayurvedic medicine to enhance memory, learning ability, concentration etc. (El-Khatib, Hegazy and Abo-El-Kassem, 2014; Bokhari *et al.,* 2016). Several studies have been previously conducted to study the toxic removal of *B. monnieri* grown in effluents and it has been found to be potential bioaccumulator of various pollutants (Borker *et al.,* 2013; Badejo *et al*., 2015). In view of the above, main objectives of this study were to: (1) calculate the heavy metal accumulation by plant; (2) translocation and bioaccumulation factor of plant and (3) interaction between contaminants and soil.

Materials and Methods

Experimental design : The experiment was conducted in the research laboratory of Coimbatore Institute of Technology (32.1211° N, 118.9445° E). Fifteen, 5 litre Perspex containers were arranged in 5 x 3 rows for sample experimentation filled with contaminated free sand and industry effluent (battery & foundry industry) in 1:1 ratio. Initial studies show that pH of the effluent increases with experimental period and optimum pH was found to be 5 – 6, it was noted and maintained daily. *B. Monnieri* was collected from the local nursery and placed under hydroponic condition in Hoagland nutrient solution ($Ca(NO_3).4H_2O$ – 3.5M, KNO_3 – 2.5M, KH_2PO_4 – 1M, $MgSO_4.7H_2O$ – 1M, H_3BO_3 – 45.2mM, $MnCl_2.4H_2O$ – 9.09mM, $ZnSO_4.7H_2O$ – 695.5µM, $NaMoO_4$ – 171.1 µM, $CuSO.5H_2O$ - 400 µM, $FeCl_3$ – 30.82mM and EDTA – 17.09mM). Evenly sized plants were taken for experimentation after five weeks of growth. The experiment was carried out for 25 days; heavy metal content in plants (roots and shoots), soil and effluent were analyzed at an interval of 5 days.

Sampling and Analysis: Effluent and soil samples were collected from the battery and foundry industries discharge in the site 11.18'66"36 N, 77.06'35"51 E in the month of November 2017. Heavy metals such as Lead (Pb), Chromium (Cr), Cadmium (Cd), Magnesium (Mg) and Zinc (Zn) in the effluent and in soil were determined using Atomic Absorption Spectroscopy (AAS). Collected effluent samples were preserved using HNO_3 at 2-3 °C, pH of sample was acidic with 2.5 for effluent. pH of the Samples were maintained 5-6 using $C_2H_3NaO_2$ buffer. Liquid samples were analyzed after filtering the dust particles in the effluent with the aid of Whatman filter paper no. 42. Heavy metal concentration in roots and shoots of the plant and soil samples were determined by acid digestion followed by using AAS.

Acid-digestion process : Root, shoot and soil samples were acid-digested to determine the heavy metal concentration (Dineshkumar et al., 2018). Perspex plastic containers and glassware were used for the preparation of solid samples.

Plant analysis : It is important to study the parameters which determine the plants ability for phytoremediation process such as bioconcentration factor (BCF; root-to-soil and shoot-to-soil concentration ratio), translocation factor (TF; shoot-to-root concentration ratio) and transposition factor (TrF; soil-to-effluent concentration ratio). In this study, these parameters were also assessed from phytoremediation potential of *B. monnieri*.

Translocation factor : Translocation factor greater than 1 is considered to be phytoextractor plant. It was calculated by the following formula :

$$\text{Translocation Factor (TF)} = \frac{\text{Concentration in shoot (ppm)}}{\text{Concentration in root (ppm)}}$$

Bioconcentration factor : Bioconcentration factor greater than 1 is considered to be hyperaccumulator plant. It was calculated by using the following formula :

$$\text{Bioconcetration Factor (BCF)} = \frac{\text{Concentration in plant (ppm)}}{\text{Concentration in soil (ppm)}}$$

Transposition factor: Transposition factor depends upon the contaminants transference from its original medium to another; other than the sample medium. It is defined as the ratio of concentration in contaminated free medium to contaminated medium.

$$\text{Transposition Factor (TrF)} = \frac{\text{Concentration in soil (ppm)}}{\text{Concentration in effleunt (ppm)}}$$

Results and Discussion

Heavy metal concentration in root, shoot, soil and effluent during the experimental period varied with respect to period. The concentration of heavy metals gradually increased in plant with increase in duration. Heavy metal concentration in soil was also estimated to study the interaction between contaminant free soil and effluent. Queiroz *et al.*, 2017 and Ramakrishnan *et al.*, 2010 have discussed the interaction between heavy metals in effluent and soil and it is important to study the progress of metal ions in soil from effluent.

