Biosorption of Heavy Metal Lead from Aqueous Solution by Non-living Biomass of Sargassum myriocystum

D. Jeba sweetly¹, K. Sangeetha² and B. Suganthi³

¹Ph.D Scholar, Dept of Biotechnology, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.
²M.Phil Scholar, Dept of Biochemistry, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.
³Associate Professor, Dept of Biochemistry, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.

Abstract
The contamination of water by toxic heavy metal ions is a worldwide environmental problem. The increasing level of heavy metals in water represents a serious risk to human health and ecological systems. Lead (Pb) is one of the metals that are extremely toxic to organisms even at low concentration. It can damage the nervous system, gastrointestinal tract, encephalopathy with pretreatment damage, kidneys and reproductive system particularly in children. Biosorption a biotechnical innovation, inexpensive and reliable method to remove lead from the solution using non living marine macro algae as adsorbent. A batch experiment for the adsorption process was studied at different pH, temperature, biomass concentration and contact time. Sargassum myriocystum, the marine macro algae exhibited maximum adsorption efficiencies of lead uptake at pH 5 and temperature at 25°C. 2g of algae biomass were found to be optimum to remove 89.75% of lead with contact time of 60min. Results indicate that Sargassum myriocystum is considered as a potential adsorbent, ecofriendly and cost-effective approach for effluent treatment.

Keywords: Biosorption, Heavy metal, Macroalgae, Sargassum myriocystum

1. INTRODUCTION
Heavy metal pollution has become a major issue in many countries because their existence in drinking waters and waste waters often exceed the permissible standards [2]. Metal ions in the environment are bio-magnified in the food chain and are accumulated in tissues; therefore, toxic effects of heavy metals in particular are especially found in animals of higher trophic levels and also in human. Heavy metals discharged into the aquatic environment will be bound predominantly to suspended materials and finally accumulate in the sediment [14]. Lead (Pb) is one of the metals that are extremely toxic to organisms even at low concentration. It can damage the nervous system, gastrointestinal track, encephalopathy with pretreatment damage, kidneys and reproductive system particularly in children [1]. Various methods employed in the removal of heavy metals from industrial effluents include, chemical precipitation, membrane filtration, ion exchange, reverse osmosis, electro dialysis, solvent extraction, evaporation, oxidation, activated carbon adsorption [9]. However, these methods are often expensive and difficult to maintain due to high capital and operational costs, as well as, extra cost of treating the resultant sludge generated before disposal [7]. Biosorption involves using biological material to remove metal or metalloid species, compounds, and particulates from aqueous solution [17]. Marine algae commonly called seaweeds are considered as the best bioindicator of heavy metal pollution, which is considered as an environmental problem of worldwide concern. Of red, green and brown algae, brown algae have been found to have better sorption capacity [3]. But not much work has been done on the biosorption capacity of the species Sargassum myriocystum. Hence this species has been selected for the present study in order to explore its biosorption capacity for heavy metals, particularly in lead.

2. MATERIALS AND METHODS
Preparation of synthetic solution
Synthetic samples were prepared by dissolving analytical grade lead nitrate in 1 L of deionized water, with a concentration of 1000 mg/L. Solutions of varying concentrations as 25mg/L, 50 mg/L, 75 mg/L, 100 mg/L and 200 mg/L were prepared through dilution and were used in batch study. NaOH and HCl solutions were used for pH adjustments.

COLLECTION OF BIOMASS
Fresh samples of brown marine macro alga, *Sargassum myriocystum* were collected from Vedhalai (09°06'N; 78°08' E), Ramanathapuram District, Tamil Nadu. The species were authenticated at Central salt and marine chemical research institute, Mandapam, Ramanathapuram District, Tamil Nadu. The macroalgae samples were rinsed with distilled water for the removal of external salts and sand. The algae was dried at 60°C overnight and stored for future usage.

**PRETREATMENT OF BIOMASS**

Acid washing (orbital rotary shaker at 250 rpm, room temperature. 10g/L solid) allowed adsorbent protonation, which eliminates interference of biosorption by other cations such as Na⁺, K⁺, Mg²⁺ and Ca²⁺ [15]. Solid sample was then dried at room temperature for three to four days until a stable weight was observed. Sample was then shredded, and stored.

