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Performances of clay aerogel polymer composites for oil spill sorption: Experimental design and modeling

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A B S T R A C T

Recently developed montmorillonite clay-based aerogels have attracted an attention owing to their highly porous internal structure. This study deals with the design of experiments applied for preparation of clay aerogel polymer composites and their testing and optimization for oil spill sorption. Three design variables have been chosen for experimentation, i.e. the amounts of montmorillonite (MMT), polyvinyl alcohol (PVA) and sodium dodecyl sulfate (SDS). Based on the experimental design the response surface models have been constructed. The objective for optimization was to maximize the performances of materials for sorption of dodecane and motor oil. To this end, the multi-objective optimization problem has been solved using NSGA-II optimization algorithm. The aerogel sorbent prepared under the optimal conditions of 2.109% w/v PVA, 2.678% w/v MMT and 0.210% w/v SDS bestowed the best sorption performance for both dodecane (23.63 g/g) and motor oil (25.84 g/g). Finally, the hydrophobic aerogel sorbent has been prepared using trimethoxy(octadecyl)-silane TMOS ($C_{21}H_{46}O_3Si$). The modified material with TMOS disclosed good sorption capacities for dodecane (10.55 g/g) and motor oil (12.25 g/g). The retention profile test has revealed that about 1.06–14.91% of liquid hydrocarbons can be recovered by free drainage. The advanced recovery of oily liquids has been achieved by centrifugation technique being of 42.29–66.02%. Likewise, the hydrophobic aerogel (modified with TMOS) has showed a good sorption capacity for dodecane (9.24 g/g) in the presence of water (W-test). In addition, the clay aerogel polymer composites have been characterized by means of scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy and X-ray diffraction (XRD) technique.

1. Introduction

Oil spill accidents are serious global environmental issues principally caused by activities related to processing, storage and transportation of oils [1,2]. Such incidents may result in a great damage of the human health quality and loss of valuable petroleum resources. Therefore, the prompt clean-up of oil spillage is essential [3]. In this regard, the advanced removal and recovery of spilt oils by sorbent materials is of great interest from both economical and ecological standpoints. So far, various materials have been applied for oil spill sorption, such as organic natural cellulosic materials [2,4–11], organic synthetic polymers [12–16] and inorganic mineral materials [4,17–20].

The porous sorbents for oil spill removal work by two principles: absorption and adsorption. Absorbents operate like sponges and collect oil by capillary action. The main role in oil absorption by capillary action is attributed to the macropores [2]. On the other side, adsorbents rely on a large surface area and the affinity of the sorbent material for the spilled oil. For the porous materials, the key role in adsorption is attributed to micropores and mesopores. Note that, according to IUPAC notation, micropores have diameters of less than 2 nm; mesopores have diameters ranging into the interval from 2 nm to 50 nm, while macropores have the diameter greater than 50 nm. Usually, when porous materials are applied for oil spill removal both phenomena (capillary action and adsorption) occur and the process is called generically *sorption*, while the materials are widely denominated as *sorbents*.

The natural cellulosic materials (e.g. kapok fibers, kenaf, sawdust, peat moss, etc.) are sorbents of low-cost being available as renewable and abundant resource supply in nature [2,4–11]. The synthetic polymeric products, like polypropylene [12,13], polyurethane [14,15] and rubbers [16] exhibit good sorption performances, but they present a shortcoming after usage since these polymers are non-biodegradable [4]. Note that, inorganic mineral materials such as, clays, perlite, vermiculite, diatomite, sepiolite,

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