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Application of aquatic plant phytoremediation as green technology treatment of lead in polluted water

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INTRODUCTION

Water contamination with heavy metals that released into the environment as a result of different activities, is a very important problem in the current world.

In recent years, there has been increased global concern over the deteriorating state of water bodies due to heavy metal pollution

***Heavy metals** accumulate in living tissues throughout the food chain which has humans at its top and danger multiplies.*

***Lead (Pb)** is one of the most abundant toxic elements. Its contamination results from mining and smelting activities, lead containing paints, paper and pulp, gasoline as well as from the disposal of municipal sewage sludge enriched with Pb*

Considerable attention has been paid to methods for metal removal from industrial wastewaters because they pose serious environmental problems and are dangerous to human health .

The currently techniques used for removing dissolved heavy metals include: ***chemical precipitation, carbon adsorption, ion exchange, evaporation and membrane processes.***

However, these techniques have certain disadvantages such as incomplete metal removal, high reagent and energy requirements and generation of toxic sludge that require disposal

Also, they can be very expensive for the treatment of low-level metal contaminated water. Most developing countries like Egypt, may not be able to afford the huge expenditure required to treat the heavy metal pollution by modern technologies

Then

Biotechnologies,

with an increasing development during the last two decades, involve the use of plants for metal removal especially aquatic macrophytes and algae .

This is called

phytoremediation

That is a cost-effective and efficient alternative for the removal of heavy metals from aqueous solutions, using green plants.

The major advantages of phytoremediation over conventional treatment methods include:

- ***Low cost;***
- ***High efficiency;***
- ***Minimization of chemical and biological sludge;***
- ***No additional nutrient requirement;***
- ***Regeneration of biosorbent; and***
- ***Possibility of metal recovery.***

- ***Phyto-filtration***, **which is a part of Phytoremediation is defined as a high metal-accumulating plants function as *biofilters,* which can be remarkably effective in sequestering metals from polluted waters**

- **The success of *Phyto-filtration* depends on : plant growth rate and the ability to uptake high metal concentrations in plant biomass.**

The bio-removal technique using aquatic plants contains two uptake processes:

(1) an initial

fast, reversible, metal-binding processes (adsorption); and

(2) a slow,

irreversible, ion-sequestration step (bioaccumulation).

The plant under investigation ,Ceratophyllum demersum L. (Coontail or hornwort) has following characteristics :

- **Perennial submerged, rootless macrophyte**
- **Grows rapidly in shallow and muddy water bodies at low light intensities.**
- **Widely distributed in all fresh water courses in Egypt especially those receiving huge quantities of agricultural waste waters**

AIM OF OUR RESEARCH

- As Previous studies reported that, ***Ceratophyllum demersum L.*** proved to be an effective bioaccumulators for Pb.

- This rending the species of interest for use in phytoremediation and bio-monitoring of polluted waters especially in view of its availability throughout the year.

