ANALYSIS

40(183), September 1, 2015

ISSN 2278–5469 EISSN 2278–5450

Discovery

Optimization and treatment of phenol bearing wastewater under visible light with laboratory synthesized photocatalyst

Dharmendra[1]☼, Sri Hari P[2], Himanshu Gupta[2]

1.Asst. Prof. Dept. of Civil Engineering, NIT Hamirpur(HP) Pin – 177005, India
2.M. Tech Environmental Engineering, Dept. of Civil Engineering, NIT, Hamirpur (HP) Pin-177005, India

☼**Corresponding author:** Asst. Prof. Dept. of Civil Engineering, NIT Hamirpur (HP) Pin – 177005, India; Email- djha24@yahoo.com

Publication History
Received: 22 June 2015
Accepted: 10 August 2015
Published: 1 September 2015

Citation
Dharmendra, Sri Hari P, Himanshu Gupta. Optimization and treatment of phenol bearing wastewater under visible light with laboratory synthesized photocatalyst. *Discovery*, 2015, 40(183), 182-189

ABSTRACT

The synthesis of a new photo catalyst Fe-Zn/GAC, for treatment of phenol bearing wastewater under visible light and the optimization of different parameters like pH, catalyst dosage, H_2O_2 dosage and under different light intensities have been carried out. The final results depicts that the photo catalyst is a better alternative for the degradation of phenol bearing wastewater. Different series of experimentation were conducted and the optimized condition was establish as pH 3.0, catalyst dose 1.5g/L, Hydrogen peroxide loading 1.35 ml/L and under 100W incandescent lamp with 5 hours of reaction time, the TOC degradation in most cases has reached greater than 80 Percent.

Keywords: Phenol, Visible Light, Photo Catalyst, Wastewater

1. INTRODUCTION

The micro-polluted water has always been a serious threat to mankind, which is a major dependant on water. Especially the trace organic contaminants had already been a worldwide problem. Phenol is a kind of refractory organic compound, having the toxicity of carcinogenesis, teratogenesis and mutagenicity (Lu et al., 2000). Phenol is extensively present in the wastewaters emitted by paper mills, pharmacies, pesticides factories, etc., because phenol is a raw material or an intermediate in these industries. Phenol may cause harmful effects on the central nervous system and heart, resulting in dysrhythmia, seizures, and coma (Warner and Harper,1985)).

The treatment of phenol in micro-polluted water has always been paid attention by many researchers. The traditional purification technique has been not suitable for the existing water source and water quality standards. Therefore, it is necessary to develop low cost and high efficient treatment technique. Photocatalysis under solar light has attracted worldwide attention because of its potential applications in water splitting and degradation of organic contaminants (Hoffmann et al., 1995). So, it is required to develop a technique with low energy consumption and freely available sources.

Phenol degradation by the use of visible light is a best alternative available currently. But, for achieving this it is necessary to use suitable photo catalyst for enhancing the rate of degradation. A number of research studies have used salts and oxides of transition metals (like Cu, Fe, Zn, Mn, Ni, Cr, Co) as homogeneous and heterogeneous catalysts, respectively (Kulkarni and Dixit, 1991). In most of the works reported it was found that, TiO_2 is an effective photocatalyst because of its chemical stability, low cost and non toxicity within a wide range of pH (Hoffmann et al., 2003). TiO_2 can be activated only under UV light of wavelengths <387 nm irradiation due to its large band gap of 3.2 eV. The solar spectrum usually contains about 5% UV light. Owing to this innate limitation, the solar energy cannot be utilized efficiently in the photocatalytic process (Hong et al., 2005). About 40-60 percent mineralization is achieved with these reagents depending upon the amount of hydrogen peroxide added to the reaction mixture, but the extent of mineralization is reported to be independent of the oxidation state of Fe (Ruppert et al., 1993) and Pignatello, 1992).

