Synthesis and Characterization $CoFe_2O_4$ via co-precipitation to application in photocatalysis heterogeneous

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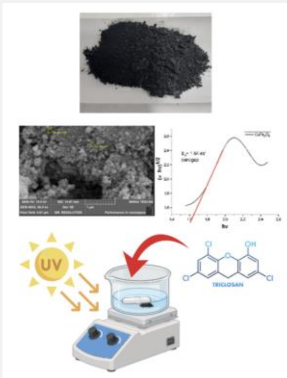

This study investigates the synthesis and characterization of $CoFe_2O_4$ nanoparticles application on emerging contaminants. The nanoparticles were produced via co-precipitation and characterized through X-ray diffraction, Fourier-transform infrared spectroscopy, ultraviolet-visible spectroscopy, scanning electron microscopy with energy-dispersive X-ray spectroscopy, diffuse reflectance spectroscopy for bandgap determination, point of zero charge. Highlights to band gap of 1.64eV could be attractive to application in solar processes. Preliminary tests demonstrated $CoFe_2O_4$ adsorption approximately 30% suggest that $CoFe_2O_4$ interaction with the contaminant can be facilitate. Besides, the photolysis observed was 52%, showing the high influency of radiation. The $CoFe_2O_4$ has potential for the remediation of emerging contaminants, however, more studies are necessary to maximize the degradation process.

Introduction

$CoFe_2O_4$, also known as cobalt-iron spinel, is an oxide with significant magnetic and electronic properties that have garnered interest across various fields. For instance, chemistry, medicine, materials science, engineering and environmental applications including remediation technologies. Spinel ferrite materials are metallic oxides with spinel structures, characterized by the general chemical formula AB_2O_4. The characteristics of spinel can be affected by synthesis methods. The co-precipitation method is relatively simple and economical compared to other synthesis method [1]. This process involves the precipitation of metal cations from a solution, followed by thermal treatment, and does not require complex or expensive equipment [1]. Cobalt ferrites, $CoFe_2O_4$, have been showed effective in the degradation of contaminants due to their spinel structure and ability to generate free radicals in advanced oxidation processes [2]. These ferrites facilitate the activation of oxygen and formation of HO• radicals. Additionally, their magnetization allows for easy separation and reuse after treatment, making them an efficient solution for the remediation of contaminated waters [5]. Triclosan is a synthetic antimicrobial agent used in personal care or cleaning products and is considered as an emerging contaminant. This way, it can be used as model molecule to evaluate the photocatalytic activity. The main objective of this study is synthesis and characterization of $CoFe_2O_4$ to evaluate the capacity as a catalyst on triclosan degradation.

Material and Methods

All reagents used were of analytical grade. The chemicals included TCS (Merck, Germany), NaOH (Neon, Brazil), $FeCl_3 \cdot 6H_2O$ and $CoCl_2 \cdot 6H_2O$ (Dinâmica Química®), NaCl, and solvents such as acetonitrile (chromatographic grade, Vetec, Brazil), ultrapure water (Reverse Osmosis OS10 LZ, Geaka), HNO_3 (Alphatec®), HCl (Synth) for pH adjustment when necessary. In this study, cobalt spinel was synthesized by co-precipitation using 0.02 mol of $FeCl_3 \cdot 6H_2O$ and 0.01 mol of $CoCl_2 \cdot 6H_2O$ in 100 ml NaOH 2 mol L^{-1}. After 24 hours of the reaction, the supernatant was eliminated, and the product was heated at 500°C for 200 minutes with a heating rate of 10°C min^{-1}. For the characterization of the $CoFe_2O_4$, the following methods were employed: X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), ultraviolet-visible spectroscopy (UV-Vis), scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS), diffuse reflectance spectroscopy (DRS) for bandgap determination, Point of Zero Charge (PZC).

Results and Discussion

Cobalt magnetic nanoparticles were obtained successfully through co-precipitation. The method is economical, quick, efficient for large-scale production and frequently employed because it yields materials with uniform particle sizes. By SEM-EDS the average particle size obtained was 45 nm. The EDS analysis shows the composition of $CoFe_2O_4$ with 10.54% oxygen, 58.48% iron, and 30.98% cobalt, resulting in a (Fe)/(Co) molar ratio of 1.88, consistent with the literature. The diffractogram of the synthesized cobalt spinel is shown in Figure 1. The presence of (111), (220), (311), (400), (422), (511), and (440) in the XRD pattern corresponds to the inverse cubic structure.

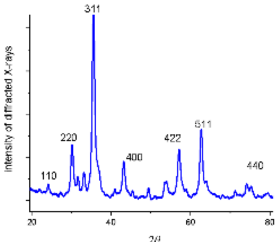

Figure 1. FTIR spectrum

The FTIR spectrum revealed two bands in the range of 400 to 600 cm^{-1}, corresponding to tetrahedral and octahedral sites in the lattice. Co-O bond vibrations are observed around 450 cm^{-1}, while Fe-O stretching appears at 523 cm^{-1}. These bands are common characteristics of ferrites and spinels.

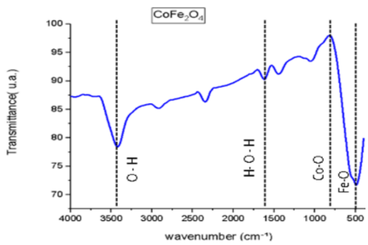

Figure 2. FTIR

The PCZ calculated was equal to 7.0. The results obtained from the zeta potential demonstrate that the particle stability range comprises regions greater than 30 mV, with the range of instability being - 30mV ≤ Zeta Potential ≤ 30mV in this, in comparison with the values obtained, the results in this range are for pH 7,10,11 and 12. The PCZ is the pH at which the adsorbent has a zero charge. Above or below this value, the adsorbent will have a negative or positive charge, respectively. Thus, the adsorption of cations is favored when pH > pHpcz and anion adsorption is favored at pH < pHpcz. The results of the zeta potential and the point of zero charge help better understand the mechanisms of photocatalysis and adsorption, in addition to allowing more precise planning of the actual conditions. The band gap obtained was 1.64 eV and the photocatalysis can be carried out using visible light (Figure 3).

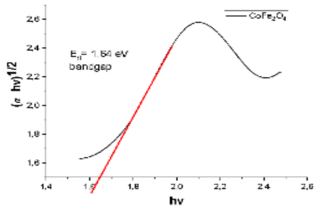

Figure 3. RDS of $CoFe_2O_4$ and band gap value

Preliminary studies of photolysis and adsorption using triclosan as model molecule were conducted with an initial concentration of 2 mg L^{-1} [5]. The photolysis observed achieved at 30 min and the results was expected since the triclosan can be removed by light effect. The adsorption observed was approximately 30% of the TCS.

Conclusions

The synthesis of $CoFe_2O_4$ nanoparticles via co-precipitation proved to be efficient and cost-effective, producing a material with promising magnetic properties and a well-characterized structure. The analysis revealed that these nanoparticles can be use as catalyst on triclosan degradation. Preliminary tests indicated that $CoFe_2O_4$ adsorption approximately 30% and 52% by photolysis. These results suggest that $CoFe_2O_4$ interaction with the contaminant can be facilitate. Besides, the band gap of 1.64eV could be attractive to application in solar processes.

Acknowledgments

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