Wastewater Treatment Using Ternary Hybrid Advanced Oxidation Processes Through Heterogeneous Fenton

Authors : komal verma, V. S. Moholkar

Abstract : In this current study, the challenge of effectively treating and mineralizing industrial wastewater prior to its discharge into natural water bodies, such as rivers and lakes, is being addressed. Particularly, the focus is on the wastewater produced by chemical process industries, including refineries, petrochemicals, fertilizer, pharmaceuticals, pesticides, and dyestuff industries. These wastewaters often contain stubborn organic pollutants that conventional techniques, such as microbial processes cannot efficiently degrade. To tackle this issue, a ternary hybrid technique comprising of adsorption, heterogeneous Fenton process, and sonication has been employed. The study aims to evaluate the effectiveness of this approach for treating and mineralizing wastewater from a fertilizer industry located in Northeast India. The study comprises several key components, starting with the synthesis of the Fe3O4@AC nanocomposite using the co-precipitation method. The nanocomposite is then subjected to comprehensive characterization through various standard techniques, including FTIR, FE-SEM, EDX, TEM, BET surface area analysis, XRD, and magnetic property determination using VSM. Next, the process parameters of wastewater treatment are statistically optimized, focusing on achieving a high level of COD (Chemical Oxygen Demand) removal as the response variable. The Fe3O4@AC nanocomposite's adsorption characteristics and kinetics are also assessed in detail. The remarkable outcome of this study is the successful application of the ternary hybrid technique, combining adsorption, Fenton process, and sonication. This approach proves highly effective, leading to nearly complete mineralization (or TOC removal) of the fertilizer industry wastewater. The results highlight the potential of the Fe3O4@AC nanocomposite and the ternary hybrid technique as a promising solution for tackling challenging wastewater pollutants from various chemical process industries. This paper reports investigations in the mineralization of industrial wastewater (COD = 3246 mg/L, TOC = 2500 mg/L) using a ternary (ultrasound + Fenton + adsorption) hybrid advanced oxidation process. Fe3O4 decorated activated charcoal (Fe3O4@AC) nanocomposites (surface area = 538.88 m2/g; adsorption capacity = 294.31 mg/g) were synthesized using co-precipitation. The wastewater treatment process was optimized using central composite statistical design. At optimum conditions, viz. pH = 4.2, H2O2 loading = 0.71 M, adsorbent dose = 0.34 g/L, reduction in COD and TOC of wastewater were 94.75% and 89%, respectively. This result results from synergistic interactions among the adsorption of pollutants onto activated charcoal and surface Fenton reactions induced due to the leaching of Fe2+/Fe3+ ions from the Fe3O4 nanoparticles. Micro-convection generated due to sonication assisted faster mass transport (adsorption/desorption) of pollutants between Fe3O4@AC nanocomposite and the solution. The net result of this synergism was high interactions and reactions among and radicals and pollutants that resulted in the effective mineralization of wastewater. The Fe3O4@AC showed excellent recovery (> 90 wt%) and reusability (> 90% COD removal) in 5 successive cycles of treatment. LC-MS analysis revealed effective (> 50%) degradation of more than 25 significant contaminants (in the form of herbicides and pesticides) after the treatment with ternary hybrid AOP. Similarly, the toxicity analysis test using the seed germination technique revealed ~ 60% reduction in the toxicity of the wastewater after treatment.

Keywords : chemical oxygen demand (cod), fe3o4@ac nanocomposite, kinetics, lc-ms, rsm, toxicity
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