Journal of Environmental Management 230 (2019) 405–412

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Oil spill cleanup employing magnetite nanoparticles and yeast-based magnetic bionanocomposite

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ARTICLE INFO

Keywords:
Magnetic bionanocomposite
Temperature
Oil spill
Water treatment
Two layers oil removing
Modified ASTM F726–12

ABSTRACT

Oil spill is a serious environmental concern, and alternatives to remove oils from water involving biosorbents associated to nanoparticles is an emerging subject. Magnetite nanoparticles (MNP) and yeast magnetic bionanocomposite (YB-MNP) composed by yeast biomass from the ethanol industry were produced, characterized, and tested to remove new motor oil (NMO), mixed used motor oil (MUMO) and Petroleum 28 °API (P28API) from water following the ASTM F726–12 method, which was adapted by insertion of a lyophilization step to ensure the accuracy of the gravimetric approach. Temperature, contact time, the type and the amount of the magnetic material were the parameters evaluated employing a fractional factorial design. It was observed the removal of 89.0 ± 2.6% or 3522 ± 118 g/kg (NMO) employing MNP; 69.1 ± 6.2% or 2841 ± 280 g/kg (MUMO) with YB-MNP; and 55.3 ± 8.2% or 2157 ± 281 g/kg (P28API) using MNP. The temperature was the most significant parameter in accordance with the Pareto's graphics (95% confidence) for all oil samples considered in this study as well as the two magnetic materials. Contact time and the interaction between the materials and temperature were also relevant. The D-Optimals designs showed that the NMO and P28API responded in a similar way for all evaluated parameters, while the uptake of MUMO was favored at higher temperatures. These behaviors demonstrate the influence of oil characteristics and the intermolecular forces between the oil molecules on the mechanism dragging process performed by the attraction between magnetite nanoparticles and a 0.7 T magnet. It was clear that this kind of experiment is predominantly a physic phenomenon which cannot be described as adsorption process.

1. Introduction

Water contamination and pollution are worldwide environmental concerns. Mostly, the contaminated water includes different kinds of oils that are composed of heavy metals and organic compounds, which present toxic and phytotoxic characteristics (Franco et al., 2014; Thompson et al., 2015; Fatoba et al., 2015). In addition, when an oil spillage occurs over water bodies, the luminosity through the water and the gas transfer between water and air can be compromised, causing serious impacts on aquatic life (Chen et al., 2013; Pintor et al., 2016).

In Mexico back in 2010, an oil spillage occurred in the Deepwater Horizon where a semi-submersible oilrig spilled millions of barrels of oil into the water. In an attempt to minimize the effects of the spillage on the environment, around 2 million gallons of dispersants were deployed to the water (Allan et al., 2012; Paul et al., 2013). Unfortunately, the use of dispersants increases the solubility of organic compounds in water, such as polycyclic aromatic hydrocarbons, thus, rise the potential of causing mutagenesis to several species (Allan et al., 2012; Paul et al., 2013). Another serious problem that faces us today is the inappropriate disposal of other kinds of oil, such as motor oil, which is composed of toxic organic substances (80–95%) and various types of additives (5–20%). This is considered an environmental concern that triggered some studies in this area (Carrilho and Gilbert, 2001; Ramadass et al., 2015).

The development of possibilities for oil cleanup from soils and water bodies has been a research focus on diverse areas of knowledge. In the

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https://doi.org/10.1016/j.jenvman.2018.09.094
Received 21 May 2018; Received in revised form 5 September 2018; Accepted 26 September 2018

