Biosorption of Nickel from Electroplating Wastewater using Green Algae Volvox

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Abstract
Of all the forms of water pollution, heavy metal pollution is the most hazardous as the pollutant is present in mobilized form. The ability of green algae volvox to biosorb nickel ions was investigated in batch mode so that it may be applied for the treatment of industrial wastewaters. The batch studies provide significant information regarding biosorption of nickel on green algae volvox in terms of pH and biomass dose for maximum removal of Ni(II) from the aqueous solution. The studies indicated that volvox is an effective biosorbent for Ni(II) removal. The maximum biosorption capacity was found to be 35.71 mg Ni(II)/g at an algal dose of 1g/L in 60 min of contact time with initial Ni(II) concentration of 100 mg/L and optimum pH of 4. The equilibrium studies in batch systems were described by Thomas and Freundlich isotherms. Best fit was obtained for both the isotherm models.

It was found that the adsorption equilibrium data fitted well to the Langmuir model. With the advantage of high metal biosorption capacity, the biomass of volvox has the potential to be used as an efficient and economic biosorbent material for the removal of chromium from electroplating industrial wastewater.

Keywords: Electroplating wastewater, Volvox, Biosorption, Nickel(II).

Introduction
The presence of heavy metals in water ecosystems has become a problem due to their harmful effects on human health and aquatic life even at low concentrations in the environment[3,7,9]. It is recognized that finding methods for removal of heavy metals from aqueous water is of great importance. Nickel is one such heavy metal which is present in the industrial effluents. Various methods used for removal of Ni(II) ions include chemical reduction and precipitation, reverse osmosis, ion exchange and adsorption on activated carbon or similar material[8,13]. The application of these treatment processes to low metal concentration wastewater is sometimes restricted due to technological or economical reasons[11,12].

Biological methods such as biosorption for the removal of heavy metal ions may provide an attractive alternative to physico-chemical methods[10]. Biosorption process offers the advantages of low operating costs, possibility of metal recovery, potential biosorbent regeneration, minimization of the volume of chemical and biological sludge to be disposed of and high efficiency in detoxifying very dilute liquid streams. Use of various algal biomasses has been investigated as biosorbent materials for metal removal[1,2,4-6]. Volvox, a genus of chlorophytes, a type of green algae, is widely distributed in variety of freshwater habitats ponds and ditches, even in shallow puddles, in many parts of the world.

The utilization of volvox as an efficient and cost-effective biosorbent is of much interest and promising. In this work, biosorption features of Volvox Sp. to remove Ni(II) ions from electroplating industrial wastewater were investigated as a function of contact time, pH, algal dosage and initial Ni(II) concentration. The kinetics was obtained from batch experiments. The removal mechanism was discussed by analyzing the concentration of Ni(II) and total nickel in the solution.

Material and Methods
Chemicals and Equipment: All the reagents used were of AR grade. Standard acid and base solutions (0.1N HCl and 0.1N NaOH) were used for pH adjustments. pH measurements were made using a pH meter. Nickel ions were determined spectrophotometrically by atomic adsorption spectrophotometer.

Collection of Biomass and Preparation of Biosorbent: Fresh algal biomass was collected from nearby fresh water pond. The collected biomass samples were washed with water to remove dirt and adherent particles. The biomass was placed in $CaCl_2$ solution for 30 minutes and then the contents were filtered. Then they were oven dried at 80˚C for 1 day and they were shredded to finer particles.

Batch adsorption experiments: The adsorption features of the biosorbent volvox were investigated as a function of initial pH, initial heavy metal concentration, biosorbent dose and contact time. The equilibrium and kinetics were obtained from batch experiments, using 250mL flask containing 100mL of heavy metal solutions kept at room temperature (298˚K). Batch adsorption experiments were conducted in triplicate and the average results are reported.

All the adsorption experiments were conducted in an incubator shaker at 150rpm. After desired contact time, flasks were removed and allowed to stand for two minutes. The solution was filtered through whatmann filter paper no. 44 and filtrate was analyzed for Ni(II) concentration in Atomic Absorption spectrophotometer.