**BATCH STUDIES**

The sorption experiments were conducted in 250-mL Erlenmeyer flasks containing 100 mL of aqueous stock solution. The biosorption capacity of seaweed was determined by contacting various concentrations 25mg/L to 200mg/L of 100 ml of lead stock solution with seven different concentrations of seaweed biomass (1g to 7g) at different pH (2 to 7). Batch experiments were also carried out at different contact time (30minutes to 330minutes at 250 rpm) and different temperature range of 20–50 °C. The filtrate containing residual concentration of lead was determined by Atomic Absorption Spectrophotometer.

**DETERMINATION OF CADMIUM IONS IN THE SOLUTION**

Biosorption experiments were carried out in duplicate and average values were used in the analysis. The percent biosorption of metal ion was calculated as follows,

\[
\text{Biosorption (\%)} = \left(\frac{C_i - C_f}{C_i}\right) \times 100
\]  

Where:

- \(C_i\) = initial metal ion concentration, mg/L⁻¹
- \(C_f\) = final metal ion concentration, mg/L⁻¹

An atomic absorption spectrophotometer (Perkin- Elmer A Analyst 300) was used to determine the amount of Lead in aqueous solutions before and after the equilibrium was established. The hollow cathode lamp was operated for Lead.

**3. RESULTS AND DISCUSSION**

In the present study brown algae was used for the biosorption of Lead. The parameters affecting the biosorption were studied. The effect of each parameter was discussed below.

**EFFECT OF pH**

From the figure it evident that, as the pH increases (2 to 5) adsorption capacity increases and the maximum removal of 93.34% lead is observed at the pH 5. At pH higher than 5 the adsorption capacity decreases. The maximum uptake of lead by green algae *Cladophora fascicularis* was at pH 5.0 which is in accordance with our findings [8].

![Figure 1 Effect of pH on biosorption of Lead by Sargassum myriocystum](image)

In accordance with our finding [4] reported that *Laminaria hyperborea* and *Bifurcaria bifurcata* showed to be the most efficient biosorbents for lead (about 50 mg g⁻¹ uptake capacity, at pH 5) and *Sargassum muticum* and *Fucus spiralis* presented a relatively high uptake capacity for cadmium and zinc, particularly at pH 5.
EFFECT OF BIOMASS CONCENTRATION

From figure 2 it is evident that the biomass concentration of 2g has shown maximum removal of 89.75% of lead when compared to all other concentrations. The percentage uptake of lead by the biomass was found to be decreased gradually with increased concentration greater than 2g. Our results are in accordance with observation made by [16] in the uptake of lead by brown algae Sargassum filipendula.

According to [10] it has been suggested that electrostatic interactions between cells can be a significant factor in the relationship between biomass concentration and metal sorption. In this connection, at a given metal concentration, the lower the biomass concentration in suspension, the higher will be the metal/biosorbent ratio and the metal retained by sorbent unit, unless the biomass reaches saturation. High biomass concentrations can exert a shell effect, protecting the active sites from being occupied by metal. The result of this is a lower specific metal uptake, that is, a smaller amount of metal uptake per biomass unit.

![Figure 2 Effects of biomass concentration on biosorption of Lead by Sargassum myriocystum](image)

EFFECT OF CONTACT TIME

From figure 3 it is observed that maximum sorption 91.73% took place in 60 min. [12] observed that 90% of total adsorption of lead, copper, cadmium, zinc and nickel occurred within 60 minutes by the marine algae, Sargassum sp., Ulva sp. Gracilaria from dilute aqueous solutions. According to [11] contact time of 1 hr is optimum for the biosorption of lead metal ion from industrial effluents using macro algae, Caulerpa fastigiata.

![Figure 3 Effects of contact time on biosorption of Lead by Sargassum myriocystum](image)
EFFECT OF TEMPERATURE
From figure 4 it is clear that the maximum uptake of 86.67% lead was obtained after which there was a decrease in the sorption capacity indicating that 25°C is the optimum temperature for maximum biosorption.

The temperature profile indicates that as the temperature increases the sorption capacity increases to a maximum value and then decreases. This is because the biosorbent loses its properties at very high temperatures due to denaturation [6]. The present study also reveals the same that, as the temperature increases the adsorption capacity decreases.