AIM OF OUR RESEARCH

Then The primary objective **of the present investigation is to:**

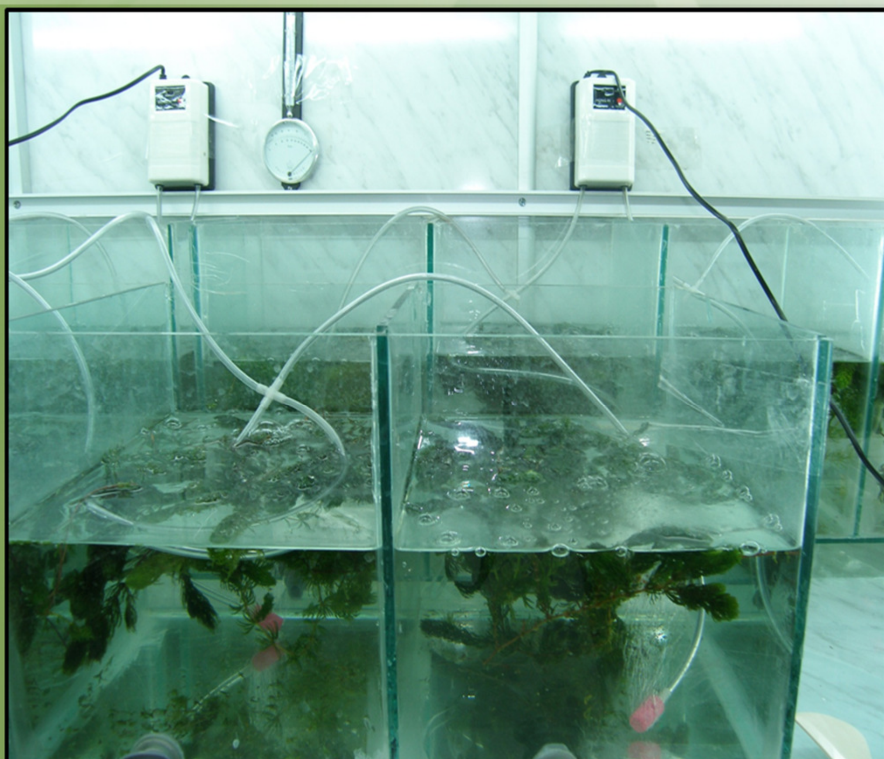
1. **investigate the removal efficiency of lead from polluted water by *Ceratophyllum demersum*, growing in a hydroponic system.**

2. **Study the effect of contact time and initial concentration of lead ions on the absorption and adsorption processes were also investigated.**

MATERIALS

AND METHODS

1. Hydroponic system



2. Sample preparation

- **Three concentrations of lead were used in this study (0.125, 0.250, and 0.500 µg/ml).**

- **About 100 g fresh weight of *C. demersum* was placed in each of the four compartments in the holding tank assigned for the different treatments.**

