Chemical Engineering Journal 220 (2013) 221–227

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

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

Filtration of engineered nanoparticles in carbon-based fixed bed columns

Mandu Inyang [a], Bin Gao [a,*], Lei Wu [a], Ying Yao [a], Ming Zhang [a], Lin Liu [a,b]

[a] Department of Agricultural and Biological Engineering, University of Florida, Gainesville, FL 32611, United States
[b] School of Environmental Science and Engineering, Donghua University, Shanghai 201620, China

HIGHLIGHTS

- Iron-impregnation improved removal ability of carbons to ENPs.
- Iron-impregnation biochar was the best filter material for ENPs.
- CNT showed high mobility in all the carbon-enabled filters.

ARTICLE INFO

Article history:
Received 5 December 2012
Received in revised form 15 January 2013
Accepted 17 January 2013
Available online 26 January 2013

Keywords:
Biochar
Carbon
Nanoparticles
Sorption
Filtration
Transport

ABSTRACT

Widespread applications of engineered nanoparticles (ENPs) have raised concerns over their occurrences in the environment. In this work, laboratory experiments and mathematical modeling were conducted to determine whether carbon materials could be used to remove 3 ENPs: silver nanoparticles (AgNPs), carbon nanotubes (CNTs), and titanium dioxide ($NTiO_2$) from water. Hickory chips biochar (HC) and activated carbon (AC) were used and the two carbons were modified with iron impregnation to enhance their affiliation to the ENPs. Results from batch sorption experiments showed that all the carbon sorbents could sorb the ENPs in aqueous solutions and the iron modification improved their sorption ability. When the carbons were packed in sand columns, however, the unmodified carbon showed little removal efficiency to the ENPs, no better than the sand media. Similarly, the columns enabled with iron-modified carbons had better filtration ability to the ENPs, particularly to $NTiO_2$ and AgNP. Among all the carbons, the iron-modified biochar was the best in filtering all the ENPs. Simulations from a model based on the advection-dispersion equation matched the filtration and transport of ENPs in the columns well. The DLVO theory also accurately described the interaction between the ENPs and the carbon materials. Findings from this study indicate that biochar, particularly after modification, can be used as a low-cost filter material to remove ENPs from water.

1. Introduction

Engineered nanoparticles (ENPs) have become the foundation of a novel brand of technology, impacting new consumer products, manufacturing techniques, and material usages [1]. This can be attributed to their intrinsic properties, such as high surface area to volume ratio, small size (1–100 nm), and unsaturated surface atoms that readily bind to other atoms [2,3]. In addition, most ENPs exhibit various quantum effects such as resonance, optical properties, mechanical strength, thermal and electrical conductivity that can be exploited in the development of various household and industrial applications [4]. The projected global demand for nano-material products is expected to reach $1 trillion dollars in 2015 [4,5], which will increase loadings of ENPs to the environment and pose a risk to soil and groundwater systems.

ENPs may be released into the environment from both point sources (e.g., production facilities, landfills, and wastewater treatment plants) and non-point sources (e.g., accidental spills and wear from ENP products) [4]. As a result, the occurrences of ENPs in aquatic systems, particularly from municipal discharges and wastewater treatment plants, have been reported in several recent studies [6–8]. Because of the potential toxic effect of ENPs to the aquatic environment and ecosystem [9–11], it is crucial to develop cost-effective treatment technologies to remove them from water systems. To our knowledge, however, only little research has been conducted to study the removal of aqueous ENPs, particularly with respect to evaluating the removal ability of carbon-based filters to ENPs in aqueous solutions.

* Corresponding author. Tel.: +1 352 392 1864x285.
E-mail address: bg55@ufl.edu (B. Gao).

1385-8947/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2013.01.054