Results and Discussion

Effect of contact time: Fig. 1 shows the effect of contact time on the extent of adsorption of chromium on algal biomass, i.e. volvox sp. It has been observed that maximum adsorption took place within first 60 min. The biosorbent showed 77.9% of zinc removal from 100mg/L solution at a contact time of 60 minutes. The data obtained from this experiment was further used successfully to evaluate the kinetics of the adsorption process.

Influence of biosorbent dose: The experiment was conducted with 100 mg/L solution of Ni(II) for optimum contact time, the algal dosage was varied from 0.25 to 2.0 g/L in 100 mL metal solution. The removal percentage of Ni(II) as a function of adsorbent dosage was shown in fig. 2. It was apparent that the removal percentage of Ni(II) increased rapidly with increasing algal biomass due to the greater availability of the biosorbents. Specific removal capacity is a measure of the amount of Ni(II) bound by unit weight of sorbent. The competition of the ions for the available sites caused decrease in the specific removal capacity with increment in adsorbent dosage. The optimum algal dosage was found to be 1g/L.

Effect of pH: It is well known that pH could affect the protonation of the functional groups on the biomass as well as on the metal chemistry. The effect of pH on Ni(II) removal by volvox sp. was studied at optimized adsorbent dose and contact time by varying pH from 2.0-7.0 (Fig. 3). As the pH of the nickel solution increased from 2.0 to 7.0, the adsorption capacity of chromium was changed i.e. it first increased and then dramatically decreased up to pH 7.0. At pH higher than 7, the precipitation of insoluble metal hydroxides takes place restricting the true biosorption studies. The results showed strong pH dependence of biosorption.