- **The plants were treated under the above mentioned laboratory conditions till equilibrium reached.**

3. Analyses

- **Water samples were collected from all compartments daily for the first 5 days for lead analyses, then every 5 days till equilibrium reached.**
- **Exactly 0.2 g (fresh weight) of plant material was used for batch adsorption experiment for all compartments and extracted for exchangeable lead analyses (adsorbed fraction)**
- **And another 0.5 g (fresh weight) of plant material were collected at the same intervals and digested (absorbed fraction)**

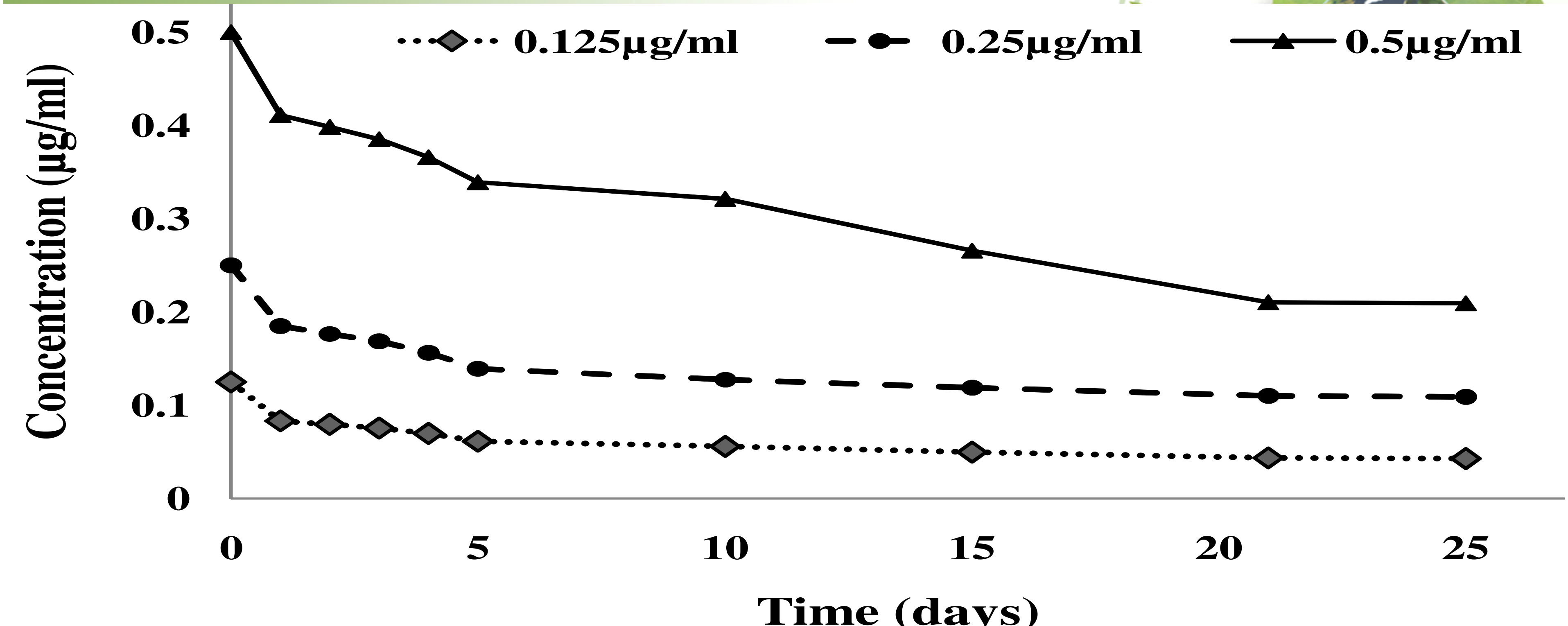
The removal efficiency (R) of Pb from aqueous solution was defined as