A good phytoremediation plant should possess TF and BCF greater than one (Rezania *et al.*, 2016, Riaz *et al.*, 2017). The translocation factor, defined as the ratio between metal concentration in shoot and aerial parts to the metal concentration in root parts of the plant. TF capacity of *B. monnieri* was shown in Fig. 1. The results show that Cr was translocated more than any other metals (Tang *et al.*, 2017). The TF of Zn and Mg were found to be in the range of 0.40 – 0.55 at the end of 25 day. Meanwhile, Cd concentration decreased after 20^{th} day of the experiment.

Ratio between the metal concentrations in plant parts to the source of contaminants is known as Bioconcentration Factor (BCF). BCF of root and shoot were calculated and plotted as shown in Fig. 3 and 4. Mg possessed highest BCF value for shoot than any other metal whereas all other metals were found to be less than 1. BCF of each metal varied in the root; Zn and Mg had high BCF value although not > 1 (Saxena and Saiful-Arfeen,

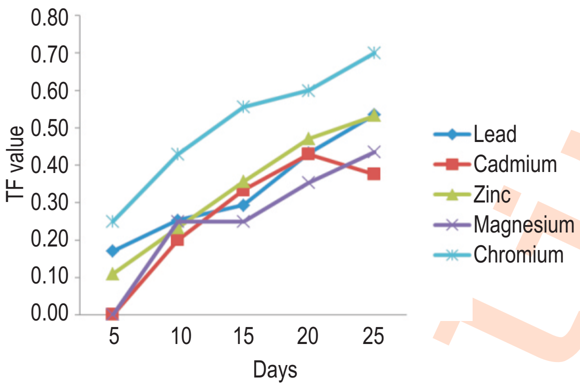

Fig. 1: TF value for *B. monnieri* under treatment.

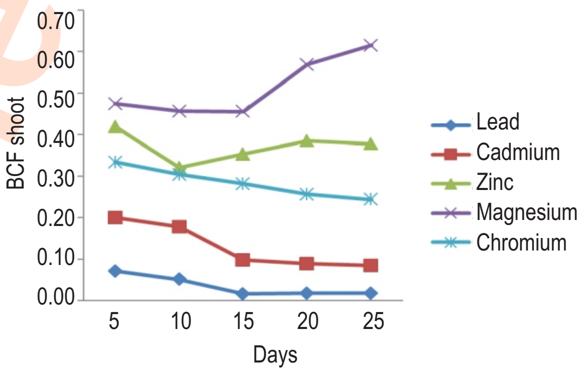

Fig. 2: BCFShoot value for *B. monnieri* under treatment.

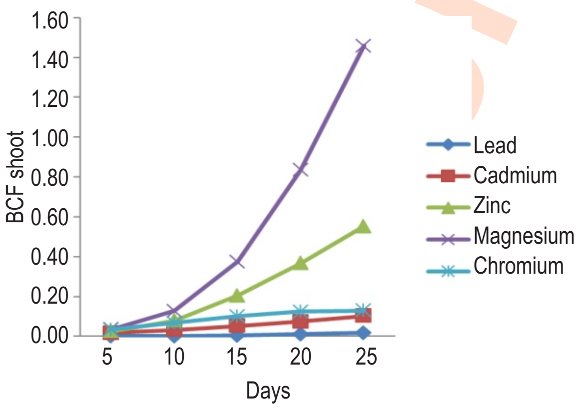

Fig. 3: BCFRoot value for *B. monnieri* under treatment.

