Yellow tartrazine dye degradation mediated through the composite $NiFe_2O_4$ and Biochar from sewage sludge.

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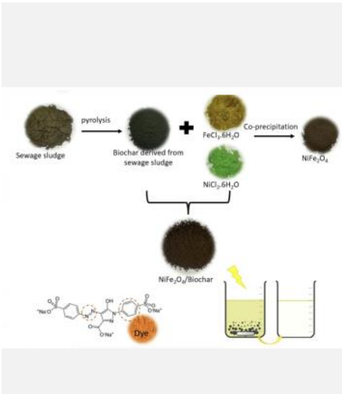
E.R.L. Tiburtius[1], *C.N. Benetti*[1], *J.M. Aquino*[2] *(1) State University of Ponta Grossa, Av. General Carlos Cavalcanti, Uvaranas, 84030-900, Ponta Grossa, Brazil, erltiburtius@gmail.com (2) Federal University of São Carlos, Rodovia Washington Luís, km 235, 13565-905, São Carlos, Brazil.*



This study investigates the photocatalytic degradation of the yellow tartrazine dye using the $NiFe_2O_4$/biochar composite. The $NiFe_2O_4$ spinel was synthesized via coprecipitation and combined with biochar derived from sewage sludge. Photocatalytic activity was evaluated by varying the ratios of $NiFe_2O_4$ and biochar, with the optimal ratio being 75:25%. Significant reductions in absorbance were observed at both 260 nm (aromatic groups) and 430 nm (azo groups). At first, the synergisms between spinel and biochar permitted the better electrostatic interactions. In addition, highlights the potential of biochar-based catalysts in photocatalysis at pH 7. Kinetic analysis indicated a pseudo-second order reaction model with a correlation coefficient (R^2 = 0.98). And the main advantage use biochar is its high capacity of adsorption and ecological origin contributing to sustainability.

Introduction

Water contamination has caused harmful impacts on the environment. Untreated effluents containing dyes, such as tartrazine (TAZ), are extremely harmful to animals, humans, and the environment. TAZ has high solubility in water, which increases its chance of being found as a contaminant in industrial effluents. This compound has the molecular formula $C_{16}H_9N_4Na_3O_9S_2$, with chromophoric groups and aromatic groups that absorb at 430 nm and 260 nm, respectively [1]. Advanced oxidation processes (AOPs) are an efficient alternative for treating effluents before they are released into the environment. The use of photocatalysts in the degradation of these compounds, such as the composite of iron nanoparticle spinels with biochar derived from sewage sludge has been received attention [2]. Biochar is the product of the thermal decomposition of biomass and when coupled with magnetic iron spinel its efficiency improves in the degradation of various pollutants. [3]. The objective of this work was to carry out the synthesis of the $NiFe_2O_4$/biochar composite and evaluate the photocatalytic activity in the degradation of the TAZ. The sewage sludge, a compound rich in nutrients and organic matter present in wastewater treatment plants, was used.

Material and Methods

For the synthesis and obtaining of the magnetic spinel, the coprecipitation method was used, mixing ferric chloride ($FeCl_3.6H_2O$) and nickel chloride ($NiCl_2.6H_2O$). For the precipitation route of the precursors, 2 mol L^{-1} NaOH was used. After that, the samples were washed, filtered, and placed in a conventional muffle furnace at 500 °C for 200 minutes to obtain the magnetic spinels. The biochar was synthesized by pyrolysis from sewage sludge collected at a wastewater treatment plant in the city of Ponta Grossa-Brazil. The sludge was dried at 100ºC in an oven for 3 hours, then calcined in a conventional muffle furnace, and the obtained powder was then pyrolyzed at 550ºC for 120 minutes to obtain the biochar. For the $NiFe_2O_4$/biochar composite, quantities of $NiFe_2O_4$ and biochar were mixed in different proportions and dispersed in 15 mL of ultrapure water and 15 mL of ethanol. For complete homogenization, an ultrasound bath was used for 40 minutes. The sample was kept in an oven for 12 hours at 80ºC, and after drying, the sample was ground and calcined for 120 minutes at 200ºC. For the degradation experiments, 200 mL of TZA dye (50 mg L^{-1}), magnetic spinel (1 g L^{-1}), and biochar (1 g L^{-1}) were used. The experiments were conducted in a bench reactor using a mercury vapor lamp (125 W) covered with glass at pH 7. Photolysis and adsorption tests (control experiments) were also carried out with tartrazine in the dark and under constant stirring.

