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Indian
Journal of Advances in
Chemical Science

Indian Journal of Advances in Chemical Science S1 (2016) 236-238

Nano Zero-valent Iron for the Removal of Color and Chemical Oxygen Demand of Textile Effluent

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Received 22nd April 2016; Revised 23rd April 2016; Accepted 02nd May 2016

ABSTRACT

Nanoscale zero-valent iron (ZVI) was synthesized in the laboratory for treatment of textile wastewater in terms of color and chemical oxygen demand (COD) removal. The nano ZVI was synthesized by borohydride reduction method. The synthesized nanoscale ZVI particles were characterized by scanning electron microscope and particle size analyzer. Batch studies were carried under varied conditions of pH, dosage and contact time. COD was reduced to 85% from initial concentration of 9,600 mg/L and color reduced to 55% from initial absorbance value of 0.6596 at 655 nmat a pH of 2.48 at 150 min of contact time and an adsorbent dosage of 1.5 g. Color removal increased with a decrease in pH.

Key words: *Nano zero valent iron, Chemical oxygen demand, Color, Textile effluent.*

1. INTRODUCTION

Water is one of the most essential components required for survival of any life form on planet earth. In fact, it is the reason why life is possible on earth. All life forms depend on water, which makes water very important. Today, due to enormous population increase, economic growth, industrialization, and urbanization, nations are finding their water reserves insufficient to meet the rising demand. Not only industries demand huge quantities of water, but they also discharge large quantities of used water containing a variety of pollutants. Particularly, textile industries use large quantities of water for fabric processing and generate high quantities of liquid effluent, especially rich in dyes. Colored water released during the dyeing of fabrics may be the most problematic since even a trace of dye can remain highly visible with several adverse consequences for humans and other life forms, as well as to the environment. Other industries such as pulp and paper mills, dyestuff, distilleries, and tanneries also produce highly colored waste water. Although, there are some established technologies for color removal such as the use of activated carbon, peat, wood chips, fly ash, and brown coal, these have limited removal efficiencies. Nanotechnology started in early 1959 by the renowned physicist Richard Feynman has widespread applications. Nanomaterial's, typically range in size from 1 to 100 nm, and the application of nanomaterials for environmental remediation is promising. Dye is a colored substance that has an affinity to the substrate to which it is being applied. The dyes can adhere to compatible surfaces by solution or by forming covalent bond or complexes with salts or metals by physical adsorption or by mechanical retention. As dyes are generally stable and persistent organic pollutants in the environment, and due to concern that such artificial compounds are xenobiotic, methods for their degradation have been increasingly explored and developed. Environmental remediation with zero-valent iron (ZVI), also expressed as Fe_0 was born when Reynolds used iron in groundwater monitoring. Nowadays, iron is used to treat textile wastewater for the removal of dyes. Nano ZVI has recently become the most common metallic reducing agent (reductant) for environmental applications due to its abundance, low toxicity, low cost and effectiveness [1,2]. The reductive transformation of these contaminants (dyes) involves [3]:

- Direct electron transfer from ZVI at the surface of the iron metal (surface-mediated process).
- Reaction with dissolved Fe^{2+} or H_2, which are products of oxidative iron corrosion. Two electrons produced during the reaction with ZVI serving as the electron donor can be used to reduce relatively oxidized contaminants.

The general steps in reduction mechanism for dyes occur in several reaction steps as follows:

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i. Contaminant gets diffused into the solution and onto the metal surface
ii. Adsorption takes place on the metal surface
iii. Electrons get transferred from ZVI to contaminants, resulting in a chemical reaction
iv. Formation of intermediate (reduced) products and also corrosion of iron may take place due to oxidation
v. Diffusion to the solution and desorption of the product(s).

Due to their high surface area, unusual lattice planes, large number of highly reactive edges, corner defect sites and high surface to volume ratio, nanomaterials are used as effective adsorbents. They also offer the advantage of reduced volume of adsorbent when applied to real scale systems.

The objectives of the current study are to synthesize and characterize nano ZVI as an adsorbent and to evaluate the performance of nano ZVI in the reduction of color and chemical oxygen demand (COD) of textile wastewater.

2. EXPERIMENTAL

2.1. Nanomaterial Synthesis

Nano ZVI was synthesized using ferric chloride ($Fecl_3$) and sodium borohydride ($NaBH_4$) [4]. 5.406 g of $Fecl_3$ was dissolved in 4/1 volume of ethanol (240 ml) and deionized water (60 ml) in a beaker. In another beaker, 3.783 g of sodium $NaBH_4$ was dissolved in 1000 ml distilled water. For better growth of iron nanoparticles, the excess $NaBH_4$ solution is required. The above solutions are mixed in a separate 2L beaker and stirred using a magnetic stirrer for 10 min at an rpm of 160. It is allowed to settle for few minutes. The supernatant was washed off, and the iron particles were retained with the help of 2 No. Whatman Filter paper. Iron particles thus formed were washed with ethanol. This is the key step in the synthesis of nanoparticles, and it also prevents from rapid oxidation of ZVI. The nanoparticles were finally dried in oven at 50°C overnight. A thin layer of ethanol can be applied to prevent from future oxidation. The governing reaction of the formation of ZVI is given below.

$$2FeCl_3 + 6NaBH_4 + 18H_2O \rightarrow 2Fe^0O + 6NaCl + 6B(OH)_3 + 21H_2.$$

2.2. Characterization of ZVI

Synthesized nano ZVI was characterized for surface structure and particle size distribution using scanning electron microscope (SEM) and particle size analysis.

