Journal of Environmental Chemical Engineering 3 (2015) 2331–2341

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

Removal of phosphate using chitosan-polymer composites

A. Rajeswari, Augustine Amalraj, Anitha Pius*

Department of Chemistry, The Gandhigram Rural Institute, Deemed University, Gandhigram, Dindigul, Tamil Nadu, 624 302, India

ARTICLE INFO

Article history:
Received 12 May 2015
Accepted 26 August 2015
Available online 2 September 2015

Keywords:
Chitosan
Polyvinyl alcohol
Polyethylene glycol
Phosphate
Adsorption

ABSTRACT

In the present study, removal of phosphate ions using polyethylene glycol/chitosan and polyvinyl alcohol/chitosan composites was investigated. The polyethylene glycol/chitosan and polyvinyl alcohol/chitosan composites were found to be effective for the removal of phosphate anions. The prepared adsorbents were characterized by scanning electron microscopy (SEM), energy dispersive analysis of X-rays (EDAX), Fourier transform infra-red (FTIR) and X-ray diffraction (XRD). The removal of phosphate has been found to be dependent on contact time and pH. Adsorption isotherm studies indicated that polymer composites satisfy Langmuir and Freundlich models. The rate of reaction follows pseudo-second-order kinetics. The results of the study indicated that polyethylene glycol/chitosan and polyvinyl alcohol/chitosan composites are useful materials for the removal of phosphate from aqueous solution.

Introduction

Drinking water collected from wells, rivers and ponds is contaminated by various nutrients and phosphate is one of them. Phosphates are irreplaceable for human health and for all living organisms. It is essential for the development of bones, teeth, genes, proteins and for biological cycling of energy as well as for photosynthesis. Sources of phosphates to surfaces waters include agriculture (fertilizers, animal manures, and run-off), animal wastes, human sewage, food wastes, urban run-off, vegetable matter, industry and detergents. Agriculture is a main source of phosphates and inadequately treated sewage also continues to be a significant source of phosphate, whereas detergents are a minor contributor [1]. Detergent phosphates have thus been estimated to contribute to only 3–7% of total phosphate inputs to surface waters [2]. The only concern about phosphates is "eutrophication": because phosphates are a key nutrient for plants, too much phosphate in water can lead to excessive growth of plants and algae ("phytoplankton") [3]. The removal of phosphate from drinking waters may be achieved by applying several physical and chemical methods, such as ion exchange, extraction, flotation, coagulation, electro-deposition and precipitation [4,5].

However, most of these methods are considered non-viable due to the cost factor. Adsorption technique has been considered as one of the most effective and economical methods for the removal of pollutants from aqueous solutions [6,7]. In recent years, a variety of adsorption materials have been reported in the literature for their capacity to remove anions from aqueous solutions, e.g. activated carbon [8], bottom ash [9], zeolite [10], silica gel [11], and various resins [12]. Chitosan (1,4-linked-2-amino-2-deoxy-β-D-glucan) is one of the most abundant polysaccharides, which is derived from chitin. Since it is inexpensive, non-toxic and possesses potentially reactive amino functional groups, chitosan has been evaluated for numerous applications, including medicine, food, cosmetics and wastewater treatment [13–17].

In recent years, polymer blending has become a method for providing polymeric materials with desirable properties for practical applications. In particular, chitosan blended with polyvinyl alcohol (PVA) has been reported to have good mechanical and chemical properties and, as a topic of great interest, has been extensively studied in the biomedical field. The enhanced property has been attributed to the interactions between PVA and chitosan in the blend through hydrophobic side chain aggregation and intermolecular and intramolecular hydrogen bonds. The adsorption properties and mechanisms of the PVA and chitosan blend for metal removal have however seldom been studied [18]. Polyethylene glycol (PEG) has been widely used because of their biocompatibility and minimal toxicity and good solubility in water or other common solvents. PEG and chitosan hydrogel can swell extensively due to the positive charges on the network and in response to changes in the pH of the medium. It is reported already that it is possible to improve adsorption properties of chitosan through the formation of blends with PEG [19]. But the blends were not tested for environmental applications so far.

In the present study chitosan composites were prepared with polyvinyl alcohol and polyethylene glycol and studied the morphology. The suitability of the prepared composites for the

* Corresponding author. Tel.: +91 451 2452371; fax: +91 451 2454466.
E-mail address: dranithapius@gmail.com (A. Pius).

http://dx.doi.org/10.1016/j.jece.2015.08.022
2213-3437/

removal of phosphate from aqueous solutions was evaluated under different experimental conditions and the kinetics of phosphate removal was also studied. Perusal of literature does not show a study has been carried out for the removal of phosphate from water using PEG/chitosan and PVA/chitosan composites.

Materials and methods

Materials required

Chitosan with a degree of deacetylation of 90% (80 meshes) was purchased from Pelican biotech and chemicals and laboratory, Kerala. Polyethylene glycol (PEG), polyvinyl alcohol (PVA) (with a degree of polymerization of 1750), $CaCO_3$, HCl and potassium dihydrate phosphate were purchased from Sigma Aldrich, Mumbai, India. Stock solution of phosphate from potassium dihydrate phosphate was prepared by dissolving an appropriate amount of substance in Millipore water.