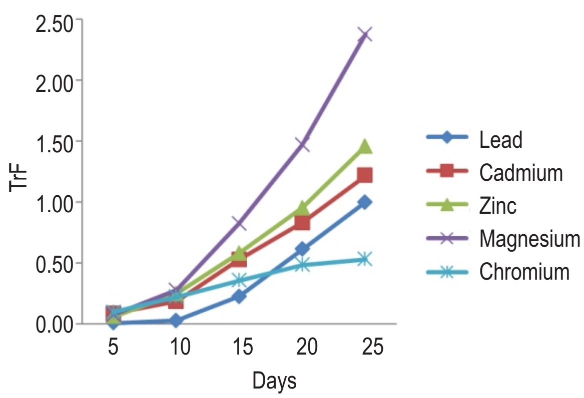

Fig. 4: TrF value for *B. monnieri* under treatment.

Table 1: Heavy metal concentration in effluent

Heavy metal content	**Concentration (mg l^{-1})**
Cadmium	1.84
Chromium	1.35
Lead	25.28
Magnesium	25.32
Zinc	41.96

2009). The BCF of metals in roots and shoots were in the order of Mg < Zn < Cr < Cd < Pb.

It is evident that the contaminants present in the effluent translocated to soil. So, it is important to calculate TrF value as much as TF and BCF. TrF value of Mg and Zn metals were found to be high compared to other metals, it is understood initial metal concentration plays a major role in TrF. TrF value was used to calculate the transfer rate of contaminants from liquid medium to solid. The initial metal concentration in effluent plays an important role in metal interaction with soil.

As mentioned in Table 1, initial metal concentrations played a significant role in heavy metal accumulation. In particular, the results indicated that *B. monnieri* could tolerate higher concentrations of Cr, Pb, Zn, Mg and Cd in effluent. The essential elements of this study are Mg and and Zn (micronutrients) which possess higher BCF value for both roots and shoots and in TrF. This is due to the ability of plants to uptake essential elements compared to non-essential elements also plants may develop tolerance strategies that reduce their uptake and accumulation (Saha *et al*., 2015; Sarathambal *et al*., 2017; Sung, Lee and Munster, 2015). Plants which are possessing < 1 for TF and BCF values are considered to be unsuitable for phytoextraction process (Romanova, Shuvaeva and Belchenko, 2016; Romero-Hernández *et al*., 2017). Results indicate that the root parts of the plant possess high concentration of metal ions which indicates a higher accumulation of ions to protect photosynthetic tissue in the above ground parts (Saha, Banerjee and Sarkar, 2015; Salama, Al Watban and Al-Fughom, 2011). High concentration of metal ions in the root indicates that element compartmentalization, tolerance strategy by the plant in respect to the different metal ions and the level of concentration (Hazra *et al*, 2015; Zengin and Munzuroglu, 2005). This tolerance strategy is common in wetland plants and helps the plant to protect photosynthetic tissues in the above ground parts from the harmful effects of toxic metal ions (Wang *et al*., 2002; Akinbile, 2016; Mustapha, 2018). Presence of higher metal concentration in below ground parts of the plant was patterned with most authors (Victor *et al*., 2016, Ton *et al*., 2015, Saxena and Saiful-Arfeen, 2009). As the impression of plant tolerance strategy BCF value for root and shoot were controlled to <1. Aquatic plants accumulate higher concentration of metal ions in the belowground parts as a consequence of multiple factors such element compartmentalization, tolerance strategy, accumulation capacity of root cell walls and intercellular air spaces (Singh and Rai, 2016, Sidhu *et al*., 2017). TrF value of metal ions were mostly depends upon the initial metal concentrations, indicated in Fig. 4. The role of belowground parts of the plant accumulates bulk metal ions and supports the ecological restoration of environment by phytostabilisation mechanism (Singh, Eapen and D'Souza, 2006, Rezania *et al*., 2016, Riaz *et al*., 2017, Tang *et al*., 2017).

The current work on *B. monnieri*, an aquatic plant on phytoremediation with industrial effluent was found to be positive approach. Even though TF and BCF value were < 1, the plant can accumulate contaminants more than 10% from the contaminated medium as greater 50% of contaminants transferred to soil from effluent in a minimum period. It is concluded if the aquatic plant cultivated four times over a period of 20days each, contaminants in soil and effluent could be removed completely.

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