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Bioaccumulation of nickel by aquatic macrophytes

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ABSTRACT

Aquatic plants are being used successfully for the accumulation of trace elements in natural and constructed wetlands. Four aquatic plants were examined for their ability to remove heavy metals from contaminated water. In our study, bioaccumulation abilities of *Lemna*, *Apium*, *Ceratophyllum* and *Groenlandia* species were found. As for the results, different rates of Ni were removed mostly by *Groenlandia* on the 6th day correlated with time and concentration. The BCF rates for Ni are found in the concentration values ranging from 576 to 1867 mg g^{-1} for *Lemna trisulca*, 587–1116 mg g^{-1} for *Apium nodifolium*, 920–2945 mg g^{-1} for *Grolandia densa* and 489–774 mg g^{-1} for *Ceratophyllum submersum*. Maximum rates for Ni are determined for *Grolandia densa* and the minimum rate is 489–774 mg g^{-1} for *Ceratophyllum submersum*.

Keywords: Accumulation; Aquatic macrophytes; Heavy metal; Nickel; Removal

1. Introduction

Some plants may be used for accumulation in the remediation process, which makes it possible to remove several pollutants, including heavy metals from soil and water [1]. This ability is harnessed to remove toxic heavy metals and trace elements from contaminated soils and waters in a process referred to as remediation [2]. Aquatic plants *Lemna trisulca*, *Ceratophyllum submersum*, *Groenlandia densa* and *Apium nodiflorum* have been exposed to biocontrate heavy metals such as Fe and Cu up to 78 times their concentration in the water [3]. The accumulation of some other heavy metals and trace elements (Cu, Cd and Zn) by several species of aquatic plants are demonstrated in this study. Duckweed exhibited some symptoms of toxicity at higher levels of element supply (except for Cr), the toxicity effects of the trace elements on plant in descending order of damage were Cu > Se > Pb > Cd > Ni > Cr [4–6].

Not all aquatic plants are equally effective in removing heavy metals. Based on earlier reports, plants such as *Phragmites canadensis*, *Groenlandia densa*, *Ceratophyllum demersum*, *Bacopa monnieri*, have been found suitable for the removal of different metals [7–12]. Several research groups have developed many wastewater treatment systems using diverse plant groups. Among all aquatic plant species that were tested for Ni accumulation, *Azolla*, water hyacinth and *Salvinia* proved to be the best at a Ni concentration of 1601 g kg^{-1} [13], while *Azolla* and *Salvinia* accumulated 9 and 6.3 g kg^{-1} Ni, respectively and were recommended to be used as indicators of Ni pollution [14–16].

In the light of the studies carried out with aquatic plants, which grew in tropical and subtropical regions, our studies aim to find out the accumulation of Ni by several aquatic plants, such as *Lemna trisulca*, *Ceratophyllum submersum*, *Groenlandia densa* and *Apium nodiflorum*.

2. Materials and methods

Lemna trisulca, *Apium nodiflorum*, *Groenlandia densa* and *Ceratophyllum submersum* were collected from the Lake

Işıklı, in the province of Denizli, Turkey in May 2007 and were transferred to the laboratory in polyethylene bags (Fig. 1). After the termination of each experiment, the plants were washed well in tap water and distilled water. The washed samples were carefully dried of adherent water using absorbent paper. Samples were dried to a constant mass in a fan-forced oven at 80°C (overnight). Then the samples were heated on a heating block until the nitric acid solution evaporated. Afterwards, the samples were cooled, 10 ml of concentrated $HNO_3/H_2SO_4/HClO_4$ acid mixture (10:1:4 v/v) was added and the mixture was heated again at 150°C. Digestion was continued until the solution became clear. Then the samples were cooled again. The solutions were filtered and made up to 100 ml with deionized water. Trace element analyses were carried out by the acid digestion of dried and ground tissue samples as described by [19], followed by measurement of total concentrations of trace elements in the acid digest by AAS, 700, Perkin Elmer. The bioconcentration factor (BCF) provides an index of the ability of the plant to accumulate the metal with respect to the metal concentration in the substrate. The BCF were calculated as described by [6]:

2.1. Statistical method

All experiments were carried out in duplicate and the results were analyzed using the Minitab statistical package program.