EFFECT OF INITIAL CONCENTRATION OF LEAD
The sorption of metals on Sargassum myriocystum biomass increases as the initial metal ion concentration increase from 25 mg/L to 200 mg/L, indicating that biosorption is even favorable for the higher initial metal ion concentrations. The biosorption process is favorable for metal ion removal at all concentration investigated.

CHARACTERIZATION OF BIOSORBENT
SCANNING ELECTRON MICROSCOPE (SEM)
In general characterization of biosorbents by Scanning Electron microscope (SEM) offers topographical and elemental information of solids with a virtually large depth of field, allowing different specimen parts to stay in focus at a time.
SEM has a high resolution, making higher magnification possible for closely spaced materials. In the present study, surface morphology of control, pretreated and biosorbed algae were observed using Scanning Electron Microscope.

![Figure A](image1.png)

![Figure B](image2.png)

![Figure C](image3.png)

**Figure A- Normal algae, B- pretreated algae and C- Algae after Biosorption.**

Fig C shows that after biosorption morphological changes occur, probably it may due to the exposure of heavy metal to the algae. It is clear that the lead has been sorbed on the active sites of the biosorbent. It is evident from the figure that the pretreated biomass presents an uneven, compacted structure crossed by large canals, so it confirms the effective adsorption of lead by observing difference in surface morphology of biosorbent before and after biosorption.

**FOURIER TRANSFORMATION INFRARED SPECTROSCOPY (FTIR)**

The pretreated and biosorbed algal biomass samples were analysed using Fourier transform infrared spectroscopy. The algal biomass samples were encapsulated in KBr at a ratio of 1:100. The IR spectrum was collected using a Perkin-Elmer Spectrometer within the range 400-4000cm$^{-1}$.

![Fig A Biomass before biosorption](image4.png)
In Fig A (Pretreated) the peaks corresponding to the functional groups of seaweed biomass showed some vibration frequency changes after treatment with the lead ions, which is observed in the Fig B (biomass after lead sorption).

In Figure B the peaks at 3842.20 \(\text{cm}^{-1}\) corresponds to the C-H, O-H, N-H groups, 601.79 \(\text{cm}^{-1}\) corresponds to C-Cl groups are disappeared suggesting that C-H, O-H, N-H and C-Cl groups are involved in the biosorption process. The absorption peak at 3425.58 corresponds to the –OH groups shifted to 3448.72 \(\text{cm}^{-1}\), 1527.62 corresponds to the –N=O groups shifted to 1535.34 \(\text{cm}^{-1}\), 1450.47 corresponds to the –C=C groups shifted to 1458.18, 1095.57 corresponds to the C-N groups shifted to 1273.02 \(\text{cm}^{-1}\), indicating that these groups are involved in the biosorption process. The new peak at 1103.28 \(\text{cm}^{-1}\), 810.10 \(\text{cm}^{-1}\), 717.52 \(\text{cm}^{-1}\) corresponds to the C-O and C-H groups appeared suggesting that these groups are involved in the biosorption process.

FTIR technique proved to be an efficient tool for detecting structural changes and probable binding sites induced by the presence of a metal pollutant, cadmium, in the marine environment [13]. Lead adsorption showed a strikingly deeper trough at 1384.5 \(\text{cm}^{-1}\) indicating possible binding to the nitro N=O stretching. These identified regions may be indicative of functional groups responsible for the individual metal-binding activity of the adsorbent apart from the groups indicated in previous studies [5].

4. CONCLUSION
The biomass of brown algae *Sargassum myriocystum* was found to be a potential low-cost adsorbent for the removal of lead from aqueous solution. Based on the results obtained, it can be concluded that the dried biomass of *Sargassum myriocystum* has high affinity towards the heavy metal particularly Lead. Hence this property can be effectively utilized for the removal of the heavy metals from the various industrial wastes containing heavy metals.

REFERENCES

AUTHOR
D. Jeha Sweetly doing Ph.D Biotechnology in Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamilnadu, India. She has completed M.sc and M.phil degree in Biotechnology in 2009 and 2012, respectively. She has attented many International and National Conferences.