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Development of an efficient catalyst from magnetite ore: Characterization and catalytic potential in the ozonation of water toxic contaminants

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ABSTRACT

This study presents the preparation, characterization and activity of a novel natural mineral-based catalyst for the ozonation of water recalcitrant compounds. The raw and calcined magnetite had the specific surface area of 27 m^2/g and 34 m^2/g, respectively. The effects of solution pH, catalyst dose, model dye concentration, and reaction time on the degradation and mineralization of a selected reactive azo dye viz. Reactive Red-120 (RR-120) were evaluated. Calcined magnetite attained greater catalytic potential than the raw ore in the degradation of RR-120. Oxidation via radical species on the surface of the catalyst was the main mechanism of RR-120 degradation in the developed catalytic ozonation process, occurring with a pseudo-first-order reaction rate at a constant of 0.082 min^{-1} under the optimum pH of 11 and catalyst dose of 3 g/L. Accordingly, considering its abundance in nature together with its very high catalytic potential, calcined magnetite is a promising and reliable catalytic material for the ozonation of inhibitory and recalcitrant compounds in water and wastewater.

1. Introduction

Ozone, as the most powerful conventional oxidant, has received much attention for its application in the water and wastewater industries. Several applications of ozone in the water and wastewater fields have been reported mainly involving disinfection, taste and odor control, decolorization, and oxidation of organic and inorganic compounds [1,2]. Nonetheless, because of its low water solubility, low stability, and slow reaction rate with some organic compounds [1], the application of ozone for water and wastewater treatment is known as a cost-intensive technology. Therefore, to be cost-effective, the efficacy of single ozonation process (SOP) reactions need to be enhanced both by increasing the solubility of molecular ozone and via its decomposition to generate more active oxidant agents (such as •OH) with higher reaction rates. A promising and efficient alternative for enhancing the ozonation process is the addition of a homogeneous or heterogeneous solid as a catalyst into the ozonation reactor and creating a catalytic ozonation process (COP). Heterogeneous COPs have been shown to be more efficient at degrading the contaminants in water and wastewater. In a heterogeneous COP, the catalyst can enhance the ozonation reactions in several ways: the ozone interacts with the reactive functional groups on the catalyst's surface and generates very reactive oxidant species with much higher oxidation potential than molecular ozone through a chain of reactions; the catalyst provides a surface for the reaction of molecular ozone with the target compound; the catalyst can adsorb the compound, which finally reacts with dissolved ozone. The main significant concern in COP systems that still requires further investigation and documentation is the selection of a solid with both high potential for catalytic activity and low cost.

Materials such as activated carbon and activated carbon supported materials, metal ions and metal oxides alone and on supports, and natural (raw and processed) minerals have been investigated for their ability to catalyze the ozonation of several classes of toxic water and wastewater contaminants. Nawrocki and Kasprzyk-Hordern [3] recently reviewed the efficacy and mechanisms of ozonation catalyzed by various materials.

Reviewing the literature indicates that many synthetic and natural materials have been investigated for their potential to catalyze the ozonation of various classes of organic contaminants in water and wastewater including activated carbon, activated carbon supported catalysts [4–9], metal oxides such as MnO_2 [10], cerium, manganese and cobalt oxides [11], β-MnO_2 nanowires [12], TiO_2 [13] alumina [14], alumina supported catalysts [15–17], biomass, char and wood fly ash [18], modified diatomaceous porous fill [19], perovskite [20], zeolite [21], brucite [22,23], bauxite [24], goethite [25], and copper sulfide [26,27]. Although some of these synthesized materials have shown considerable catalytic activity in ozonation process, their production might be problematic from an environmental viewpoint and may be cost-intensive. These defects limit the application of synthetic catalysts in full-scale systems. To

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