$$\% R = (C - C_F / C) * 100$$

Where: C and C_F are the initial and final concentrations of Pb, respectively.

RESULTS AND DISCUSSION

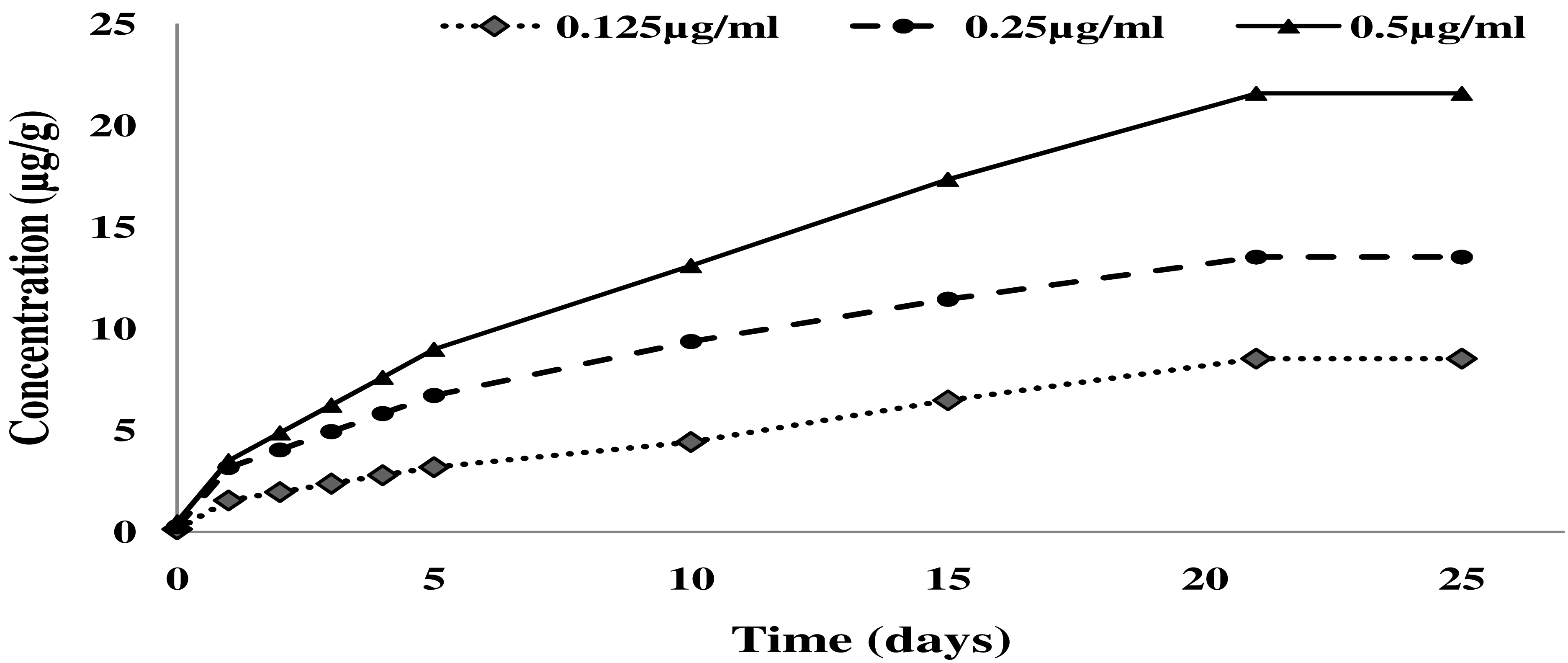
1. Lead removal from nutrient media



This figure showed that the removal of lead in three different concentrations was very fast in the first five days where the maximum metal removal observed with lower initial concentrations (0.125 µg/ml), compared to two other concentrations. The concentration was reduced to 33.6 % Pb removal after the 1st day , to (51.2%) after 5 days and to (65.6%) by the end of the experiment (25 days).

- This observation can be explained by the fact that at low concentration of metal ions, the ratio of sorptive surface area to total metal ion available is high and thus, there is a greater chance for metal removal. As such, at low initial metal ion concentrations, the removal capacity is high. When metal ion concentrations are increased, binding sites become more quickly saturated as the plant biomass remained constant.

