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Modeling of basic green 4 dynamic sorption onto granular organo–inorgano pillared clays (GOICs) in column reactor

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HIGHLIGHTS

▶ Comments about results and the effects of some parameters are added in the new text.
▶ Yoon and Nelson model is introduced for comparison with Clark Model.
▶ More information's are give about experimental conditions.

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ABSTRACT

In this study, the ability of organo–inorgano pillared clays to remove a dye (Malachite Green) was investigated. The effects of operating conditions, such as flow rate, initial dye concentration, GOICs particle size and bed height have been studied. Breakthrough data for BG4 removal (pH = 6, $T = 25\ ^\circ C$) reveal that, the dynamic adsorption is significantly influenced by flow rate, initial dye concentration, GOICs particle size and bed height and a modification of these parameters can greatly influence the process efficiency. Dynamic behavior of the column was predicted with the combination of mass transfer model and Freundlich equation (Clark model). A good evaluation of Clark parameters versus operating parameters (concentration and velocity) is obtained and a generalization of the Clark model (C3BZ model) is proposed. It was found that the C3BZ model under the different conditions appeared able to well represent the adsorption of the BG4 onto GOICs.

1. Introduction

Over the past decade, the Pillared Inorganic–Organic Clays (PIOCs) have been used increasingly as an alternative to activated carbon and other adsorbents due to their environmental compatibility, low cost, high adsorption capacity and simplicity of use. They are prepared in various ways, generally by incorporation of metallic polycations replacing the exchangeable cations in the interlayer space of clay minerals. The most frequently used as pillaring agents are species of Al, Ti, Cr and Fe [1–4]. Organic–inorganic modification of clay minerals offers the potential to remove both organic and inorganic pollutants from wastes, due to their intriguing structural diversity [5,7]. In this way, numerous studies have been directed towards the use of organo–inorgano pillared clays in powder (POICs) or granular (GOICs) form for the removal of dyes from aqueous solution [8–14].

Due to continuous wastewater flow, batch reactor, the most reported method in POICs and GOICs adsorption studies, is not appropriate for industrial applications. In order to obtain basic engineering data, continuous flow system is an effective process suitable for large wastewater volumes and cyclic sorption/desorption; fixed-bed reactor is a simple model for the determination of bed operation life span and regeneration time.

The performance of such adsorption process is described through the concept of the breakthrough curve. The time for breakthrough appearance and the shape of the breakthrough curve are very important characteristics for process design because they directly affect the feasibility and economics of the sorption phenomena.

Several models have been proposed to describe the breakthrough curves [15,16]. Among them, Clark proposed an evaluation of the breakthrough curve expressed through a generalized logistic function basis of a mass-transfer concept in combination with the Freundlich adsorption isotherms [16–19].

Following previous works [12–14], the present study was focused on evaluating the performance of the granular organo–

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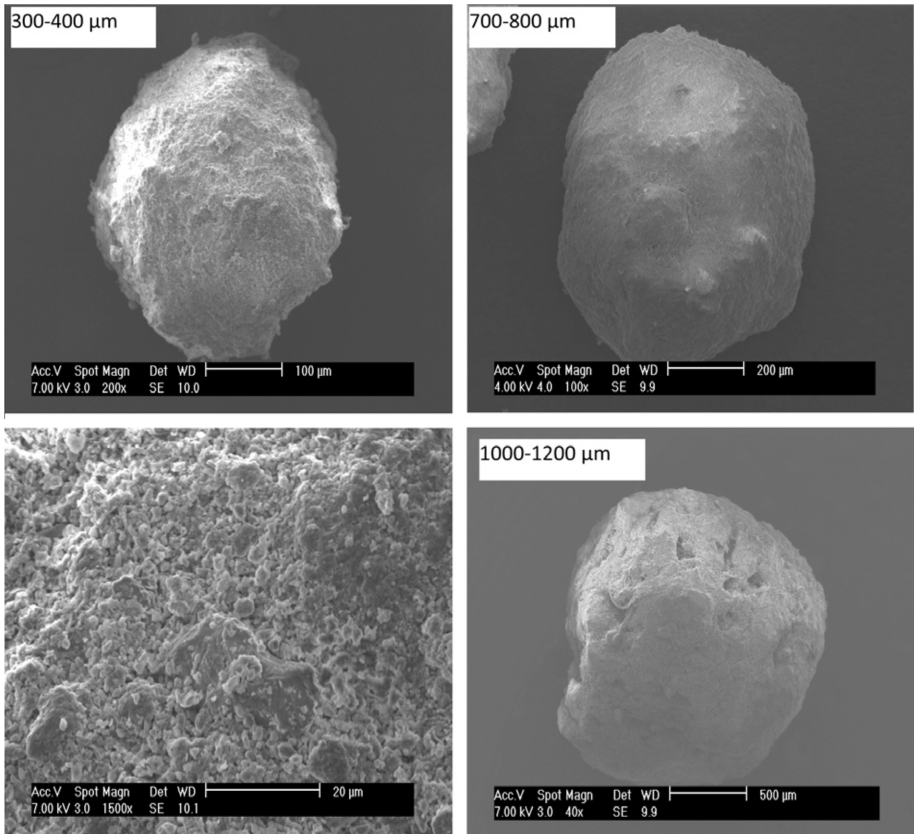