3. Results and discussion

Lemna trisulca, *Ceratophyllum submersum*, *Apium nodifolium* and *Groenlandia densa* species have accumulated the metal nickel in different rates correlated with time and concentrations. On the first day, the aquatic plants that we used in our study were accumulated in the concentrations of 1, 3 and 7 mg/l, in which *A. nodiflorum* had the minimum accumulation. On the contrary, in the concentrations of 5 mg/l, the accumulation values were minimum in the tissues of *L. trisulca*, and maximum in the *G. densa*. On the second day, the accumulations of *G. densa* were maximum in all concentrations but the accumulations were minimum in *C. demersum*. On the third day, the results followed a different way; *G. densa* accumulated maximum in 1 mg/l Ni concentrations, but the minimum

$$\mathrm{BCF} = \frac{\text{Initial concentration of the element in the external nutrient solution (mg/l)}}{\text{Trace element concentation in plant tissue } (\mu\text{g g}^{-1}) \text{ at harvest}}$$

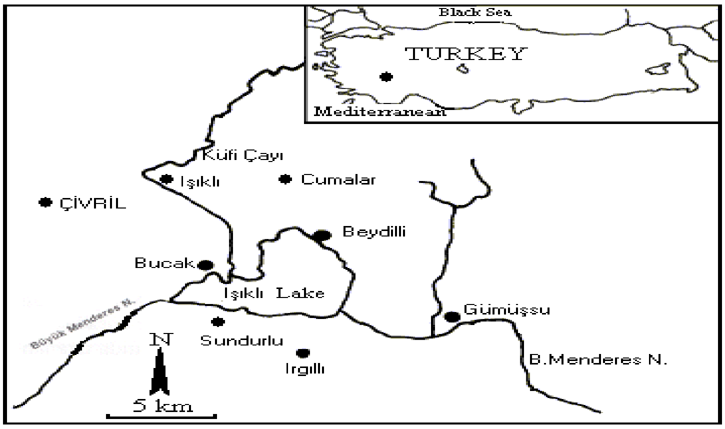

Fig. 1. Map of the study area.

accumulation is detected in *A. nodiflorum* in 3, 5 and 7 mg/l concentrations, the absorption was maximum in *G. densa*, while it was minimum in *C. demersum*. On the fourth day, the maximum accumulations were detected in *G. densa* and the minimum in *C. demersum* at concentrations. It was observed that there are accumulations of Ni by different aquatic plants in the literature. Calculations and interpretation of results were based on accumulation values of metals during the experiment (Table 1).

There were no statistically significant differences between the species of *Lemna*, *Apium* and *Ceratophyllum* species. When we considered the changes of the metal accumulation of Ni in 1 mg/l with time, there were differences between the rates of metal accumulations in on the 1st, 2nd and 3rd days (Fig. 2).

When the metal accumulations in 3 mg/l concentration are correlated with time, the rates of accumulations on the 1st and 2nd days were quite different from the accumulations on the 4th day, when they were compared to each other. A meaningful statistical difference was found in the accumulation rates on the 3rd and 4th days (Fig. 3).

These differences were significant ($P < 0.001$) between

Table 1
Accumulations of Ni by different aquatic plants in the literature

Species	Concentration ($mg.g^{-1}$)	Reference
Ceratophyllum demersum	1.52	[17]
Phragmites communis	2.22	[17]
Eichornia crassipes	10.7	[18]
Ceratophyllum demersum	20	[19]
Juncus bulbosus	23	[20]
Lagarosiphon sp.	44	[19]
Z. palustris	93.6	[21]
Myriophyllum brasiliense	1077	[22]
Eichhornia crassipes	1500	[23]
Elodea canadensis	2150	[5]
Lemna polyrrhiza	5500	[24]
M. spicatum	5800	[25]
Azolla filiculoides	20339	[8]

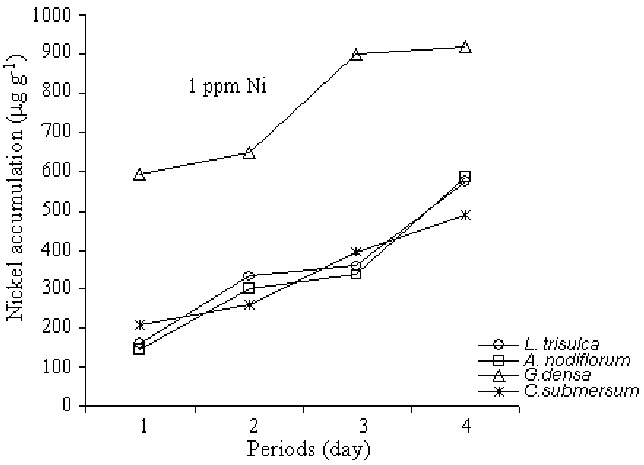

Fig. 2. The accumulation of Ni at different metal concentrations and exposure time by aquatic plants.

