Journal of Water Process Engineering 8 (2015) 45–54

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

Treatment of hydroquinone by photochemical oxidation and electrocoagulation combined process

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ARTICLE INFO

Article history:
Received 24 January 2015
Received in revised form 27 August 2015
Accepted 3 September 2015
Available online 19 September 2015

Keywords:
Electrocoagulation
Photochemical oxidation
Aluminum electrode
Hydroquinone
p-Benzoquinone

ABSTRACT

Today, considerable attention has been focused on the improved elimination of non-biodegradable pollutants through hybrid (combined) processes. In this study, a combination of electrocoagulation (EC) and photochemical oxidation (PCO) was proposed for the removal of hydroquinone (HQ) from aqueous solution. The experiments were carried out to investigate the effects of current density, HQ concentration, UV light power and different combination of both processes (EC and PCO recirculation loop process, only EC, only PCO with or without air supply) on the removal efficiencies of HQ and *p*-Benzoquinone (BQ). Furthermore, the adsorption capacity of aluminum hydroxide electrocoagulant flocs was calculated and the oxidation extent of HQ to BQ was investigated. According to the results, HQ removal efficiency increased nearly 40% owing to air supply in the reaction medium, while high removal extent of BQ by electrocoagulant flocs increased the performance of the EC–PCO process which allowed the removal extent of HQ to be as high as 91.5% at the following operating conditions; current density: 5 A/m^2, UV light power: 24 W (37 W per dm^3 of the solution), operating time: 60 min.

1. Introduction

Phenol as well as phenol derivatives such as hydroquinone (HQ) present in wastewater effluents from many industrial processes have been a serious environmental hazard, as they are considered as priority pollutants because of their high toxicity. These phenolic compounds are used so they emerge in wastewaters of various branches of chemical process industries such as coke, synthetic coal fuel conversion, petrochemical, pharmaceutical plants, petroleum refinery, dye, plastic, pulp and food-paint processing industries [1–4]. Specifically, HQ is used as a developing agent in photography, lithography, X-ray film, dye and pigments and as an intermediate to produce antioxidants for rubber and food [5]. HQ is a typical intermediate product in the oxidation of most aromatic products. Furthermore, HQ has been also detected in cigarette smoke and in diesel engine exhaust, and it is released to the atmosphere from production of coal-tar chemicals and from coal gasification condensate water [6].

Occupational exposure to HQ may occur by inhalation or dermal contact. Headache, dizziness, nausea, vomiting, dyspnea, erosion of the gastric mucosa, edema of internal organs, cyanosis, convulsions, delirium, and collapse may result from the ingestion of a large amount of hydroquinone in humans [6]. HQ is also a skin irritant in humans. Long-term occupational exposure to HQ dust can result in eye irritation, corneal effects, and impaired vision. US Environmental Protection Agency (EPA) has not yet classified hydroquinone for carcinogenicity, but there are some evidences of carcinogenic activity in orally-exposed rodents and increased skin tumor incidence has been reported in mice treated dermally [6]. On the other hand, HQ in wastewater is a protoplast poison [7]. Phenol is toxic to fish at 1–2 mg/L concentration level [8] and it is considered lethal to most of the aquatic organisms exposed to concentrations of 10–100 mg/L [9]. Moreover, these aromatic products cause to severe illnesses such as leukemia [10] and some serious human organ malfunctions [11]. Consequently, phenolic compounds are toxic for human health and constituting an important environmental hazard.

Hence, wastewaters contamined by these compounds should be treated before discharged sewage system. Many efforts have been made for the conventional physicochemical and biological treatment methods of wastewater rich in phenolic compounds. However, these methods have some disadvantages. For example, adsorbents, are usually difficult to regenerate them and have a high

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http://dx.doi.org/10.1016/j.jwpe.2015.09.001
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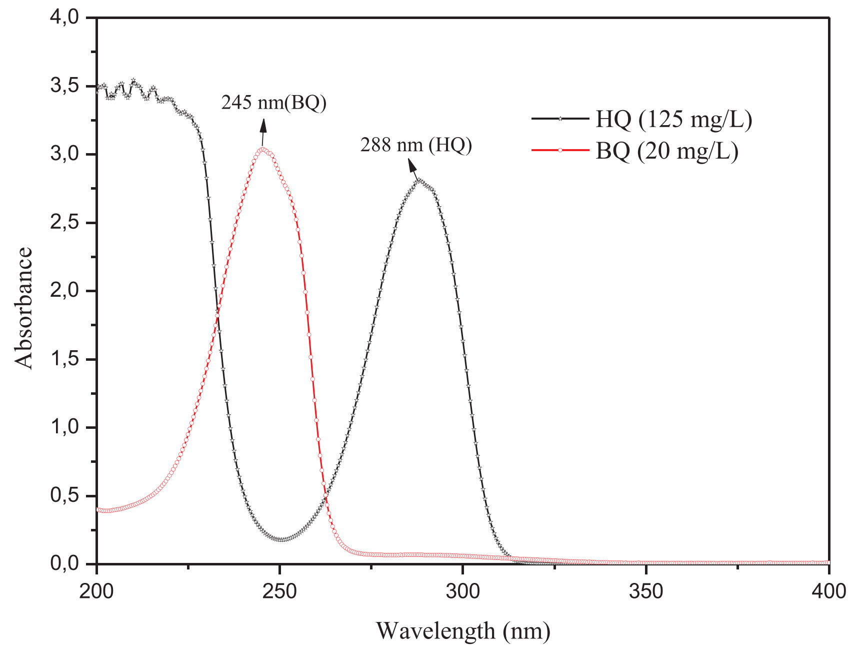

