2021-2022
Second semester

University of Bahrain
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Comparison Study of the Degradation of Azo Dyes by Spinel Ferrite Nanoparticles

Abstract

This project is studying the removal of textile wastewater specifically azo dyes using spinel ferrite nanoparticles. Magnesium ferrite ($MgFe_2O_4$) nanoparticles were synthesized using sol-gel method and characterized using XRD. It has been used for the degradation of azo dyes using three methods: Adsorption, Fenton, and Photocatalytic. Box-Behnken Design for Adsorption has been employed to find the effect and optimum values of adsorbent dosage, initial dye concentration, and pH of the solution. While for Fenton, Central Composite Design has been utilized to study the effect of catalyst dosage, initial dye concentration, pH, and H_2O_2. Both process were optimized using the aforementioned designs and the optimum value for each variable was found to maximize the removal efficiency. In addition, a study was carried out for adsorption isotherms and Langmuir model gave a better fit than Freundlich model. Kinetics were also studied using five models for the three degradation methods and pseudo second order was found to be the best model for all processes.

Design and Implementation

The magnesium ferrite nanoparticle was synthesized using sol gel method and annealed at 500 ^oC, then characterized using X-ray Diffraction. Several preliminary experiments were done such as dye screening, choosing the ranges of the factors like pH, catalyst dosage, H_2O_2, and the initial concentration of the dye. Design of experiment approach was used to design the experiments condition and to get the optimum conditions for the degradation process where Box-Behnken Design was used for Adsorption process and Central Composite design for Fenton process. An experiment on Adsorption isotherms was conducted to study the relation between concentration and adsorbed amount of dye. To study the behavior of the degradation of dyes using magnesium ferrite nanoparticle a kinetic study was carried out for each degradation method and data were collected.

Conclusion

The objectives of this work were synthesizing magnetic spinel ferrite nanoparticles and using them in the degradation of azo dyes. Magnesium spinel ferrite nanoparticles were synthesized by sol-gel method which is a conventional and feasible method used for the preparation of magnetic nanoparticles. The synthesized nanoparticles were used in the degradation of Novacron golden yellow dye by different degradation methods. Adsorption and Fenton processes were optimized using response surface methodology, where Box–Behnken Design was used for the Adsorption and Central Composite Design was used for Fenton. The significant variables for each model were evaluated and the optimum condition for maximum removal efficiency were found. At optimum conditions, the maximum removal efficiencies were 41.33% and 18.32% for Adsorption and Fenton respectively. Moreover, an experiment was carried out for the adsorption isotherms. Langmuir isotherm model found to be fitting the synthesized nanoparticles better than Freundlich model. Furthermore, a kinetic study was carried out on Adsorption, Fenton and Photocatalytic processes. Upon analyzing the experimental data, pseudo-second order was found the most suitable model among the proposed models.

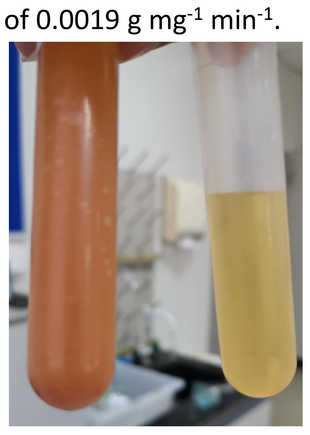
Objective and Motivation

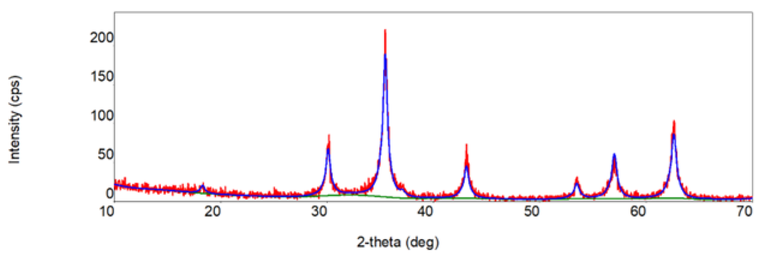
Dyes discharge poses harm to the environment as it contains toxic material. Therefore, the wastewater from industries must be properly treated to remove any hazardous dye before releasing it to the natural environment. This effect led to the need to develop new and more effective wastewater treatment methods. Many treatment processes which include chemical and physical were reported, among which catalytic methods are efficient and economical because they have a simple work-up procedure and ease of handling. Nano-catalysts can be employed at lower temperatures to speed up the reaction, and they have a huge surface area with a large number of active sites that minimize the total mass needed of the catalyst.

The aim of this project is to synthesis magnetic spinel ferrite nanoparticle having MFe2O4 formula (where M= is a metal such as Mg, Cu, Zn, Ni or Co) and to investigate the catalytic activity of this nanoparticle for color removal of Azo dyes. A compassion study for the suitability and the effectiveness of the nanoparticle for different dye degradation methods such as adsorption, Fenton, and Photocatalytic degradation will be studied, discussed, and evaluated.

Results

The synthesized magnesium ferrite nanoparticle were characterized using X-ray Diffraction and the peaks found compared to literature to confirm the formation of the desired nanoparticles. In addition, the analysis showed a good crystallite size of 10.972 nm. The optimization for Adsorption process was successful and yielded and R2 of 0.8977. Adsorbent dosage was found to be the only significant variables among the tested variables. 41.33% maximum removal efficiency was obtained at the optimum conditions of 30 mg/L dye concentration, 1 g/L adsorbent dosage and a pH value = 3. On the other hand, Fenton process yielded a higher R2 of 0.9182. Initial dye concentration, catalyst dosage, pH value, the interaction of initial dye concentration with pH value and the interaction of initial due concentration with H_2O_2 were all significant in Fenton process. The optimum conditions for initial dye concentration, catalyst dosage, pH value and H_2O_2 were found to be 20 mg/L, 1g/L, 3 and 3% respectively. An experiment on the optimum conditions was performed and the result was 18.32% removal efficiency. The Adsorption was found to be favorable and showed a better fit for Langmuir isotherm model with a maximum adsorption capacity of 178.6 mg/g. the kinetics study revealed that the Adsorption, Fenton and Photocatalytic processes are pseudo second order. Photocatalytic process has the highest rate of 0.0059 g mg^{-1} min^{-1} followed by 0.0041 g mg^{-1} min^{-1} for Adsorption process. While Fenton process had the lowest rate of 0.0019 g mg^{-1} min^{-1}.





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