Chemical Engineering Journal 200–202 (2012) 365–372

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Valorisation of marine *Pelvetia canaliculata Ochrophyta* for separation and recovery of nickel from water: Equilibrium and kinetics modeling on Na-loaded algae

Amit Bhatnagar, Vítor J.P. Vilar *, João C. Santos, Cidália M.S. Botelho, Rui A.R. Boaventura

LSRE – Laboratory of Separation and Reaction Engineering, Associate Laboratory LSRE/LCM, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal

HIGHLIGHTS

- ▶ Biosorption of Ni^{2+} on Na-loaded brown algae was investigated.
- ▶ Biosorption involved ion-exchange between Na and Ni ions with stoichiometry 2:1.
- ▶ Nickel showed higher affinity to sulfonic groups of algae biomass.
- ▶ Hydrogen ions diffuse faster as compared to nickel and sodium ions.

ARTICLE INFO

Article history:
Received 28 April 2012
Received in revised form 16 June 2012
Accepted 18 June 2012
Available online 26 June 2012

Keywords:
Biosorption
Nickel
Algae
Mass transfer model
Ion exchange

ABSTRACT

In the present study, biosorption of Ni^{2+} by Na-loaded (raw algae treated with NaCl), algae *Pelvetia canaliculata Ochrophyta*, was studied in a batch system. Kinetics and equilibrium experiments were conducted at different pH values (2.0, 3.0 and 4.0). The metal uptake capacity decreased by decreasing the solution pH, suggesting that competition exists between hydrogen ions, present in high concentrations at low pH values, and metal ions. An ion-exchange model, considering two different binding sites, sulfonic and carboxylic groups, was developed to describe equilibrium data. A mass transfer model, considering intraparticle resistance was also developed to describe kinetics in a batch system. The release of sodium ions during the uptake of nickel ions revealed that the biosorption mechanism involved ion-exchange between sodium and nickel ions with a stoichiometrical ratio of 2:1. Nickel showed higher affinity to the sulfonic groups than for carboxylic ones of algae biomass. Kinetic results show that hydrogen ions diffuse faster as compared to nickel and sodium ions. The maximum uptake capacity of Na-loaded algae, *P. canaliculata*, for Ni^{2+} was found to be ca. 100 mg/g at pH 4.0.

1. Introduction

Heavy metals pose a serious threat to biota, due to their acute toxicity, non-biodegradable nature and biomagnification in the food chain. The presence of heavy metals in aqueous streams causes harmful effects on human health and also on the flora and fauna of receiving water bodies [1]. Removal and recovery of heavy metals is very important with respect to environmental and economical considerations. Increasingly strict discharge limits for heavy metals have also accelerated the search for highly efficient yet economical attractive treatment methods for their removal.

Ni^{2+} is one such heavy metal frequently found in wastewater streams from several industries such as electroplating, battery manufacturing, mineral processing, steam–electric power plants, and paint formulation [2]. Ni^{2+} has been classified as "essential" metal and is identified as a component in a number of enzymes, participating in important metabolic reactions, such as ureolysis, hydrogen metabolism, methane biogenesis, and acidogenesis [3]. However, excess intake of Ni^{2+} over the permissible levels results in different types of health problems such as pulmonary fibrosis, renal edema, skin dermatitis, and gastrointestinal distress (e.g., nausea, vomiting, diarrhea) [3]. The World Health Organization (WHO) requires nickel in drinking water not to exceed 0.5 mg/L [4]. Nickel complexes are least stable and therefore, nickel removal is generally difficult as compared to other heavy metals. According to the "hard–soft–acid–base" theory, nickel is an "intermediate" metal that forms less stable complexes, mainly by weaker ionic bonding [5,6]. It is therefore, essential to remove Ni^{2+} from wastewater before final disposal.

* Corresponding author. Tel.: +351 918257824; fax: +351 225081674.
E-mail address: vilar@fe.up.pt (V.J.P. Vilar).

1385-8947/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2012.06.071