2. Lead absorption (accumulation)

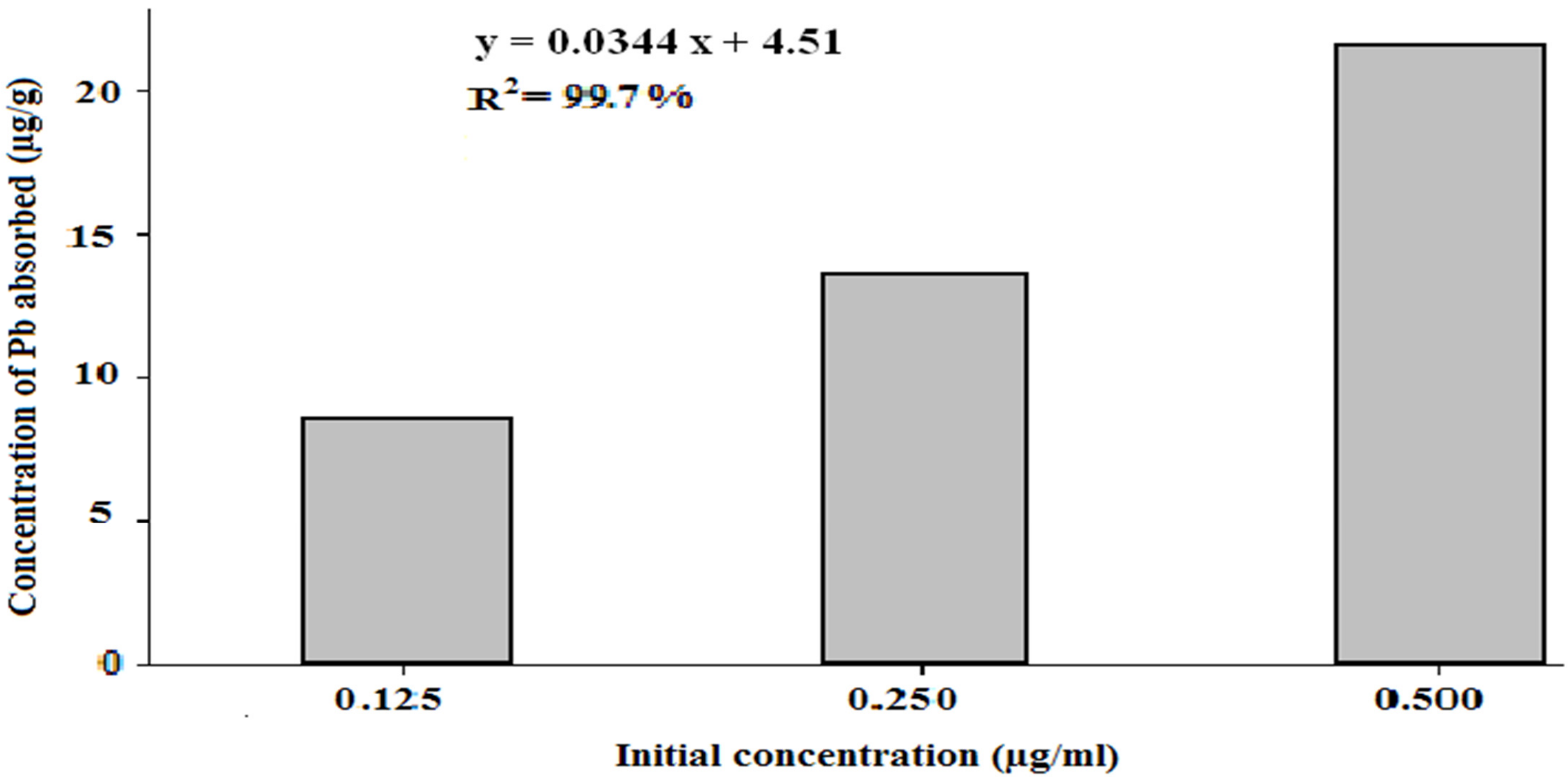


➢The experiment showed that the rate of lead uptake by *C. demersum* was very fast through the first 5 days with different type of treatments, then slowed down and became nearly constant at the last 5 days.

- The fast stage and rapidity of the uptake occurs during the first days of contact might suggest that the physical adsorption is an important removal process.

