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Synthesis of a cost-effective magnetic nanoparticles coated sugarcane bagasse and testing tetracycline removal capacity

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Abstract. This study describes a modified method to prepare nanomagnetic coated sugarcane bagasse. Under the general chemicals: iron (II) sulphate heptahydrate ($FeSO_4.7H_2O$); sodium hydroxide, hydrochloric acid, and iron (III) chloride hexahydrate ($FeCl_3.6H_2O$) these were commercially available and a simple method, authors were successfully synthesized Fe_3O_4 nanoparticles coated sugarcane bagasse. These nanoparticles were heterogenous and formed nanoclusters on the sugarcane bagasse surface under Scanning Electron Microscopy analysis. Herein, we show that given the right experimental circumstances, the novel and prospective nanomagnetic sugarcane bagasse might prove to be an intriguing adsorbent for a variety of applications. For tetracycline removal case study: the studied material was significantly adsorbed this contaminant with the highest adsorption capacity was 15 mg/g under 25 mg/L initial tetracycline concentration; pH 6; equilibrium time: 15 hours; and magnetic nanoparticle sugarcane bagasse: 1 g/L. The fundamental result in the research denotes that the material could be a potential adsorbent for eliminating various contaminants in upcoming studies.

1 Introduction

Nanomaterials-related technological developments present a fresh challenge for the design of new materials and their use in remediation, catalysis, and medical applications [1]. Iron oxide nanoparticles, like magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3), and hematite (α-Fe_2O_3), are increasingly common in nature and are primarily used as nano-adsorbents. One of the naturally occurring iron compounds with the highest abundance and most significant use is magnetite, which is also biocompatible [1-3].

Intriguing properties of magnetite include its superparamagnetic behaviour at ambient temperature, biocompatibility, lack of toxicity, and biodegradability. Environmental clean-up procedures have used magnetite nanoparticles in-situ and ex-situ cancer therapeutic applications [3-4]. Additionally, research on Fe_3O_4 nano-fluids has become more popular in areas that are polluted by petroleum. Additionally, magnetite can quicken a number of bio-upgrading procedures in the petroleum industry [5]. Given their exceptional properties and high surface-to-volume ratio, nanomaterials are particularly intriguing for use in water

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purification applications [6]. Due to its numerous cutting-edge uses, such as wastewater treatment, iron oxide nanoparticles have become common in nanomaterials. One of the most common varieties of iron oxide nanoparticles is magnetite. Furthermore, the heavy metal ion in water may be absorbed by magnetite nanoparticles.

Nanoparticles' vital magnetic properties greatly determine the potential uses for which they may be applied. For instance, iron oxide nanoparticles larger than 28 nm can be employed for magnetic isolation since they are ferric-magnetic [4-6]. Iron oxide that is smaller than 28 nm, however, is super-paramagnetic at ambient temperature. Magnetite has also been used in the past to extract crude oil from pores during improved oil recovery [5-6]. Researchers are particularly interested in studying various ways of magnetic nanoparticle manufacturing and characterization based on these features and qualities.

Magnetic nanoparticle materials with the necessary magnetic characteristics, such as magnetic iron oxide nanoparticles, are mostly used in biomedical applications. The three main benefits are cost, stability, and compatibility; magnetic iron oxide nanoparticles are cheap to make, have enough physical and chemical stability, are biocompatible, and are safe for the environment [5-7]. The potential for their particular bio applications, such as magnetic separation, targeted drug administration, MRI, magneto-ion-conducting fluid hyperthermia and chemoablation, and biosensing, is crucial [8].

As effective adsorbents for pollutant removal, magnetic nanoparticles coated on various materials have also been used in numerous investigations. As an illustration, Cd(II), Ni(II), and Cu(II) were among the ion metals in water that magnetic nanoparticles coated cationic resin to bind to [1]. Tetracycline is removed from water using iron-magnetic coated pine bark [8]. To treat Ni and Co in water, modified polyurethane-magnetic nanoparticles have been used as an adsorbent [2]. Arsenic removal from aqueous solution utilizing rice husks coated with iron oxide [3]. For Cd(II) sorption, a nanomagnetic walnut shell was created [4], etc. An innovative nano magnetic adsorbent composite material made from sugarcane bagasse was created in this study. It could be a potential adsorbent which can be utilized to eliminate various contaminants in wastewater such as tetracycline which was selected in this presented study.

2 Materials and method

2.1 Materials

Analytical grade chemicals were used in this study, the iron (II) sulphate heptahydrate ($FeSO_4.7H_2O$) and tetracycline were purchased from the website sigmaaldrich.com. Sodium hydroxide, hydrochloric acid from Vietchem company and iron (III) chloride hexahydrate ($FeCl_3.6H_2O$) were bought from Xilong Chemical company.