Fig. 1. SEM images of prepared GOICs [12].

inorgano pillared clay (GOICs) prepared by high shear wet granulation in the removal of color from textile wastewater in a fixed-bed reactor. The color uptake capacity of GOICs was investigated as a function of flow rate, initial dye concentration. This study also aimed to propose a generalization of the clark model and studied its application using basic green 4 dynamic sorption datasets.

2. Materials and methods

2.1. Preparation and characterization of sorbent

The adsorbent used in these studies was the granular organo–inorgano pillared clays prepared by high shear wet granulation according to a previous method [12]. The 300–400 μm, 700–800 μm and 1000–1200 μm size range of GOICs was used in these studies. Solid morphology of GOICs was determined by scanning electron microscopy (Philips XL30 with EDS, and EPMA CAMECA SX 100). SEM images (Fig. 1) show that the prepared GOICs are approximately spherical with porous structure [12].

In the following, these granules were assumed to be spherical, non-friable mechanically and having a suitable mechanical strength to remain stable in water [12]. Selected GOICs have been previously characterized by X-ray diffraction (XRD), surface acidity and zetametry, laser granulometry, infrared spectrometry (FT-IR) and BET specific surface area (SSA) [12,13]. Physical properties of the GOICs are summarized in Table 1.

2.2. Adsorbate

The basic dye used in the present study is basic green 4 (malachite green oxalate; molecular weight = 420). The working solutions were prepared by diluting 1.0 g L^{-1} stock solution.

Table 1
Physical properties of GOICs used for BG4 adsorption.

Properties	Particle size of GOICs (μm)		
	300–400	700–800	1000–1200
Apparent density (g/cm^3)	1.42	1.21	1.02
True density (g/cm^3)	2.11	1.94	1.86
Porosity	0.33	0.40	0.46

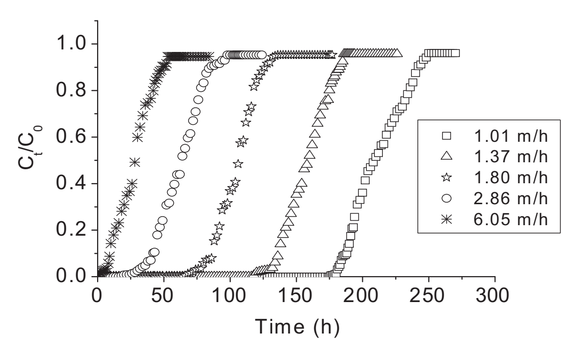

Fig. 2. Effect of flow rates on the breakthrough curve of BG4 adsorption on GOICs (C = 100 mg/L).

2.3. Column adsorption experiments

Column experiments were performed in a fixed bed mini Perspex column reactor with an internal diameter of 1.1 cm and a length of 5 cm packed with GOICs. Wall effects were neglected since the column diameter was at least more than 10 times larger than the particles size. The experiments were conducted by pump-