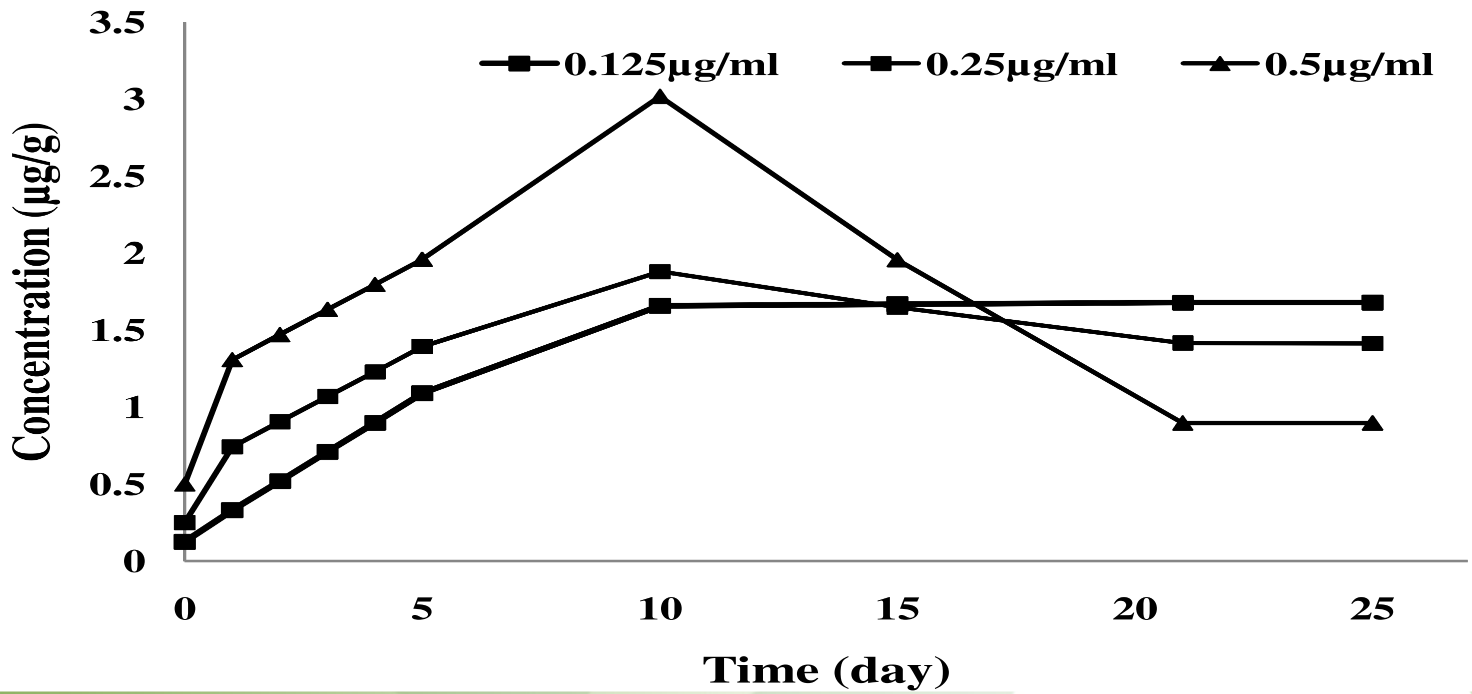
- By time there were an increase in lead accumulation by *C. demersum* with the different applied treatments . For example, the initial content of Pb in the plant was 1.0704 µg/g. After one day of the experiment, in the first treatment (0.125µg/ml), the lead content was increased up to 1.5442 µg/g , reached a value of 4.4224 µg/g after 10 days and attained its maximum (8.5289 µg/g) by the end of the experiment.