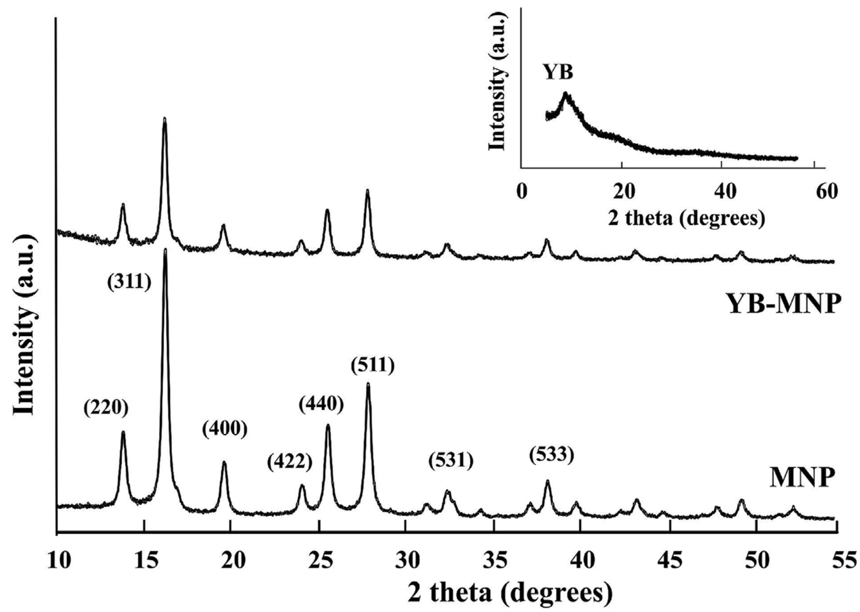

Fig. 1. Powder X-ray diffractograms from YB (yeast biomass), YB-MNP (yeast magnetic bionanocomposite) and MNP (magnetite nanoparticles), displaying the Bragg peak reflections of magnetite for the magnetic materials.

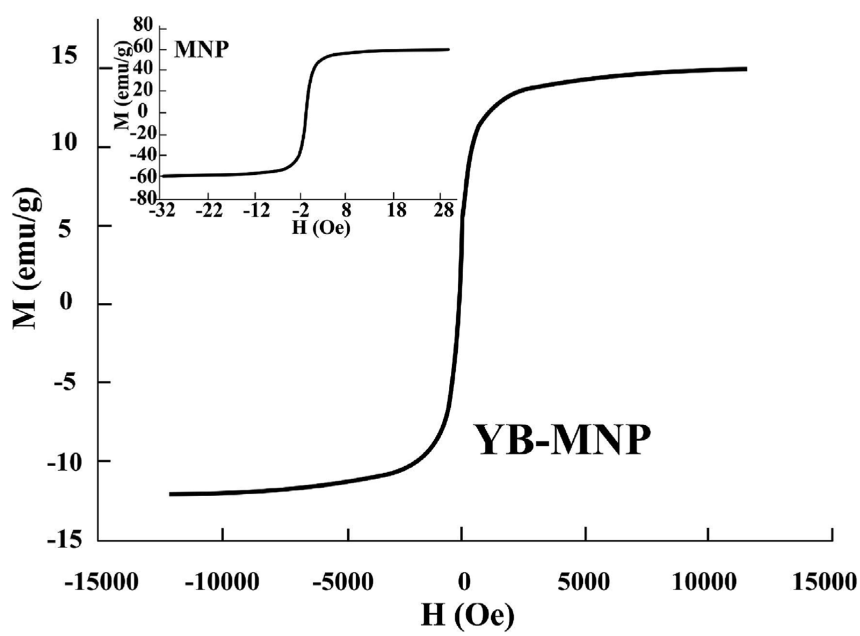

Fig. 2. Susceptibility of magnetization curves for YB-MNP and MNP.

last few years, different alternatives have been reported to draw oils from water. Biosorbents such as fungal, algal biomass, egg shells, and vegetable tissues (Araújo et al., 2007; Gonzales et al., 2008; Srinivasan and Viraraghavan, 2010a, 2010b; Mishra and Mukherji, 2012; Muhammad et al., 2012; El-Nafaty et al., 2013) have been used to remove synthetic and natural oils from water. The main advantages of the employment of biological materials for water treatment are their availability, large-scale production, low cost, and their sorption sites rich surfaces (Carrilho et al., 2002; Labuto et al. 2018).

In the last years, nanotechnology has been a distinguished area of research due to the unique characteristics of developed materials and the promising results for high capacity of removal of contaminants from water (Nassar, 2010; Qu et al., 2013; Hammouda et al., 2015; Falah et al., 2016; Huang et al., 2016; Li et al., 2016). Several nanomaterials have been developed in the last years aiming at removing oil from the water; including: aerogels, foams, sponges and polymers coated with nanoparticles (Chu and Pan, 2012; Calcagnile et al., 2012; Gui et al., 2013; Yang et al., 2014; Chin et al., 2014; Fatoba et al., 2015; Saber et al., 2015; Mirshahghassemi and Lead, 2015; Jiang et al., 2015; Nikkhah et al., 2015; Liu et al., 2015; Zhou et al., 2015; Kumar et al., 2015; Nyankson et al., 2016; Yu et al., 2016; Maleki, 2016; Peng et al., 2016; Reddy et al., 2016). The magnetite nanoparticles have been used together with these aforementioned materials since they are cost effective, can be easily produced, and show good biocompatibility and superparamagnetic behavior. This latter characteristic allows the recovery of the magnetic material from the solution by the application of a magnetic field (Yu et al., 2015; Liang et al., 2015; Raj and Joy, 2015). Moreover, magnetite nanoparticles are chemically stable and naturally occurring based materials, which are believed to be non-hazardous, nontoxic and non-carcinogenic (Stokinger, 1984; Gu and Bernard,