Preparation of PEG/chitosan and PVA/chitosan composites

PEG/$CaCO_3$ and PVA/$CaCO_3$ powder were added to 150 ml distilled water and blended by a mechanical stirrer in a boiling water bath for 2 h. Then chitosan was introduced to the above solution, shaken at 80 °C for 6 h. The obtained mixture was cooled to room temperature, HCl (5 M) was added to the solution and the mixture was stirred vigorously to dissolve $CaCO_3$ and to produce CO_2 gas bubbles, finally it was filtered, dried and the material obtained was used as adsorbent. The above mentioned procedure was followed for the preparation of PVA/chitosan composites. The mixed solution of PEG/$CaCO_3$/chitosan and PVA/$CaCO_3$/chitosan was prepared according to the following weight ratios: 10/5/2, 10/5/4, 10/5/6, 10/5/8 and 10/5/10. The ratio10/5/10 was fixed taking into consideration it good adsorption capacity.

Adsorbent characterization

The surface morphology and elemental composition of the adsorbent before and after adsorption was analyzed by scanning electron microscopy (SEM) and Energy dispersive analysis of X-rays (EDAX). The IR spectra of the adsorbent before and after adsorption were recorded by a Fourier transform infrared spectrometer and also were characterized by X-ray diffraction patterns (XRD).

Adsorption experiments

Adsorption experiments were carried out by batch study. About 0.1 g of the polymer composite adsorbent [polyethylene glycol/chitosan and polyvinyl alcohol/chitosan] was added to 50 ml of 10 mg L^{-1} adsorbate stock solution. Mixture was shaken by a

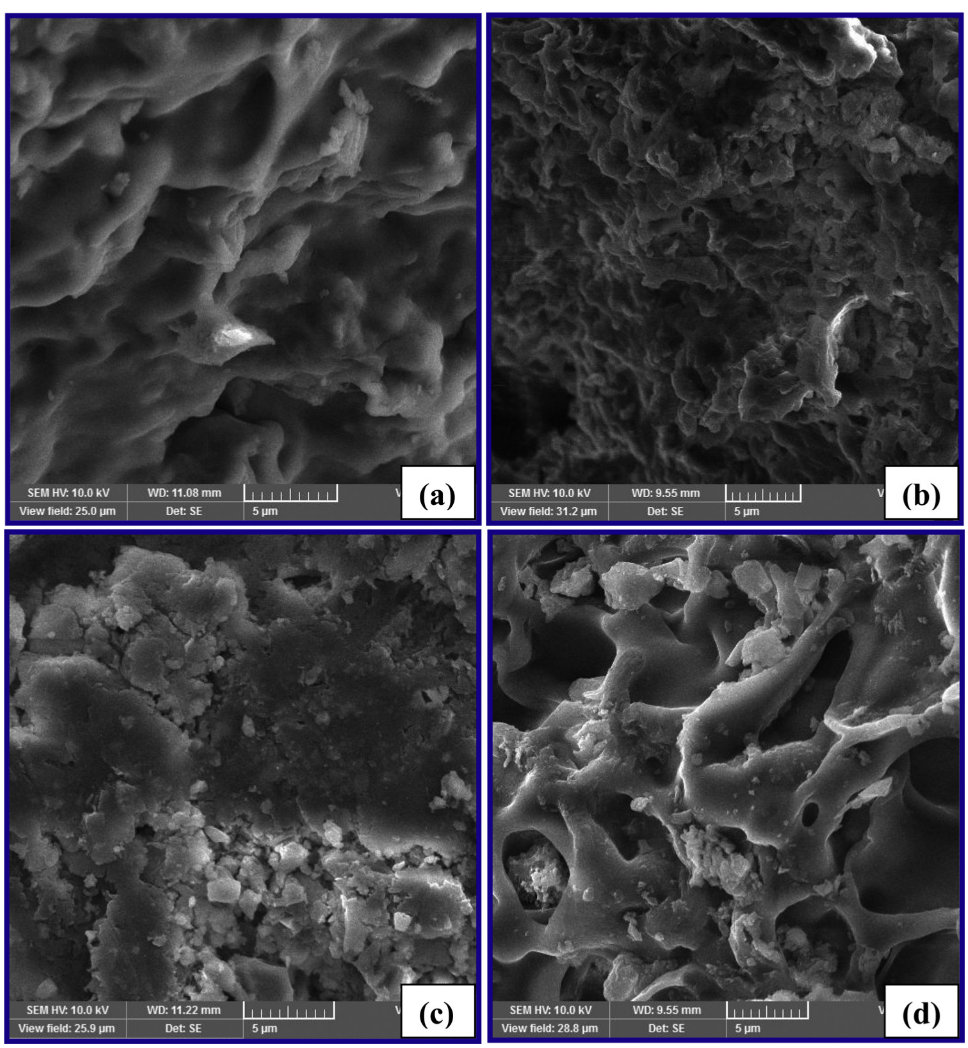

Fig. 1. SEM images of (a) PEG/chitosan (b) PVA/chitosan (c) phosphate adsorbed PEG/chitosan (d) phosphate adsorbed PVA /chitosan.