Applied Water Science (2020) 10:80
https://doi.org/10.1007/s13201-020-1163-x

ORIGINAL ARTICLE

Ammoniacal nitrogen removal by *Eichhornia crassipes*-based phytoremediation: process optimization using response surface methodology

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Received: 27 November 2018 / Accepted: 18 February 2020 / Published online: 28 February 2020
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Abstract

Eutrophication is a serious environmental issue that needs urgent concern. There is necessity to treat wastewater with high ammoniacal nitrogen (AN) concentration to the permissible standard limit to protect the aquatic ecosystem. This study investigated the optimum condition for AN removal from wastewater using *Eichhornia crassipes*-based phytoremediation process. Face-centered central composite design (CCD) was employed as the experimental design, in which four operational variables including pH (4–10), retention time (2–14 days), macrophyte density (5–30 g/L) and salinity (0–5 g NaCl/L) were involved in the study, while five responses were investigated, namely AN removal efficiency (Y_1), fresh biomass growth (Y_2), COD (Y_3), BOD (Y_4) and TSS (Y_5). AN removal was the main focus in this study. Through numerical optimization, the highest AN removal efficiency of 77.48% (initial AN concentration = 40 mg/L) was obtained at the following optimum condition: pH 8.51, retention time of 8.47 days, macrophyte density of 21.39 g/L and salinity of 0 g NaCl/L. The values predicted from the models agreed satisfactorily with the experimental values, which implied that response surface methodology was reliable and practical for experimental design developed using optimization of the phytoremediation process. The validation experiment using real semiconductor effluent further supported the high potential of the *E. crassipes*-based phytoremediation system to remove AN and other organic pollutants in this industrial effluent under optimal condition.

Keywords Wastewater treatment · Water hyacinth · Phytoremediation · Optimization · Ammoniacal nitrogen

Introduction

Semiconductor industry is recognized as one of the fastest growing industries due to the high global demand of electronic products (Huang et al. 2017). Semiconductor manufacturing processes are complex which include silicon growth, oxidation, doping, photolithography, etching, stripping, dicing, metallization, planarization, cleaning (Wong et al. 2013). During semiconductor manufacturing processes, a vast amount of water is consumed in chemical mechanical polishing (CMP) process for planarizing the surface of the silicon wafer, thus producing a huge quantity of wastewater containing both organic and inorganic pollutants (Nur Farehah et al. 2014). Ammoniacal nitrogen (AN) is one of the major pollutants present in semiconductor wastewater. High AN concentration in waterbodies will induce eutrophication, which subsequently contribute to oxygen-level reduction and aquatic species loss (Xiang et al. 2015). In Malaysia, AN concentration in industrial effluent is necessary to be treated to comply with standard discharge limit of 20 mg/L as stipulated by the Environmental Quality Regulations 2009. However, existing AN removal technologies are found to be inefficient and inadequate, thus contributing to high AN content in semiconductor effluent ranging from 40 to 250 mg AN/L (Aoudj et al. 2017). In order to overcome the aforementioned issue, there is an urge to look for an alternative solution which is accomplished with sustainable and cost-effective characteristics, especially in developing countries including Malaysia.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s13201-020-1163-x) contains supplementary material, which is available to authorized users.

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