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The effect of ultrasound on phenol adsorption onto granular activated carbon

Jung hyun lim, Yong gyu Son, Eun ju Cho, Hyun jun Kim, Ming can Cui and Jee hyeong Khim (School of Civil, Environmental and Architectural Engineering, Korea University)

1. Introduction

Phenolic compounds which are generated by petroleum and petrochemical, coal conversion and phenol producing industries, are common contaminants in wastewater. Phenols are widely used for the commercial production of a wide variety of resins including phenolic resins, which are used as construction materials for automobiles and appliances, epoxy resins and adhesives, and polyamide for various applications [1,2]. Phenols are considered as priority pollutants since they are harmful to organisms at low concentrations and many of them have been classified as hazardous pollutants because of their potential to harm human health. Increasing concern for public health and environmental quality has led to the establishment of rigid limits on the acceptable environmental levels of specific pollutants. Because of their toxicity, phenols have been included in the US Environmental Protection Agency (EPA) list of priority pollutants [3]. Thus, the removal or destruction of phenols from process or waste streams becomes a major environmental problem. Adsorption is well-established technique for the removal of low concentrations of organic pollutants from potable water, wastewater and aqueous solutions. Activated carbon is one of the most effective adsorbents for organic compounds because of their extended surface area, high adsorption capacity, microporous structure and special surface reactivity. Ultrasound has been proven to be a very useful tool in intensifying the mass transfer process and breaking the affinity between adsorbate and adsorbent. Systematically yet. The objective of the present work was to investigate the adsorption kinetics of phenol from aqueous medium containing 20% (v/v) 1-butanol onto GAC in the presence of ultrasound for different ultrasonic powers. The removal of phenol without the addition of 1-butanol in the presence of ultrasound is due to both adsorption and ultrasonic degradation, but the removal by simple stirring is only due to adsorption. In order to suppress the ultrasonic degradation and make a correct and viable comparison of the adsorption in the absence and presence of ultrasound, 1-butanol was used during adsorption experiments. The goal of the present work is to clarify the effect of ultrasound on the adsorption of phenol by activated carbon rather than an enhancement of the removal of phenol from aqueous solutions In order to gain insight into the dynamics of the process, the mechanism controlling the rate of adsorption was also studied. The sonochemical degradation of phenol and the scavenging effect of 1-butanol alcohol were investigated.

hyeong@korea.ac.kr

2. Material and method

Phenol supplied by samchun (99.0 %) was used as an adsorbate. Granular activated carbon (GAC) employed as the adsorbent in the present study was supplied by samchun. Prior to use, the carbon was pretreated by washing repeatedly in D.I. water for 1 h. The ultrasonic irradiation was carried out with equipment operating at 170 kHz. In the case, the ceramic transducer is located at the side of the vessel. The ultrasonic waves were introduced from the side of the solution. The cylindrical reactor was thermostated by a water jacket. The temperature inside the reactor was kept constant. Acoustic power dissipated in the reactor was measured using standard calorimetric method. In all adsorption experiments, phenol solutions of 100 mgL^{-1} were prepared by dissolving the appropriate amount in 20% (v/v) 1-butanol aqueous solution. For the determination of adsorption kinetics onto GAC in the presence of ultrasound, an adsorbent weight of 1 g was transferred to the ultrasonic reactor containing a volume of 100 mL of phenol aqueous solution at a concentration of 100 mgL^{-1}. The temperature was maintained constant and equal to 294 ± 3℃ K. Strong convective currents occur within the reactor here and there along the transducer axis. These effects associated with hydrodynamic phenomenon due to cavitation are responsible for the perfect mixing of the reactor content. It was thereby established that under ultrasonic irradiation the used reactors are completely stirred tank reactor. Identical experiments were repeated in the absence of ultrasound using a glass reactor and a magnetic stirrer with a stirring speed of 50 rpm. The reactor provides uniform mixing conditions due to continuous agitation. All other conditions, such as temperature and pH, were the same as those used for ultrasound-assisted adsorption. After selected times of sonication (or stirring), the adsorption kinetics was determined by following the phenol concentration change in the reactor. The amount of phenol adsorbed at any time t was calculated. All experiments were conducted in triplicate and the mean values were reported.