Considering these factors, we have decided to prepare a photo catalyst, for the phenol bearing wastewater degradation in terms of TOC. Fe-Zn/GAC was the catalyst synthesized. Degradation experiments were performed with the addition of different amounts of photo catalyst and H_2O_2 under an incandescent lamp to optimize various parameters. This work may provide new insights for the design and preparation of new high efficiency visible light photo-catalyst.

2. MATERIALS AND METHODS

Granular activated charcoal (GAC) was procured from NICE chemicals, India. Ferric nitrate ($Fe(NO_3)_3.9H_2O$) was procured from Thermo fisher scientific. Sodium hydroxide (NaOH) was bought from Ranbaxy. Sulphuric acid was procured from Rankem. Zinc nitrate ($Zn(NO_3)_2.6H_2O$) and Hydrogen peroxide (H_2O_2) were purchased from Merck. Phenol (C_6H_6O) from Hi Media was used as a pollutant in synthetic wastewater for photocatalytic experiments. Visible light source were incandescent lamps of 15W, 100W, 200W of Crompton Greaves Company, and their light intensities are of 110 lumens, 1320 lumens, 3000 lumens respectively, according to the information provided by the manufacturer. Double distilled water was used for all the experimentations.

2.1. Synthesis of Fe-Zn/GAC

GAC was first tested for weight loss and ash conversion percent by keeping some amount of it in muffle furnace at a temperature of 350^{0}C for 3 hours. GAC found to sustain its weight up to 99 percent and little ash conversion was observed thus making it being considered for doping Iron and Zinc over the surface of GAC. Under continuous stirring over magnetic stirrer (Remi equipments make), 3.640 gm of Ferric nitrate and 2.275 gm of Zinc nitrate hexahydrate were dissolved in 50 mL of distilled water at 30^{0}C temperature. Alongside GAC was washed with distilled water for removal of fine remains of charcoal on its surface, then added to the solution over the magnetic stirrer and left over for 2 hours. Later, the mix was kept in an oven at 105^{0}C for 12 hours, from there it has been transferred to muffle furnace, temperature maintained at 350^{0}C for 3 hours. The resulting Fe-Zn/GAC was the catalyst prepared to target Phenol synthetic wastewater model pollutant.

2.2. Characterization of Fe-Zn/GAC

Scanning electron microscopy (SEM) images and elemental maps were obtained using a Quanta FEG 450 scanning electron microscope equipped with an energy dispersive X-ray microanalysis (EDX) system.

2.3. Photolytic studies

The photo degradation of 100mg/L phenol wastewater was performed by adding 0.5-2 g/L of catalyst Fe-Zn/GAC and with different parts of oxidant loading 0.5-2 times a mole phenol maintained at pH ranges 2.0-5.0 under different light intensities of incandescent lamp (15W, 100W, 200W). All the experiments were conducted at temperatures maintained at 32 ± 0.5^{0}C for 5 hours duration each.

2.4. Photocatalytic degradation

The photocatalytic degradation were done by batches studies. Each batch had 100mL of synthetic phenol wastewater treated under visible light for 5hours each. samples were were filtered through 0.45µm filter (Millipore Millex) and analyzed for residual concentrations of total organic carbon (TOC) by the use of visible light spectrophotometer (HACH DR 2800). To assess the impact of pH on the photo-catalytic efficiency of Fe-Zn/GAC experiments performed at pH ranging from 2.0 to 5.0. After determination of the optimal pH, additional parameters, including the catalyst dose, oxidant (H_2O_2) loading, light intensities were evaluated.

3. RESULTS AND DISCUSSION

3.1. SEM and EDX

The present study analysis was used to test the doping of bi-metal, Fe and Zn onto the surface of GAC. From the below shown magnified SEM image of the photocatalyst, Figure 2 it is clearly visible that the Iron and Zinc were doped properly on the surface of the commercial GAC. And from Figure 3, the information of various percentages of elemental composition present on the surface after doping was observed. It is observed that Fe and Zn comprise 26.64% and 11.02% of the total weight of the synthesized catalyst respectively.

