

# A Short Review on Applicable Processes for Removal of Phenol from Water



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## Abstract

In this paper, the recent advances in removal of phenol from water are briefly reviewed. The removal of phenol could be attained by adsorption, photocatalysis, ozonation, and different forms of Fenton reactions. However, the choice of the appropriate method is dependent on the initial concentration of phenol. Emphasis is given to the reports that include optimization of operating conditions and cost estimation. The merits and limitations were discussed to clarify the favorability of each method.

**Keywords:** Adsorption; Fenton; Phenol; Photocatalysis

**Abbreviations:** AOPs: Advanced Oxidation Processes; PAC: Powdered Activated Carbon; GAC: Granular Activated Carbon; PHAp: Porous HydroxyApatite; FAp: Fluoro Apatite; WC: Wood Charcoal; RHA: Rice Husk Ash.

## Introduction

Phenolic compounds exist in the wastewater of many industries such as resins, pharmaceuticals, paint, petrochemical products, and olive mills [1]. Dermal exposures to phenol are reported to cause skin damage, eye irritation, and problems to mucous membranes. Moreover, phenol is toxic to humans via oral exposure [2]. Phenolic compounds and other bio-recalcitrant organics are poorly removed in conventional biological treatment due to their toxicity that simply kill the microorganism in activated sludge systems [3]. Accordingly, many researchers tend to investigate different chemical methods for removal or degradation of bio-recalcitrant pollutants [4]. These methods include adsorption by activated carbon and polymeric adsorbents, and Advanced Oxidation Processes (AOPs) like ozonation, Fenton reactions, and photocatalysis [5-8]. The choice of the appropriate method should be based on efficiency, costs, and influent characteristics such as pH and initial concentration [9,10].

This paper aims to briefly review the recent advances of different methods that have been reported for removal of phenol from water. The applicability and merits of each method have been focused.

## Discussion

### Adsorption

Adsorption could be the first choice for removal of phenol from water because of its high efficiency and easy application using suspended Powdered Activated Carbon (PAC), Granular

Activated Carbon (GAC) columns, or recent developed adsorbents [11]. Bahdod et al [12] studied the removal of phenol by three apatite adsorbents (Porous Hydroxy Apatite (PHAp) and crystalline hydroxyl- (HAp) and Fluoro Apatite (FAp)) [12]. The best obtained adsorption capacity was 8.2mg/g with the prospect of thermal regeneration. Aghav et al. attained 88% removal of phenol using different carbonaceous adsorbents such as Wood Charcoal (WC) and Rice Husk Ash (RHA) [1]. Adsorption of phenol is applicable when the concentration of phenol is relatively low (<100mg/L). In this case, the amount of needed adsorbent is appropriate, and hence the adsorption will be cost-effective. Some industries like coal processing, resins, and refineries produce highly contaminated water with phenol concentration up to 6000mg/L. Using adsorption for removal of high phenol concentrations requires considerable amount of adsorbents. In addition, the disposal or regeneration of the contaminated adsorbents will be a concern [13].

### Advanced oxidation processes (AOPs)

The advantage of AOPs is the destruction of contaminants by degrading them into benign end products such as CO<sub>2</sub>, and H<sub>2</sub>O [14]. Gar Alalm et al. [15] investigated the removal of phenol by solar photocatalysis using naked titanium dioxide (TiO<sub>2</sub>) and TiO<sub>2</sub> supported on activated carbon (TiO<sub>2</sub>/AC) [15]. They found that complete degradation of phenol and its intermediates could be attained by TiO<sub>2</sub>/AC faster than using naked TiO<sub>2</sub>. They estimated the total cost for removal of phenol using their method by 3.19€/m<sub>3</sub>. Esplugas et al. [16] studied the

degradation of phenol by different combination of ozonation, UltraViolet light (UV), and hydrogen peroxide ( $H_2O_2$ ) [16]. Complete degradation of phenol with initial concentration of 100mg/L was attained using ozonation in about 80min. They found that other combinations like  $O_3/H_2O_2$ ,  $O_3/UV$  and  $O_3/UV/H_2O_2$  did not enhance or accelerate the degradation of phenol. Ayodele et al. [17] and Gar Alalm et al. [18] investigated the degradation of phenol using photo-Fenton process [17,18]. Photo-Fenton reaction revealed high efficiency even at high initial concentrations (>500mg/L). The total cost for removal of phenol by solar photo-Fenton reaction was estimated by 2.54€/m<sup>3</sup>. Another Fenton process that reported to achieve efficient degradation of bio-recalcitrant pollutants is electro-Fenton [6,19]. Radwan et al. [20] found that phenol could be completely degraded by electro-Fenton process using sacrificial or non-sacrificial anodes [20]. The current intensity was the key factor that influenced the degradation efficiency. The key limitation of Fenton processes is the high amount of produced sludge, but they are still preferred because of their high efficacy and low cost especially when the initial phenol concentration is high.

### Conclusion

Several methods could be applied for removal of phenol from water including adsorption, photocatalysis, ozonation, and Fenton reactions. The application of adsorption is limited to low phenol concentrations. Ozonation and photo catalysis are suitable for phenol degradation but the cost efficiency and application to high phenol concentration are still challenges. Fenton processes are the most appropriate choices in case of high phenol concentration in terms of efficiency and costs. However, the high amount of produced sludge is still a concern.

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