2.2 Preparation and synthesis magnetic nanoparticles – sugarcane bagasse (M-SB)

Sugarcane bagasse was gathered from a rural area in Hanoi City, Vietnam. The raw material was washed many times with hot water many times to removal impurities, after that dried (70^0C) in two days. And then, the material was soaked with sodium hydroxide 1M for 4 hours and washed with DI water until the pH reached neutral. Continuously, dried the milled material in an oven under 60^0C for two days. The dried sugarcane bagasse was milled and sieved to get the synchronized size (100 µm). This powder was stored into a plastic bag.

The synthesis magnetic – sugarcane bagasse was built based on the chemical reaction:

$$FeSO_4.7H_2O + 2FeCl_3.6H_2O + 8NaOH \rightarrow Fe_3O_4 + Na_2SO_4 + 6NaCl + 23H_2O$$

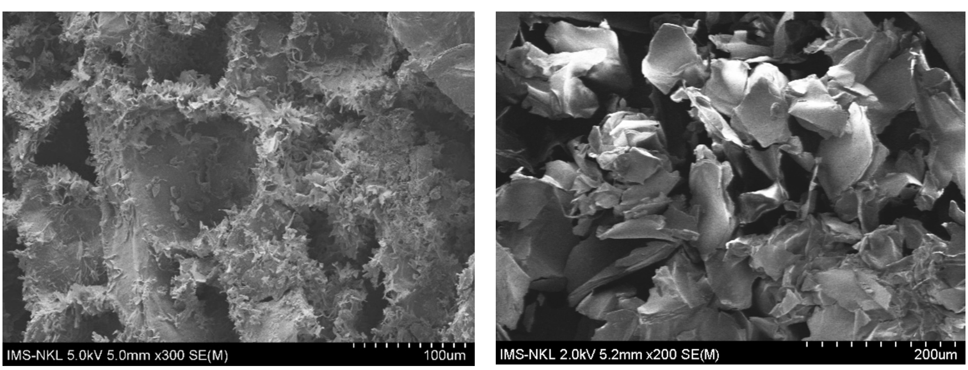
The following procedures were used to prepare the M-SB modification: The following steps were taken to prepare the solution: (1) add 5 grams of powdered sugarcane bagasse to 100 mL of distilled water; (2) prepare a solution with 10 grams of $FeCl_3.6H_2O$ and 7.2 grams of $FeSO_4.7H_2O$ in 400 mL of DI water; (3) stirring the solution until the chemicals were completely dissolved in the water; (4) combine the two solutions at room temperature (around 26^0C); and (5) stirring the combined solution while gradually adding dropwise NaOH 3M. Throughout this procedure, the pH was tested till it reached 10; (6) The suspension was heated under 80^0C for two hours, changing the colour of the solution from brown to black; (7) The solid was filtered and rinsed with distilled water multiple times; Ultimately, the solid was dried in an oven under 70^0C for one day.

3 Results and discussions

3.1 Morphology of magnetic nanoparticle sugarcane bagasse

The treated sugarcane bagasse with NaOH and nano-magnetic sugarcane bagasse were analysed under SEM analysis (Figure 1). Figure 1a indicates that the sugarcane bagasse shield was dug and significantly broken up. The surface was rough and small piece was overlapped - making a heterogeneous surface. This is a good signal so that after synthesis, nano particles can be embedded deep into the holes and cracks of the surface.

Following precipitation, distilled water was used to clean and filter the Fe_3O_4 nanoparticles before they were eventually dried at 70°C. Temperature, concentration, drop time, and pH level of the precipitation were all carefully regulated factors that affected the mean particle size. In Figure 2, the shape of nanomagnetic sugarcane bagasse is depicted. In Figure 2, the SEM picture of sugarcane bagasse with a nanomagnetic coating is displayed. In this case study, it displays a typical aggregation of magnetic nanoparticles.



(a) (b)

Fig. 1. (a) the treated sugarcane bagasse with NaOH (100 μm); (b) the treated sugarcane bagasse with NaOH (200 μm).

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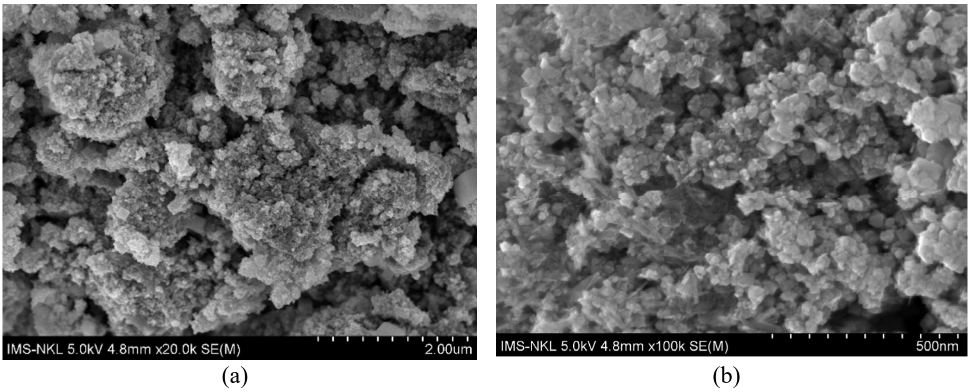

Fig 2. (a) Magnetic nanoparticle coated treated sugarcane bagasse (200 µm); Magnetic nanoparticle coated treated sugarcane bagasse (500 nm).