3.2 Effect of pH

In oxidation process, pH of the solution plays vital role on removal efficiency for the oxidation of organic wastewater. The natural pH of 100 mg/L phenol solution was found to be 6.2–6.3. In this study, pH of the phenol-containing aqueous solution was varied in the range of 2–5. For obtaining desired pH, 1N H_2SO_4 and 1N NaOH was used. The reaction was carried out at 30-35^{0}C for 5 hrs with a catalyst dose (Fe-Zn/GAC) of 1g/L and 1.3 mL/L dose of 30 wt % of H_2O_2. The results are shown in Figure in terms of TOC removal. It

clearly indicates that the degradation of the phenol increases with an increase up to 3. Furthermore for pH >3, removal efficiencies decreased. Considering these reasons, further studies were carried out at pH 3.0 only.

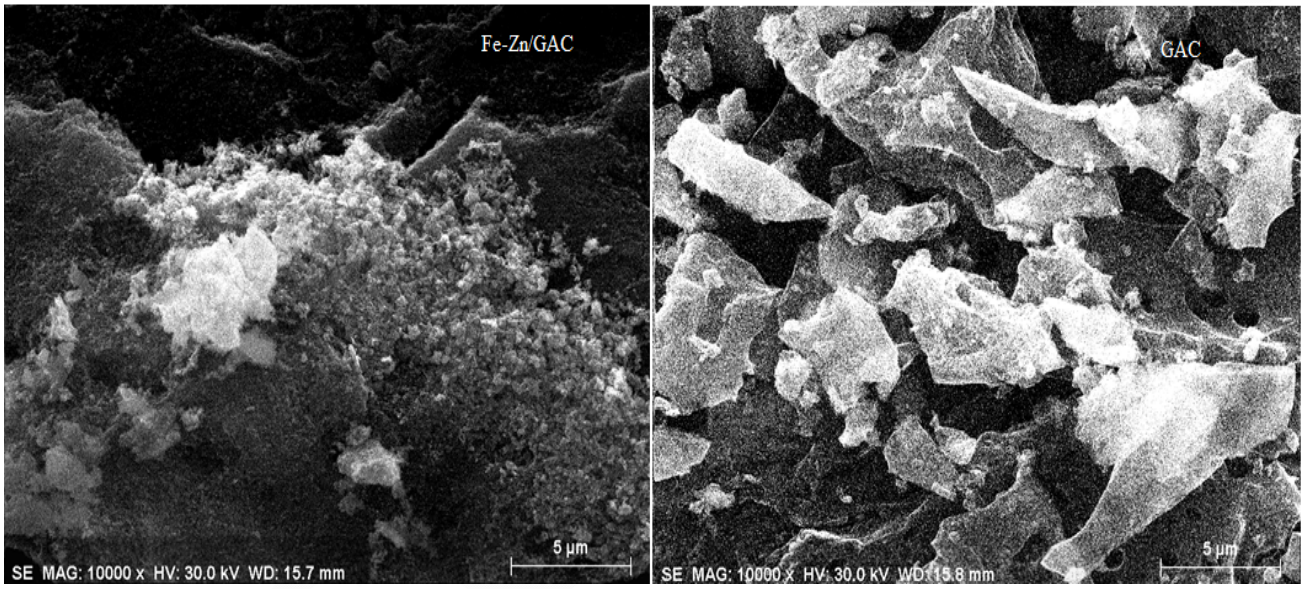

Figure 1 SEM images of photocatalyst and granular activated carbon

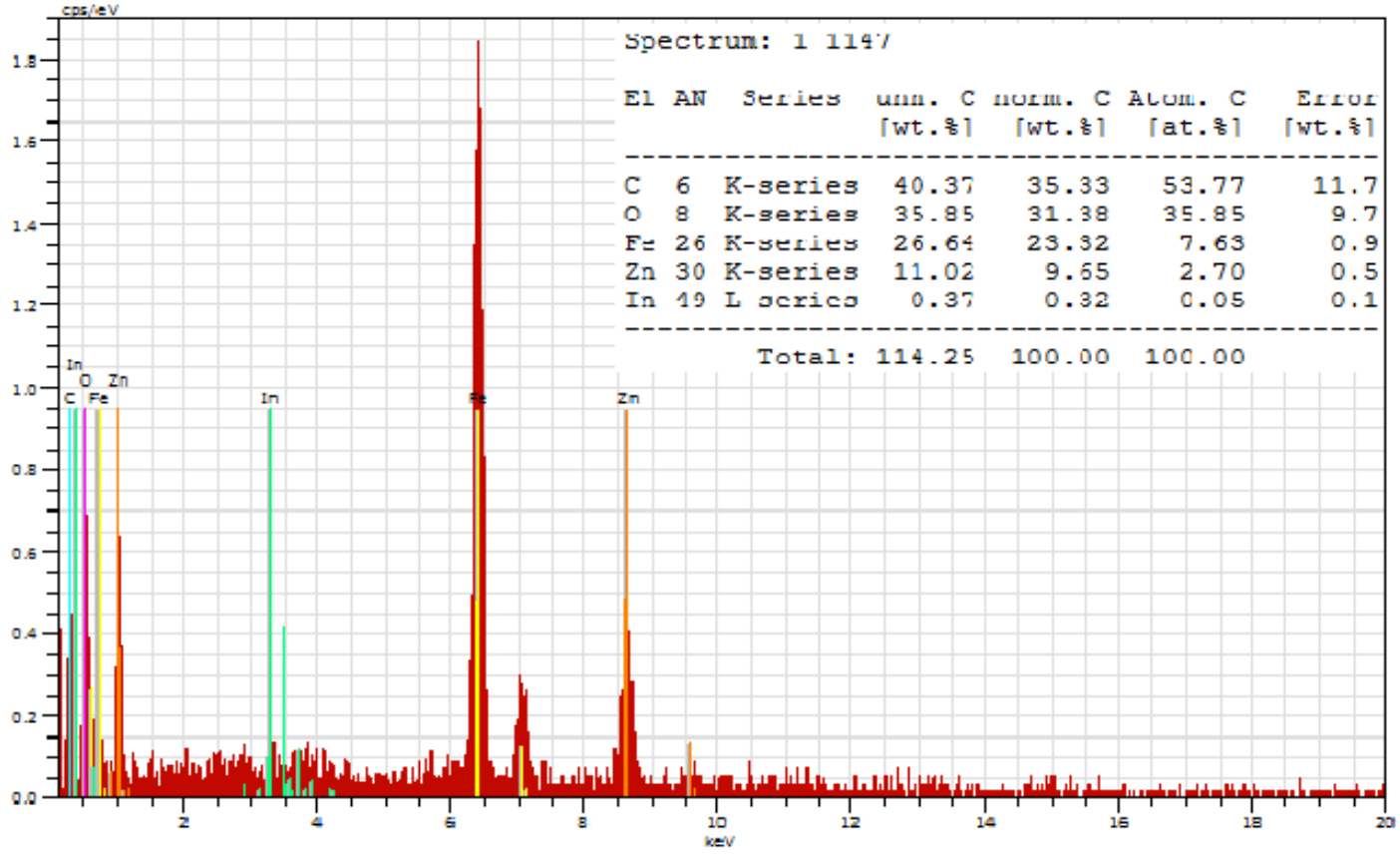

Figure 2 EDX graph depicting elemental composition of the photocatalyst

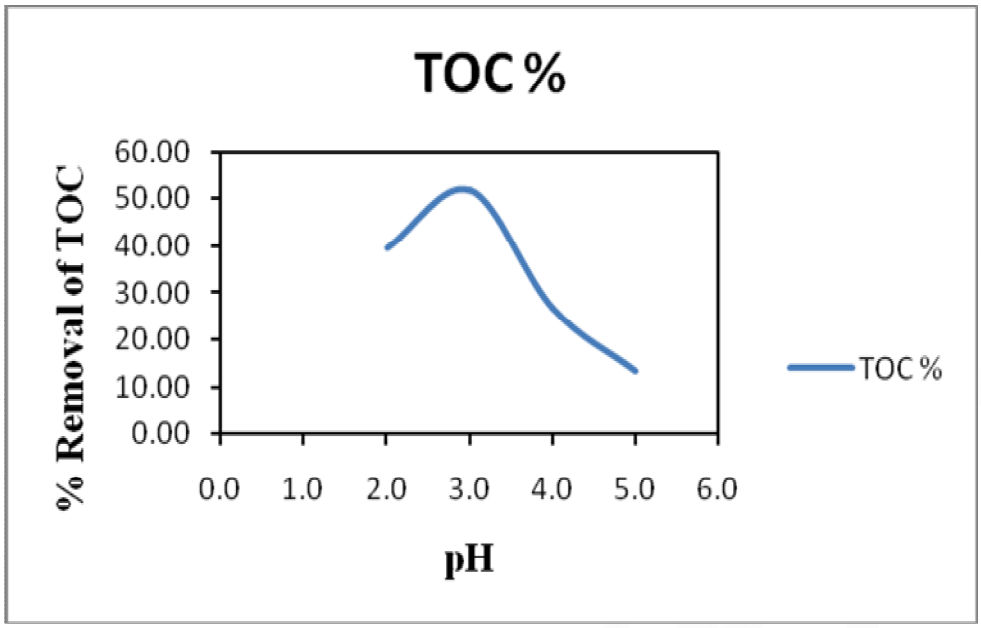

Figure 3 Effect of pH on %TOC degradation