2.3. Adsorption Studies

Batch experiments were conducted to assess the performance of freshly prepared nano ZVI in the removal of color and COD of textile wastewater. Textile wastewater was initially characterized for various physicochemical parameters. Three adsorbent dosages were considered: 0.5, 1, and 1.5 g. The pH of the working samples was adjusted to 3, 4, and 5 using HCl or NaOH. Control was set up by keeping equal volume of the wastewater sample with varying pH levels (3, 4, and 5) in the same conditions without any addition of nano ZVI.

3. RESULTS AND DISCUSSION

The structure formation of nano ZVI is shown in SEM image presented in Figure 1a. Particle size of the synthesized ZVI confirms to the nano range (Figure 1b).

From the initial characterization of the textile wastewater, COD was found to be 9600 mg/L and color (measured in terms of absorbance) was 0.6596 at 655 nm. From the batch studies, it was evident that color removal percentage increased with a decrease in pH (Figure 2); percent removal of color for pH 6, 5, 4, and 3 were 49, 50, 52, and 55%, respectively. Furthermore, it can be noticed (Figure 3) that pH gradually decreased with time and subsequently color removal increased. This is because at lower pH there were a greater number of hydrogen ions present and thus, the degradation increased. The iron particles donate two electrons to the H^+ ions converting them into atoms which in turn attack the dye particles present in the wastewater, breaking them down to amines and rendering them colorless [5]. pH of 2.48, the adsorbent dosage of 1.5 g at a contact time of 150 min resulted in color removal efficiency of 55%.

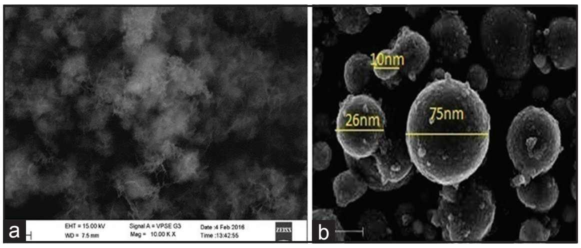

Figure 1: Scanning electron microscope image (a) and particle size image (b) of nano zero valent iron.

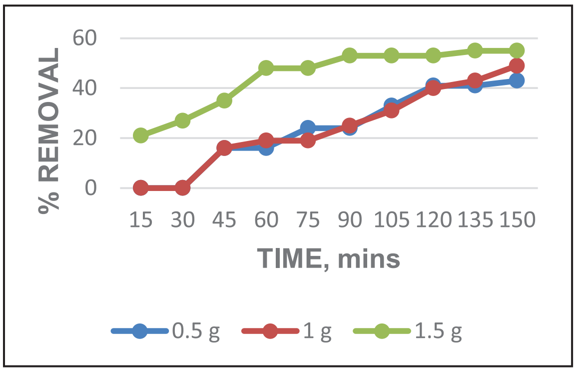

Figure 2: Color removal at pH 3.

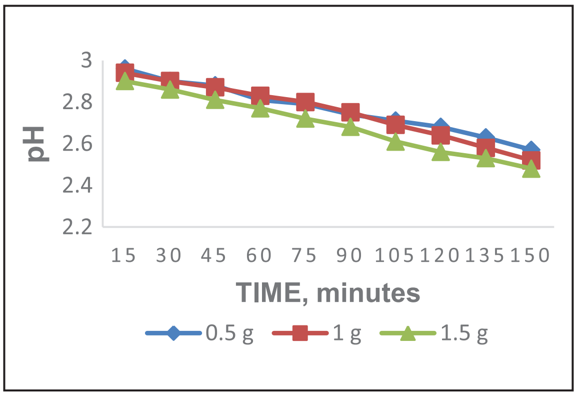

Figure 3: Decrease in pH level from pH 3.

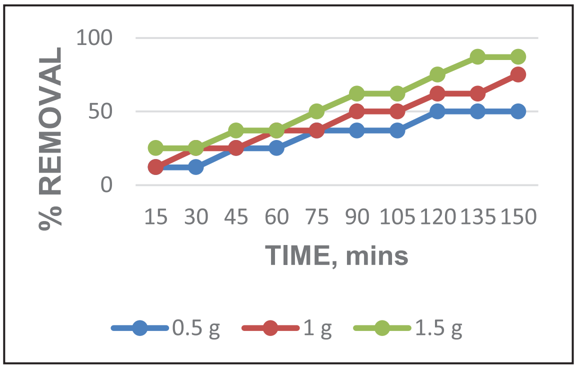

Figure 4: Chemical oxygen demand removal at pH 3.

From the Figures 2 and 4, it can be seen that higher adsorbent dosage resulted in higher removal efficiencies of color and COD. For an adsorbent dosage of 1.5 g and for 150 min of contact time, COD reduction at pH 6, 5, 4, and 3 was 80, 81, 81, and 87%.

4. CONCLUSION

ZVI particles in the nano range were successfully synthesized. The batch experiments were conducted to evaluate the performance of nano ZVI in the removal of color and COD of textile wastewater. Percentage of color removed was highest (55%) at a pH of 2.48 at 150 min of contact time and adsorbent dosage of 1.5 g. Greater the adsorbent dosage, greater was the COD reduced.

5. ACKNOWLEDGMENT

The authors would like to acknowledge imaging facility, IOE, University of Mysore, Manasa Gangothri, Mysore-06 for SEM images and particle size analysis.

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***Bibliographical Sketch**

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