3. Result and discussion

In order to make a practical evaluation of the adsorption of phenol by GAC by the conventional method and ultrasound-assisted method, adsorption experiments were carried out using aqueous solution of phenol containing 20% (v/v) 1-butanol. Therefore, the effect of 1-butanol (20%, v/v) on the adsorption kinetics of phenol was investigated in the absence of ultrasound. Adsorption kinetics was determined for an initial concentration of 100 mgL^{-1}, an adsorbent dosage of 1 g/100 mL and a stirring speed of 50 rpm.

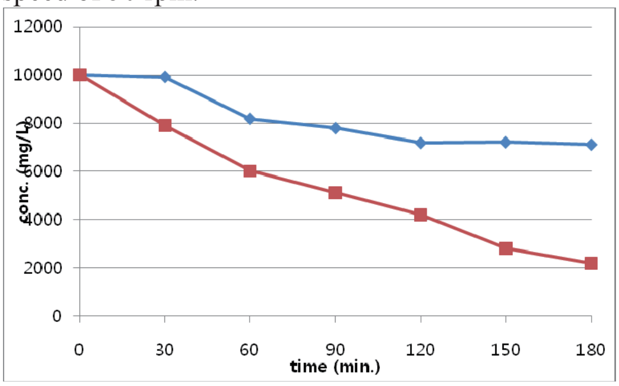

Fig. 1. Adsorption kinetics of phenol onto GAC in the absence and presence of 20% (v/v) 1-butanol (-■- without 1-butanol -◆- with 1-butanol)

Fig. 1 shows the adsorption kinetics of phenol onto GAC in the absence and presence of 1–butanol. It was observed that the adsorption decreases significantly in the presence of 1–butanol. The significant decrease of the adsorbed amount in the presence of 1-butanol is due to the competitive effect between phenol and 1-butanol for the sites available for the adsorption process. Additionally, 1-butanol screens the interaction between adsorbent and phenol molecules and the considerable increase of the solubility of phenol in the medium may be another reason for the decrease of the adsorbed amount. Utilization of 1-butanol decreases the adsorption amount, but the goal of the present work is to clarify the effect of high frequency ultrasound on the adsorption of phenol by activated carbon rather than an enhancement of the removal of phenol from aqueous solutions.

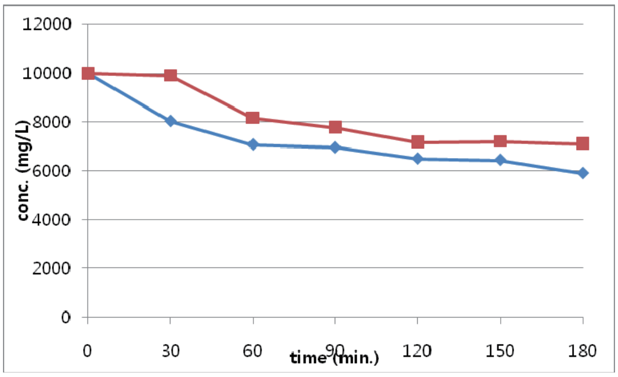

Fig. 2 Adsorption kinetics of phenol onto GAC with ultrasound (-■- without ultrasound -◆- with ultrasound)

Adsorption kinetic results of phenol from aqueous solutions containing 20% (v/v) 1-butanol onto GAC determined in the absence and presence of ultrasound. Comparison of the obtained kinetic curves shows that adsorption rate was significantly enhanced and improved in the presence of ultrasonic irradiation. The enhanced adsorption rate by sonication may be attributed to the extreme conditions generated during the violent collapse of cavitation bubbles. When the bubble is collapsing near the solid surface symmetric cavitation is hindered and collapse occurs asymmetrically. The asymmetric collapse of bubbles in a heterogeneous system produces micro-jets with high velocity. Additionally, symmetric and asymmetric collapses generate shockwaves, which cause extremely turbulent flow at the liquid–solid interface, increasing the rate of mass transfer near the solid surface.

Ackwodge

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