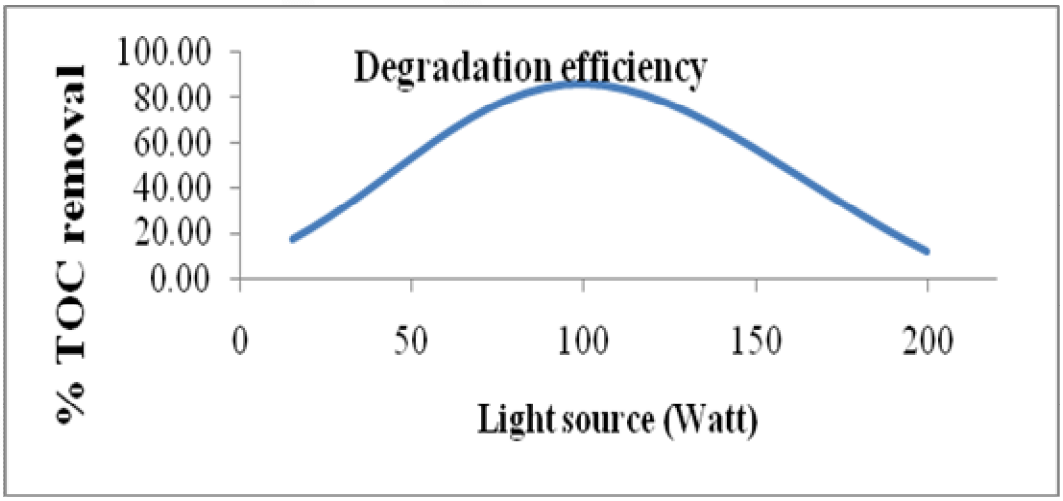

Figure 4 Effect of Light source on %TOC degradation

3.3 Effect of light intensity

The below Figure shows the degradation efficiency of light intensities from incandescent lamps (15W, 100W, 200W) for the degradation of phenol in the presence of optimized amounts of catalyst, H_2O_2 under the conditions of pH 3.0 and temperature 30-35^{0}C. The values indicate that maximum degradation was obtained by using the light source 100W. With this result the optimum conditions for treatment of phenol were set.