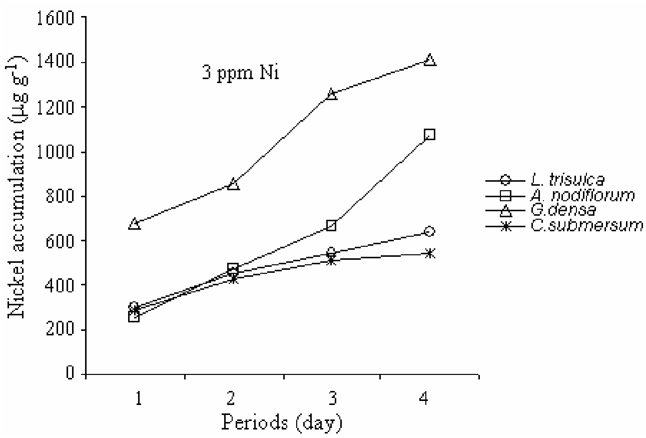

Fig. 3. The accumulation of Ni at different metal concentrations and exposure time by aquatic plants.

the species of *Lemna, Apium, Ceratophyllum* and *Groenlandia*, but not between the *Lemna, Apium and Ceratophyllum* species (Fig. 4).

The concentrations of Ni in 7 mg/l between the accumulation rates of the 1st, 2nd, and 4th days were statistically significant ($P < 0.05$) but no statistical differences between the accumulation rates of the 3rd and 4th days were found (Fig. 5).

Most studies showed that terrestrial and aquatic plants have the ability to accumulate the heavy metals that present in their environment as reported by [15]. On the other hand, the thoughts for using this plant for the studies of removing the heavy metals are limited because of the renewable and medicinal properties of most of this plant even when they are not widespread in Turkey. In our study, bioaccumulation abilities of *Lemna*, *Apium*, *Ceratophyllum* and *Groenlandia* species was determined. As for the results, different rates of Ni were

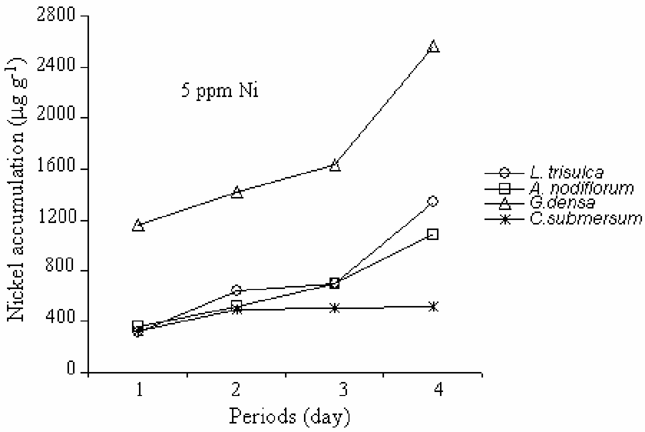

Fig. 4. The accumulation of Ni at different metal concentrations and exposure time by aquatic plants.

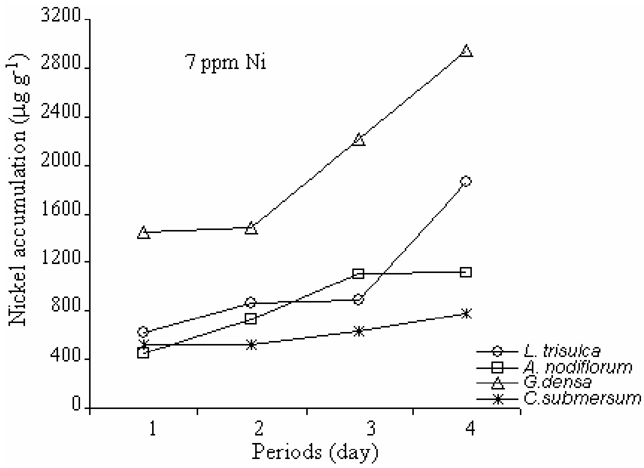

Fig. 5. The accumulation of Ni at different metal concentrations and exposure time by aquatic plants.

removed mostly by *Groenlandia* on the 6th day correlated with time and concentration. According to our study, the metal accumulation values of the aquatic plants are as follows; the BCF rates for Ni is found in the concentration values ranging from 576 to 1867 mg g^{-1} for *Lemna trisulca*, 587–1116 mg g^{-1} for *A.nodifolium*, 920–2945 mg g^{-1} for *G. densa* to 486–774 mg g^{-1} for *C. submersum*. Maximum rates for Ni are determined for *G. dens*a and the minimum rate is for *C. submersum*. The rates of metal have been accumulated by the plants that increased by the time and concentration in our results in accordance with the researches in the literature.

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