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Original Research Article

# Use of two aquatic macrophytes for the removal of heavy metals from synthetic medium

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ABSTRACT

The aim of the present study was investigation of two aquatic plants efficiency, duckweed *Lemna gibba* (floating-leaved hydrophyte) and coontail *Ceratophyllum demersum* L. (free-floating hydrophyte) on Cd and Ni removal from synthetic aqueous. Both aquatic plants were grown under greenhouse conditions in pots containing a nutrient solution amended with increasing doses of each of the contaminants tested (0, 1, 2, 4 and 6 mg $L^{-1}$) in a completely randomized design with three replications. Plants dry matter production as well as heavy metals and nutrient tissue concentrations were measured at the end of the experiment. The results showed that increasing heavy metal concentrations in nutrient solution caused a decrease in both plants biomasses. *L. gibba* reduced the contamination level which was up to 91% for Cd and 50% for Ni. In addition, the efficiency of *C. demersum* was 82.01% for Cd and 52.5% for Ni. *L. gibba* uptake both heavy metals (5.07 mg for Ni and 9.70 mg for Cd) but *C. demersum* accumulated both heavy metals (4.5 mg for Ni and 3.87 mg for Cd) less and slower for Cd removal but a little more and faster for Ni than the other plant. The Ni and Cd BCF values for *L. gibba* ranged between 270.19 to 638.95 and 942.79 to 5093.27, respectively; and for *C. demersum* ranged between 104.16 to 200 and 75 to 707.92, respectively. The high efficiency of *L. gibba* and *C. demersum* in Cd and Ni removal from synthetic medium makes it a proper treatment method.


## 1. Introduction

Heavy metals may distribute in the environment by different human activities. Pollution caused by heavy metals is a serious environmental problem in the whole world and with increasing of industrialization, heavy metals flowed into the biogeochemical cycles. This type of contaminations can get into the food chain and have undesirable effects on human health (Ali et al., 2013). Heavy metal remediation of aquatic systems is essential to reduce their impact on the biosphere. Aquatic ecosystems are mostly at risk, because they are often final receiver of these elements (Kanoun-Boule et al., 2009). The usual technologies used for heavy metal remediation are adsorption, ion-exchange, electrodialysis, reverse-osmosis, etc. Most of these technologies are expensive, energy-intensive and have been developed for the certain element. Hydrophytes have great potential to uptake heavy metals

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(Mishra and Tripathi, 2008); and in the aquatic ecosystems, these plants mostly are the first organisms that are in relation to these elements (Xu et al., 2010).

With various industrial activities, heavy metals like Ni and Cd, may inter to the environment (Bonfranceschi and Flocco, 2009). Cd is a toxic element to animals and humans; so releasing the Cd into the environment is the one of the mankind great concerns. Plants can accumulate Cd in low concentrations with no sign of toxicity, but eating them by animals or humans may cause intoxication. Humans have more longevity than animals; and because of this matter, with using Cd-contaminated food, humans are affected by Cd more than animals (Tudoreanu and Phillips, 2004; Kirkham, 2006). Cd in high doses reduced nutrient uptake, water uptake and the photosynthesis in plants (Yadav, 2010). Ni is an essential trace element for plant normal life, because it is part of some profound enzymes such as urease. But at toxic levels it has bad effects on some of vital processes in plants (Fuentes et al., 2014).

Phytoremediation has many advantages such as environmental friendliness, cost effectiveness and the possibility of harvesting the plants for the extraction of absorbed and accumulated contaminants like toxic heavy metals for recycling. Hydrophytes (aquatic macrophytes) are very useful plants for aquatic medium phytoremediation as effective heavy metals accumulators (Aravind and Prasad, 2005).

*Lemna* sp. (duckweeds) is ubiquitous free-floating freshwater monocotyledons, preparing food and habitat for a variety of omnivorous and herbivorous animals, particularly fishes, macro invertebrates and aquatic birds (Lewis, 1995). The rapid vegetative reproductive cycle (doubling time of 1–4 days or less), the genetic diversity of different duckweed populations, and the easy cultivation in lab are significant characteristic that make the *Lemna* species appropriate plants for relative ecotoxicological studies (Kanoun-Boule et al., 2009). Therefore, duckweeds have been widely used in biofiltering of heavy metals, such as Cd (Khan et al., 2009), Cu (Kanoun-Boule et al., 2009) and Ni (Demirezen, 2007; Khan et al., 2009).

