



Removal of phenol from steel industry wastewater by using electron beam

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Abstract

The degradation of phenol by electron beam irradiation in aqueous laboratory solutions and also in a real wastewater of steel industry has been investigated. The standard solutions of phenol in the range of 5-22kGy underwent electron irradiation and their concentration before and after the exposure was measured using UV-Vis spectrophotometer, for this purpose absorbance of solution was measured at 460 nm. The concentration of phenol in the effluent before and after irradiation at 10kGy was measured by GC/MS analysis. The effect of experimental parameters like absorbed dose and initial concentration on the efficiency removal was studied. According to the observations, with increasing absorbed doses the removal percentage increases and also by increasing the concentration the amount of removal gradually decreases. In the optimum dose, 10 kGy, the removal percentages of phenol in the standard solution with concentration of 10 mg/L and wastewater of steel industry were 93.5% and 41%, respectively.

Keywords: Electron Beam, wastewater, steel industry, phenol

Introduction

Iron and steel industry are the principal driving force propelling economic and technological growth of a nation. However, since its inception this industry is associated with widespread environmental pollution and enormous water consumption. Different units of a steel plant discharge effluents loaded with toxic, hazardous pollutants, and unutilized components which necessitates mitigation [1]. Phenol discharging from steel industry effluents, in addition to discharging from chemical plants, pharmaceuticals, and petroleum refineries resulted in its wide existence in the environment [2]. Radiation processing is capable of efficient decomposition of pollutants inside the wastewater through fast formation of short-lived reactive particles. In this study, phenol degradation by electron beam irradiation in the model solutions and real steel industry wastewater have been investigated.

Experimental

Materials and methods

All chemicals and reagents were of analytical grade (AR) or highest purity available, obtained from Merck (Germany) and Panreac (Spain), and aqueous solutions were prepared in double distilled water. The stock solution of phenol was prepared by dissolving appropriate amount of it in doubly distilled water. Experimental solutions of the desired concentrations were obtained by successive dilution. Other materials used in this study include 4-aminoantipyrine, potassium ferricyanide, chloroform, and ammonia. The wastewater of the steel industry was prepared from a steel plant in Iran.

Electron beam irradiation was performed with a Rhodotron TT200 accelerator (Belgium). A digitally calibrated pH meter Mettler Toledo, model Seven Easy (Switzerland). The analytical determination of phenol was carried out using UV-Vis spectrophotometer Beckman coulter, DU800 (USA). Gas chromatography-mass spectrometry (GC/MS) Aligent, model 7890A (USA) was used to measure the concentration of phenol in the wastewater before and after irradiation.

Experimental method

The samples were irradiated with 10 MeV electron beam accelerator. The irradiation was performed by using plexi-glass vessels with dose range of 5-22 kGy. According to the 4-aminoantipyrine method, sufficient ammonia was added to 10 mL of the phenol-containing sample to produce a final pH of 10±0.2. Then 0.5 mL of 4-aminoantipyrine solution (1% w/v) and then 2.5 mL of potassium ferricyanide solution (1% w/v) were added and the solution was thoroughly stirred. Extraction was performed with chloroform with a volume of 5 mL. Absorbance of organic solution was measured at 460 nm by spectrophotometer after extraction. The efficiency of phenol removal was calculated by following equation [3]:

$$\% \text{Removal} = \frac{A_0 - A_1}{A_0} \times 100$$

Where A_0 and A_1 are the absorbance of phenol solutions before and after treatment, respectively.

Results and discussion

Effect of radiation dose

Aqueous solutions of phenol with concentration of 10 mg/L were exposed to radiation at doses of 5, 10, 17 and 22 kGy. The relationship between degradation efficiency

and absorbed dose was investigated. Figure 1 shows the effect of irradiation dose (5-22 kGy) on the degradation of phenol. For the aqueous solution of phenol, the removal percentage in 5 kGy dose is 72% and this amount increases with increasing dose (93.5, 96.55, and 98.27 % with 10, 17, and 22 kGy, respectively). Since there on 10 kGy dose, the removal percentage is more than 90%, this dose is selected as the optimal dose.