Fig. 1. The UV absorbance spectrum of the HQ and BQ solutions.

waste disposal cost. Chemical coagulation causes extra pollution due to the undesired reactions in treated water and produces large amounts of sludge. Biological methods are not suitable for some types of wastewater due to the harmful effects of some chemicals on the organisms. Such wastewaters are needed to further treat in another process. On the other hand, advanced oxidation processes (AOPs) have been defined as eco-friendly and cost-effective processes for treatment of wastewater containing toxic and persistent organic pollutants [12–15].

Electrocoagulation (EC) has some significant advantages namely; simple equipment and easy operation and automation, a shorter retention time, high sedimentation velocity, more easily dewatered reduced amount of sludge due to the lower water content [16]. This process also requires generally no chemical adjustment of the wastewater and little space. It removes pollutants, principally by coagulation, adsorption, precipitation and flotation [17,18]. It has been successfully used to treat the wastewaters of olive mill [19,20], phosphate [21,22], surfactant [23], food process [24,25], semiconductor [26], chemical mechanical polish-

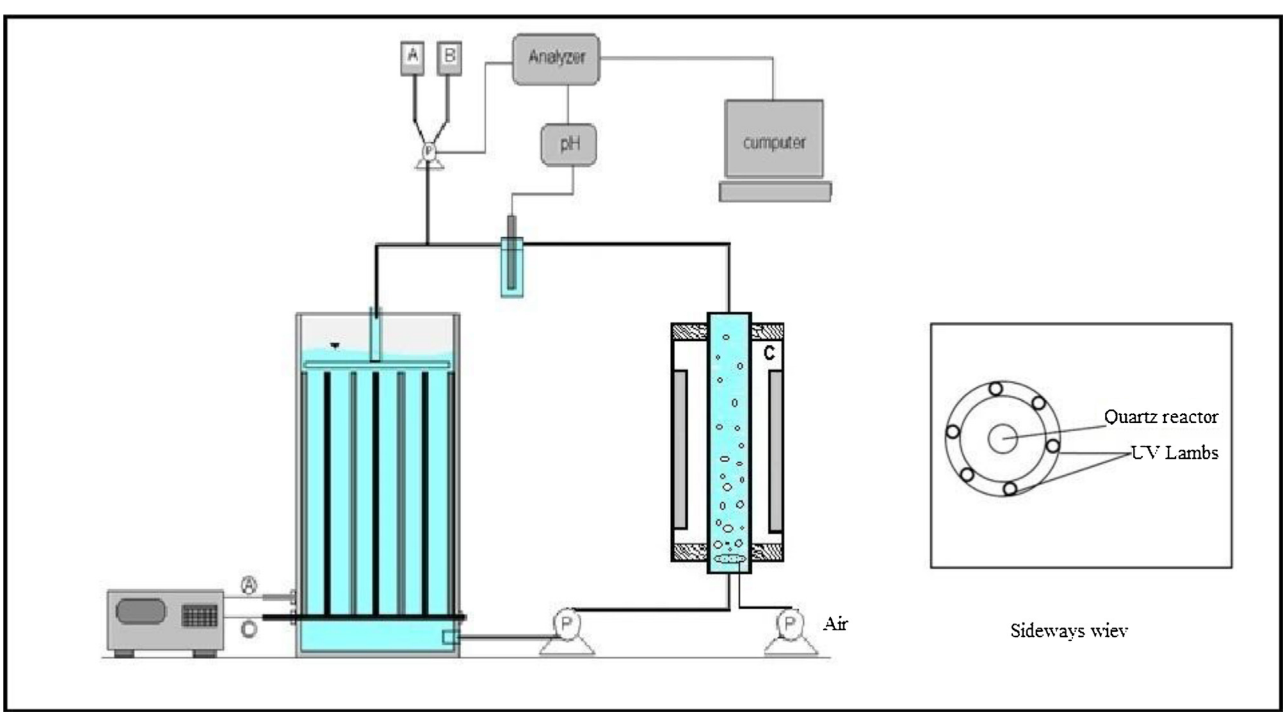

Fig. 2. The experimental setup (EC and PCO).