Results and Discussion

The photocatalytic activity of the semiconductor formed by the $NiFe_2O_4$/biochar composite was tested in different proportions of each material in the degradation of the TAZ: 25:75%, 50:50% e 75:25%. The photocatalytic capacity was observed for all proportions (Figure 1). However, the percentage of degradation was observed using the proportion of 75% $NiFe_2O_4$ and 25% biochar. The degradation rates of 81.7±1.1% and 72.01±3.6% for the wavelengths of 260 nm and 430 nm, respectively, in 30 minutes of reaction.

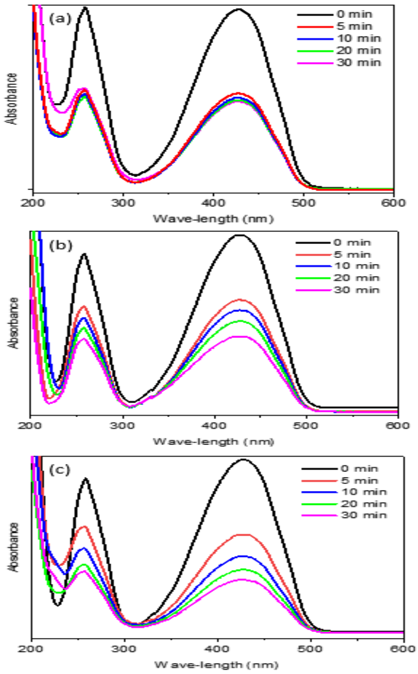


Figure 1. Spectra of dye degradation in different proportions at pH 7 (a) 25:75% $NiFe_2O_4$/biochar, (b) 50:50% $NiFe_2O_4$/biochar, (c) 75:25% $NiFe_2O_4$/biochar

These results showed the importance of high percentage of the magnetic spinel. The absorbance intensity from azo and aromatic groups were simultaneously reduced, demonstrating the high photocatalytic activity. In particular, the photolysis was 5,04+-2.89% and adsorption 83.7+-4.45% and the high adsorption rates observed suggest the effect of biochar on composite. At pH 7 the low adsorption of spinel was observed (5.93+-0.15), in fact the synergism between biochar and spinel increased the contact of TAZ and catalyst favoring the feasible electrostatic interactions. Optimizing the physical-chemical variability of the process, including pH, dye concentration, adsorbent dosage, temperature, contact time, and adsorbent particle size, is crucial for the process's effectiveness [1]. These preliminary studies showed that at pH 7 high rates of degradation were achieved, indicating be an alternative to reduce operation cost with pH correction before discharge.

The kinetics model of the tartrazine degradation reaction was studied by monitoring the decrease in its absorbance at 430 nm. The pseudo-second-order model presented the best fit (Table 1). With a correlation coefficient (R^2 = 0.99), rate constant value k = 0.3394, half-life time of 12.13 min^{-1}.

Table 1. Kinetic studies obtained during photocatalysis of Tartrazine dye degradation

Compound	Order	*k*(min^{-1})	t½(min)	R^2
75:25% $NiFe_2O_4$/ biochar	2^{st}	0.3394	12.13	0.9915

Conclusions

The evaluation of $NiFe_2O_4$/biochar composite showed the efficiency of the photocatalytic activity on yellow tartrazine dye. The results demonstrated that the composite with the proportion of $NiFe_2O_4$ (75%) and biochar (25%) derived from sewage sludge exhibited the highest degradation rates, achieving significant reductions in absorbance at 260 nm and 430 nm. The study highlights that the synergisms between spinel and biochar permits the better electrostatic interactions. Indeed, the use of biochar from sludge waste is environmentally friendly and can contribute to pollutants degradation.

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References

[1] D.H.Micheletti, J.G.S. Andrade, C.E. Porto, B.H.M. Alves, F.R. Carvalho, O.A. Sakai, V.R. Batistela. *Bioresource Technology Reports,* 24 (2023) 101598.

[2] J. Leichtweis, N. Welter, Y. Vieira, S. Silvestri, E. Carissimi. *Environmental Monitoring and Assessment.* 194 (2022) 907.

[3] A.B. Azzam, Y.A. Tokhy, F.M.E. Dars, A.A. Younes. *Environmental Science and Pollution Research.* 3 (2024).