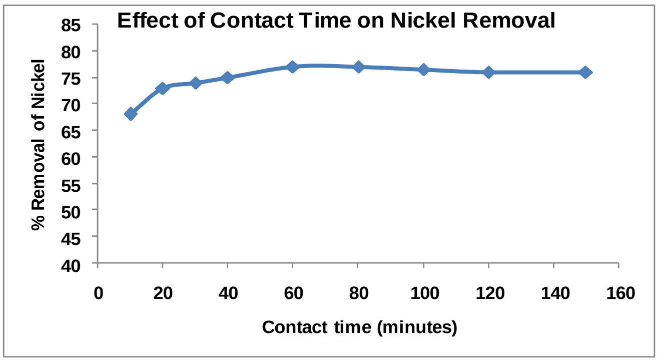

Figure 1: Effect of Contact Time

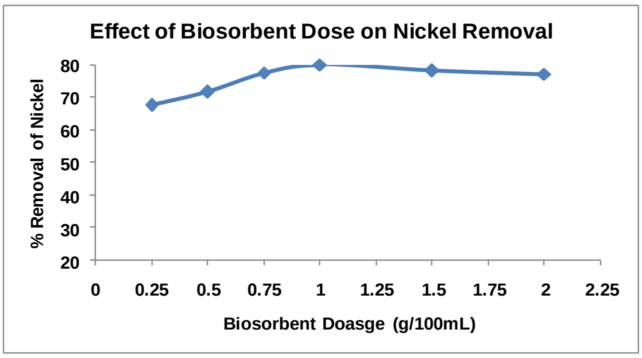

Figure 2: Effect of Biosorbent Dose

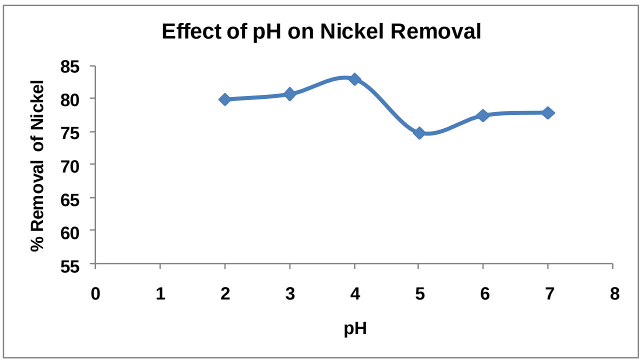

Figure 3: Effect of pH

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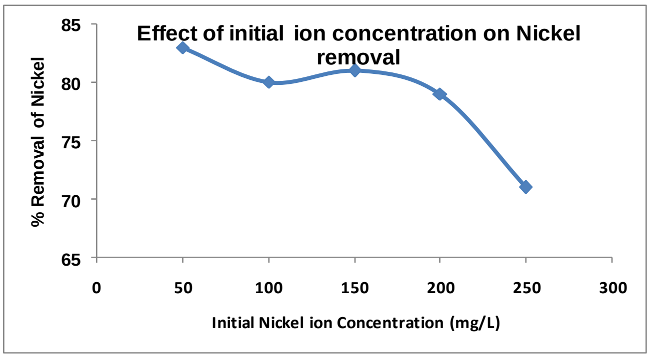

Figure 4: Effect of Initial ion Concentration

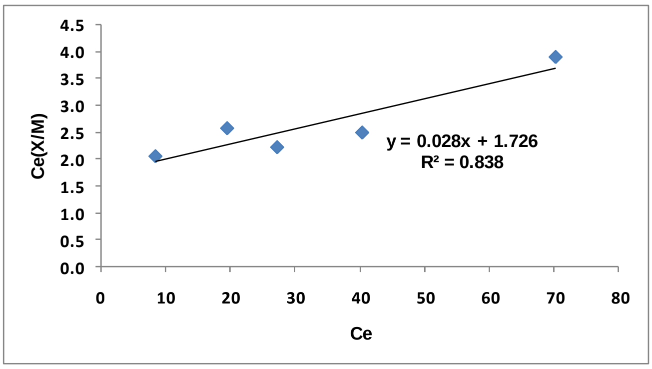

Figure 5: Langmuir Isotherm

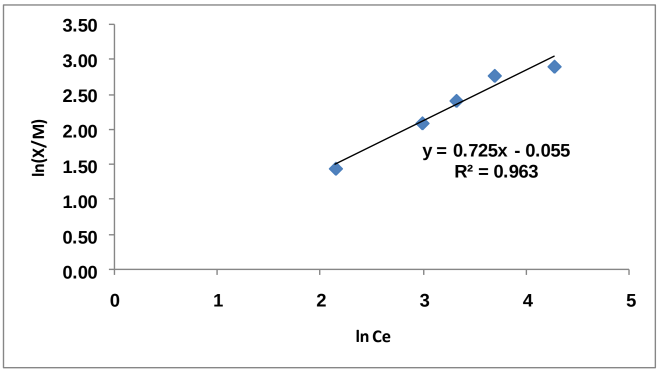

Figure 6: Freundlich Isotherm

Table 1
Langmuir and Freundlich Isotherm Constants

Isotherm Model	Parameters	Value
Langmuir	q_{max} (mg/g)	35.71
	b (L/mg)	0.016
	R^2	0.838
Freundlich	K_f	0.946
	n	1.37
	R^2	0.963

Effect of initial Ni(II) ion concentration: Effect of initial Ni(II) ion concentration on its removal was carried out at optimized adsorbent dose, contact time and pH by varying the metal ion concentration from 20-100 ppm (Fig. 4). Adsorption of Ni(II) was found to decrease with increase in metal ion concentration. This is due to increase in number of metal ions competing for available binding sites and due to lack of binding sites at higher metal ion concentration. At lower concentration, almost all the metal ions could interact with binding sites facilitating maximum adsorption at 20 ppm concentration i.e. 82.5%. Maximum Ni(II) removal was observed at 20 ppm concentration. At higher concentration more nickel ions are left unadsorbed in the solution due to saturation of adsorption sites.

Biosorption isotherm models: The Langmuir and Freundlich isotherm models were used for the mathematical description of Ni(II) ions biosorption and isotherm constants were determined. The Langmuir isotherm model assumes a monolayer adsorption onto a surface containing finite number of identical sites. Freundlich isotherm is used for modeling the adsorption on heterogeneous surfaces. The plots of non-linearized Langmuir and Freundlich adsorption isotherms were shown in fig. 5 and 6. The Langmuir and Freundlich adsorption constants evaluated from the isotherms with the correlation coefficients are also presented in table 1. The correlation regression coefficients show that the biosorption process is better defined by Langmuir than by Freundlich equation.