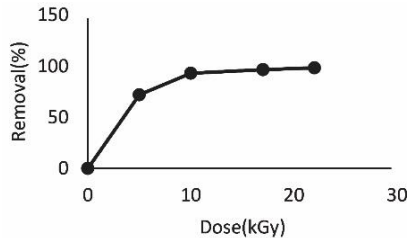


Figure 1. Effect of radiation dose on the removal of phenol;
(initial phenol concentration = 10 mg/L)

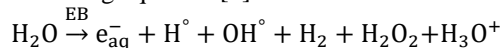
Effect of initial concentration

The initial concentration of phenol solution was varied from 1.5 to 10 mg/L (1.5, 3, 6 and 10 mg/L), and the samples were irradiated with 10 kGy dose. The percentage removal of phenol vs various concentrations has been shown in figure 2. As seen, the highest percentage removals are obtained for 1.5 mg/L solution (93.1, 94.2, 95.6 and 98.3 % with 10, 6, 3 and 1.5 mg/L, respectively).

Therefore, the results show that with increasing the initial concentration in a constant dose, the removal percentage decreases.

Proposed mechanism for degradation of phenol

Irradiation of water with ionizing radiation produces ionized and excited water molecules and free electrons as following equation [4]:



It seems that phenol is converted to oxalic acid and benzoic acid by reaction with hydroxyl radicals induced by radiolysis of water [5].

Treatment of steel industry wastewater

First, the sample containing phenol was filtered with filter paper then spilled in plexi-glass vessels. Afterward, irradiation was carried out under 10 kGy dose. The results obtained by GC/MS showed that the removal percentage of phenol from this effluent is 41% (figure 3, figure 4).

Conclusions

Based on the results of the experiments, it can be concluded that degradation of phenol by means of electron beam irradiation is a promising method with high performance. The results also show that the amount of initial concentration and irradiation dose are effective in the removal of phenol by using the electron beam.

Several advantages of this method are: (1) The process is a physical process and requires no additional chemicals, (2) This method does not damage the environment, (3) The application of electron beam processing for wastewater treatment is a cost effective process.

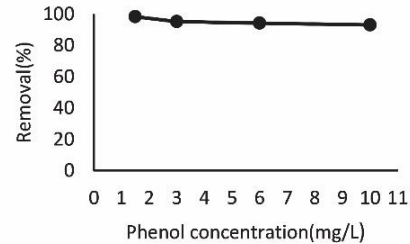


Figure 2. Effect of initial phenol concentration on its removal; radiation dose = 10 kGy.

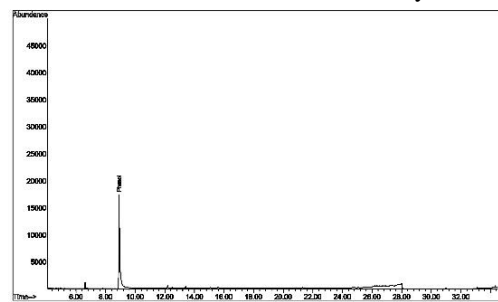


Figure 3. GC-MS chromatogram of the effluent containing phenol before irradiation

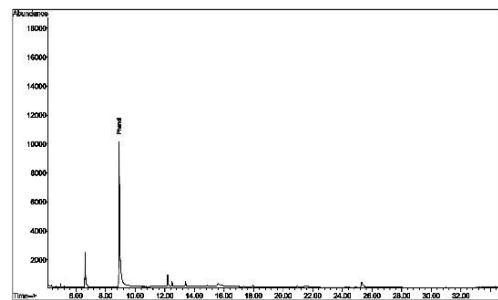


Figure 4. GC-MS chromatogram of the effluent containing phenol after irradiation

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