3.2 Tetracycline removal by magnetic nanoparticle sugarcane bagasse

The fundamental investigation of tetracycline removal by magnetic nanoparticle sugarcane bagasse was presented in this section. The residual tetracycline in the initial solutions was measured by UV-Vis (Genesys 10S model, Thermo Scientific Co.) under the wavelength 355 nm.

Effect of contact time was studied under the initial tetracycline concentration 25 mg/L, contact time 5; 10; 15; 20; and 30 hours; the studied material concentration 1 g/L at room temperature. The amount of tetracycline adsorption was rapidly increased from starting hour to 10 hours. When higher contact time investigation, the tetracycline removal was slightly changed. Since, the equilibrium adsorption time was chosen at 15 hour which was used in the upcoming tests.

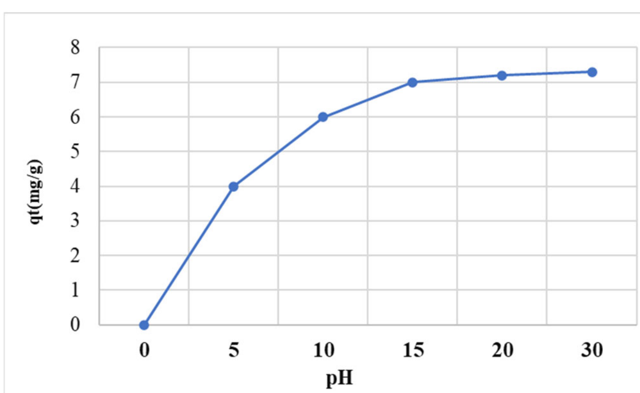

Fig. 3. Effect of contact time on tetracycline removal by magnetic nanoparticle sugarcane bagasse.

Effect of pH on tetracycline removal

Under the initial tetracycline concentration 25 mg/L; magnetic nanoparticle sugarcane bagasse concentration 1 g/L; pH: 3, 6, and 9; contact time: 15 hours at room temperature some results were reported in Figure 3 below.

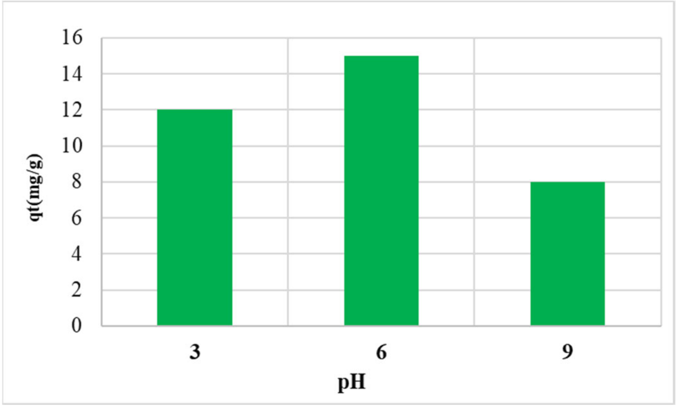

Fig. 4. Effect of pH on tetracycline removal by magnetic nanoparticle sugarcane bagasse.

The tetracycline removal capacity was increased when pH from 3 to 6. The maximum tetracycline adsorption was 15.02 mg/g at pH 6. At higher pH the tetracycline elimination was rapidly decreased. Hence, it denotes that pH can significantly influence on tetracycline removal (Figure 4).

4 Conclusion

Magnetic nanoparticles are widely used in various fields such as disoperation; sensing; adsorption; biomedical; etc. Therefore, synthesis of magnetic nanoparticles has been created by many ways. Scientific articles on magnetic materials are appearing more frequently, which suggests that the scientific community as a whole is becoming more interested in the subject. The manufacture of magnetic materials with the necessary size, shape, chemical composition, and surface chemistry has advanced significantly. The coating gives magnetic materials physical and chemical stability.

The authors of this study described an easy and efficient technique for producing sugarcane bagasse that has been coated with nanomagnets. Synthesized Fe_3O_4 nanoparticles are used in the process as a supporting element to create a promising material for removing pollutants from water. Scanning electron microscopy (SEM) was used to examine the morphology of nanomagnetic sugarcane bagasse. The formation of micro clusters of Fe_3O_4 nanoparticles. It contains spherical, 500 nm-sized nanomagnetic sugarcane bagasse particles, which may be creating a polymeric matrix during the polymerization process that disperses magnetite nanoparticles. Two prospective materials are mixed to create a potential adsorbent that may be effective at removing pollutants from water.

Based on preliminary test the tetracycline adsorption by magnetic nanoparticle sugarcane bagasse was revealed some major results: the tetracycline removal was reached the optimal value: 15 mg/g under the tetracycline concentration: 25 mg/L; pH 6; contact time 15 hour; adsorbent dosage: 1 g/L at room temperature. It indicates that magnetic nanoparticle sugarcane bagasse could be a potential adsorbent for tetracycline removal.

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