Hornweed or coontail (*Ceratophyllum demersum* L.) belong to the order Nymphaeales and family Ceratophyllaceae (the family of hornworts), grows rapidly in muddy, shallow and motionless water bodies at low intensities of light (Aravind and Prasad, 2005). *C. demersum* L. is a perennial, submerged, free floating, rootless and is cosmopolitan in distribution. This hydrophyte has a high capacity for biomass production and vegetative reproduction even under the limited nutritional conditions (Aravind et al., 2009). *C. demersum* can be a biofilter for heavy metals, such as Cd (Saygideger and Dogan, 2004; Mishra et al., 2008), Pb(Saygideger et al., 2004; Saygideger and Dogan, 2004; Mishra et al., 2006) and Ni (Khan et al., 2009; Chorom et al., 2012).

The objective of this study was to examine the capability of Iran's native aquatic macrophytes (*Lemna gibba* and *C. demersum*) for the removal of heavy metals, Ni and Cd from polluted water. The real efficiency of aquatic plants for the removal of Ni and Cd was investigated using steel industrial wastewater samples collected from Khuzestan steel industry of Ahwaz-Iran.

## 2. Materials and methods

### 2.1. Site description

The study was conducted from November to February 2011 at the College of Agriculture, Shahid Chamran University in the City of Ahvaz, Khuzestan province, Iran. Climatic conditions in the area during this period were mean daily temperature, $24 \pm 5^{\circ}$ C; mean daily relative humidity, $55 \pm 25\%$; daily maximum global radiation, between 650 and 1100 W $m^{-2}$; and direct radiation, between 400 and 1050 W $m^{-2}$.

### 2.2. Stock cultures

*C. demersum* L. is prevalently available hydrophyte in Ahvaz County, Iran. *L. gibba* L. aquatic plant is an easy available floating-leaved hydrophyte in Khuzestan province, Iran lakes and wetlands. Cultures of *C. demersum* (obtained from irrigation dike of Shahid Chamran University) and *L. gibba* (collected in lake of Soveyseh village, south-eastern Ahvaz) were grown outdoors in 30-L plastic containers filled with half-strength Hoagland-Arnon's nutrient solution (Marin and Oron, 2007). The composition of half-strength modified Hoagland-Arnon nutrient solution was: 3.0 mM $KNO_3$; 2.0 mM $Ca(NO_3)_2$; 0.5 mM $NH_4H_2PO_4$; 1.0 mM $MgSO_4$; 10 μM Fe–EDTA; 1.5 μM $H_3BO_3$; 0.25 μM $MnSO_4$; 0.1 μM $CuSO_4$; 0.2 μM $ZnSO_4$; and 0.025 μM $H_2MoO_4$. The plants were cultivated under these conditions for 4 weeks prior to the beginning of the experiments. The nutrient solution with pH 7.0 was replaced after each 3 days. Preliminary tests for pH were performed to determine the appropriate best pH range for test plant growth and metal accumulation.

### 2.3. Experimental setup

Eight-day batch experiments were conducted to evaluate Cd and Ni removal by plants, *C. demersum* and *L. gibba*. In this study, cadmium chloride ($CdCl_2 \cdot 4H_2O$) and nickel nitrate [$Ni(NO_3)_2 \cdot 6H_2O$] were used without further purification for treatments which are made with adding to half strange Hoagland nutrient solution. The experiments were performed outdoors in 3-L plastic receptacle (surface area: 432 $cm^2$). Therefore, Cd and Ni concentrations selected were 0.00, 1.00, 2.00, 4.00 and 6.00 mg $L^{-1}$. For each concentration of contamination, three replicates treated, and three receptacles without plants were set as controls. Each replica was filled with 1.8 L of half-strength Hoagland's nutrient solution contaminated with separate contamination of Cd and Ni. The initial Cd and Ni concentrations were similar to the nominal concentrations selected in this study (Tables 1 and 2).

The pH of the solutions was adjusted with 0.01 M NaOH and 0.01 M HCl to be 7.0. Every day during cultivation the evaporated volume was replaced with deionized water.

Twenty grams fresh weight (FW) of plants was added to each treatment replicate. Treatment and control vessels were randomly arranged. The water sampling period was 1, 2, 3 ... and 14 days after the start of heavy metal application. After 14th day, the experiment was stopped