Conclusion

The batch studies conducted in the present study provide significant information regarding biosorption of nickel on green algae volvox species in terms of optimum pH and biomass dose for maximum removal of Ni(II) from the aqueous solution. The studies indicated that volvox species is an effective biosorbent for Ni(II) removal. The maximum Ni(II) biosorption capacity has been found to be 35.71 mg Ni(II)/g of dry weight of biomass at an algal dose of 1g/L in 60 min of contact time with initial Ni(II) concentration of 100 mg/L and optimum pH of 4.

The Langmuir and Freundlich adsorption model were used for the mathematical description of the biosorption of Ni(II) ions onto algal biomass and it was found that the adsorption equilibrium data fitted well to the Langmuir model. With the advantage of high metal biosorption capacity, the biomass of volvox has the potential to be used as an efficient and economic biosorbent material for the removal of chromium from electroplating industrial wastewater.

References

1. Al-Homaidan A.A., Al-Qahtani H.S., Al-Ghanayem A.A., Ameen F. and Ibraheem I., Potential use of green algae as a biosorbent for hexavalent chromium removal from aqueous solutions, *Saudi J. Biol. Sci.*, **25(8)**, 1733 **(2018)**

2. Ali Ali Redha, Removal of heavy metals from aqueous media by biosorption, *Arab J. Basic Appl. Sci.*, **27(1)**, 183 **(2020)**

3. Dulla J.B., Tamana M.R. and Boddu S., Biosorption of copper(II) onto spent biomass of Gelidiella acerosa (brown marine algae): optimization and kinetic studies, *Appl. Water Sci.*, **10**, 56 **(2020)**

4. El-Wakeel, Shaimaa Moghazy, Reda Labena A. and Husien Shimaa, Algal biosorbent as a basic tool for heavy metals removal; the first step for further applications, *J. Mater.Environ.Sci.*, **10**, 75 **(2019)**

5. Gupta Asha, Yadav Reena and Devi Parmila, Removal of hexavalent chromium using activated coconut shell and activated coconut coir as low cost adsorbent, *The IIOAB J.*, Special issue on Frontiers in Industrial Microbiology and Environmental Biotechnology, **2(3)**, 8 **(2011)**

6. Gonzalez, Felisa Romera García, Esther Ballester, Antonio Blázquez, Maria Luisa Muñoz, Jesús García-Balboa and Camino, Algal Biosorption and Biosorbents, Microbial Biosorption of Metals, Springer **(2011)**

7. Hazrat Ali, Ezzat Khan and Ikram Ilahi, Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity and Bioaccumulation, *J. Chem.*, https://doi.org/10.1155/2019/6730305 **(2019)**

8. Liping Deng, Yang Zhang, Jie Qin, Xinting Wang and Xiaobin Zhu, Biosorption of Cr(VI) from aqueous solutions by nonliving green algae Cladophora albida, *Miner. Eng.*, **22**, 372 **(2009)**

9. Modher A. Hussain, Aishah Salleh and Pozi Milow, Characterization of the Adsorption of the Lead (II) by the Nonliving Biomass Spirogyra neglecta (Hasall) Kutzing, *Am. J. of Biochem. Biotechnol.*, **5(2)**, 75 **(2009)**

10. Parameswari E., Lakshmanan A. and Thilagavathi T., Effect of pretreatment of blue green algal biomass on bioadsorption of chromium and nickel, *J. Algal Biomass Util.*, **1(1)**, 9 **(2009)**

11. Quintelas C., Fernandes B., Castro J., Figueiredo H. and Tavares T., Biosorption of Cr(VI) by a Bacillus coagulans biofilm supported on granular activated carbon (GAC), *Chem. Eng. J.*, **136**, 195 **(2008)**

12. Sabino De Gisi, Giusy Lofrano, Mariangela Grassi and Michele Notarnicola, Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review, *Sustain. Mater. Techno.*, **9**, 10 **(2016)**

13. Singh Jiwan and Kalamdhad Ajay S., Effects of Heavy Metals on Soil, Plants, Human Health and Aquatic Life, *Int. J. Res. Chem. Environ.*, **1(2)**, 15 **(2011)**.

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