4. CONCLUSION

In this study, the Fe-Zn/GAC catalyst was developed and adopted to degrade phenol wastewater. The optimized conditions obtained by experimentation for degradation of 100mg/L are at pH 3.0, 1.5 g/L Fe-Zn/GAC, 1.35 ml/L H_2O_2 under the irradiation of 100W incandescent lamp of light intensity 1320 lumens. The results have shown that Fe-Zn/GAC is a good photo-catalyst for mineralization of phenol under visible light.

REFERENCE

1. Chiou C H., Wu C Y., and Juang R S., (2008). Photocatalytic degradation of phenol and m-nitrophenol using irradiated TiO_2 in aqueous solutions. Seperation and Purification Technology 623. pp 559–564.
2. Dhananjeyan MR., Mielczarski E., Thampi KR., Buffat P., Bensimon M., Kulik A., Mielczarski J., and Kiwi J., (2001). Photodynamics and surface characterization of TiO_2 and Fe_2O_3 photocatalysts immobilized on modified polyethylene films. The journal of physical chemistry 105. pp 12046–12055.
3. Ho C H., Clark R B., and Guerin M R., (1976). Direct Analysis of Organic Compounds in Aqueous By-Products from Fossil Fuel Conversion Processes. Journal of Environmental Science and Health 7. pp 481-489.
4. Hoffmann M R., Martinn S T., Choi W., and Bahnemann D., (1995). Environmental applications of semiconductor photocatalysis. Chemical Reviews 95. pp 69-96.
5. Hoffmann M R, Herrmann J M., Fujishima A., and Salem I., (2003). Recent Studies on the Catalytic Activity of Titanium, Zirconium, and Hafnium Oxides. Catalysis Reviews 45. pp 205-296.
6. Hong T., Wang Z P., Cai W M., and Lu F., Zhang J., Yang Y Z, Ma N, and Liu Y J., (2005). Visible-light-activated nanoparticle photocatalyst of iodine-doped titanium dioxide. Chemistry of Materials 17. pp1548–1552.
7. Keith L H., and Telliard W A., (1979). Priority Pollutants I, A Perspective View. Environmental Sciences and Technology 13. pp 416-423.
8. Kulkarni S U., and Dixit S G., (1991). Destruction of phenol from wastewater by oxidation with SO_2^{3-}-O_2. Industrial & Engineering Chemistry Research 30(8). pp 1916 –1920.
9. Lu W Z., Li B G., and Li Y C., (2000). Technique of industrial water treatment. Oil-Chemistry Engineering Publisher of China 12. pp 67-82.
10. Pignatello J., (1992). Dark and photoassisted iron(3+) catalyzed degradation of chlorophenoxy herbicides by hydrogen peroxide. Journal of Environmental Science and Technology, 26. pp 944-951
11. Ruppert G., Bauer R., and Heisler G J., (1993). Mineralization of Azo Dye Using Combined Photo-Fenton and Photocatalytic Processes under Visible Light. Journal of Photochemistry and Photobiology A: Chemistry 73. pp 75-78.
12. Wang W Y., and Ku Y., (2006). Photocatalytic degradation of Reactive Red 22 in aqueous solution by UV-LED radiation. Water Research 4012, pp 2249–2258.
13. Warner M A., and Harper J V., (1985). Cardiac dysrhythmias associated with chemical peeling with phenol. Anesthesiology 62. pp 366–367.

14. Zhan Y., Zhoua X., Fua B., and Chen Y., (2011). Catalytic wet peroxide oxidation of azo dye (Direct Blue 15) using solvothermally synthesized copper hydroxide nitrate as catalyst. Journal of Hazardous Materials 187. pp 348–354.