By the end of experiment, the concentration of accumulated Pb demonstrated that, the uptake of Pb by *C. demersum* increased with increasing metal concentration where the maximum Pb absorption was recorded at 0.500 µg/ml treatment.



3. Lead adsorption (exchangeable fraction)

- Generally, the biosorption mechanisms include ionic interactions and formation of complexes between metal ions and functional groups of the cell wall components.
- The first stage of metal accumulation involved adsorption of metal onto the cell wall of microorganisms, algae and aquatic macrophytes.
- The adsorption fraction represents very loosely bound elements and may regulate and/or reflect the composition of surface water



➢The figure here demonstrated that the initial concentration of the adsorbed Pb onto the tested plant was 0.3099 µg/g. This value was increased gradually in the three treatments, attaining their maxima, after 10 days.

➢Afterword, a relative decrease was observed in the adsorbed fraction of Pb in the first and second treatments (0.125 and 0.250 µg/ml). While a sharp decrease was recorded in the third treatment.

➢ In the last 5 days of experiment, nearly no change was detected in the adsorbed fractions in the three treatments. The reduction in Pb adsorbed fraction, at higher Pb concentrations, may be due to the decrease of available adsorption sites to accommodate adsobate ions (Pb).

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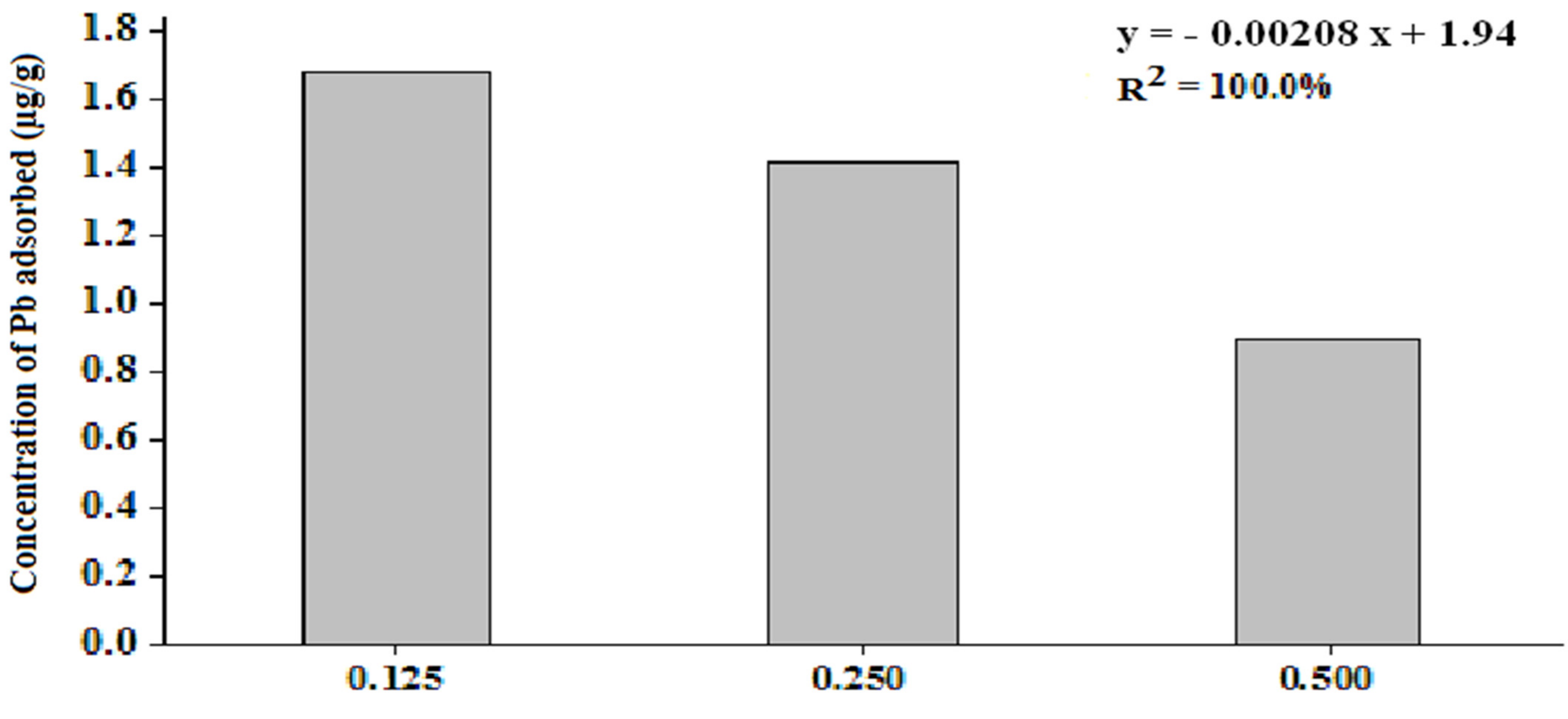
By the end of experiment, the results showed that the adsorption of Pb by *C. demersum* decreased with increasing metal concentration. The highest Pb adsorption was recorded at 0.125 µg/ml treatment and the lowest one was recorded with 0.500 µg/ml.



CONCLUSION

1) This investigation examined the efficiency of C. demersum, grown in a hydroponic system, in the removal of lead from contaminated solutions.

2) Comparing the concentrations of Pb accumulated in the plant tissue with that adsorbed onto its surface in the three treatments , it was observed that C. demersum can accumulate and adsorb high amount of Pb in concentration and duration dependent manner.

3) The average concentration of Pb absorbed by c. demersum increases as the concentration of Pb increases in the nutrient media whereas, the average concentration of the adsorbed Pb acquired the opposite trend.

CONCLUSIONS

6) The maximum Pb accumulated was achieved after 20 days while, the maximum adsorption was achieved after 10 days of the experiment. In all treatments, more than 50% of the Pb was removed by C. demersum after 20 days of the experiment.

7) Generally, methods using living plants to remove metals from water appear as alternative eco-friendly and cost effective process for water treatment. Moreover, C. demersum is a widely distributed, easily cultivated and controlled and is well adapted to contaminated environments.


Thanks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