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Kinetic study for aerobic treatment of phenolic wastewater

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ABSTRACT

Conventional physico-chemical treatment of industrial wastewater containing compounds such as phenol encounters difficulties due to low substrate level, additional use of chemicals, and generation of hazardous by products along with increased process cost. Biological treatment appears to be a solution for treatment of such industrial wastewater. In the present study an aerobic sequential batch reactor (SBR) has been used for treatment of synthetic wastewater containing phenol. The effects of increasing phenol concentrations on the sludge characteristic have been also investigated. It was observed that, activity of activated sludge for acclimatization of phenol decreases at concentrations above 2000 mg L^{-1}. It may be attributed to toxicity of phenol to active biomass at higher concentrations. Kinetics of phenol degradation has also been studied using Haldane model.

1. Introduction

Water is basic need of life on earth. Although 70% of the earth is water, but only one percent is accessible in form of surface freshwater. This one percent surface water is regularly renewed by

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rainfall and thus is made available for human use. Water is the biggest crisis faced by world today. Toxic compounds are naturally not present in water. When these compounds enter the stream, they show adverse effect towards living organisms. The major agents creating toxic pollution are herbicides and pesticides originating from agriculture and industrial effluents. Phenol and its compounds are toxic to environment. Although Phenol is reported as toxic and inhibitory substrate, however it is also carbon source for an acclimated biomass [1]. Phenol is a known human carcinogen [2]. Molecule of phenol has a hydroxyl group attached to the benzene ring structure. Phenol is an organic compound which is translucent, crystalline white powder, hygroscopic and changes to red color when comes in contact with air. It is soluble in water, petroleum glycerol and alcohol. Phenol is weakly acidic as the molecule has little tendency to lose H^+ ion from the hydroxyl group to form water-soluble phenoxide anion $C_6H_5O^-$. Since phenol is soluble in water, its degradation to reach safety levels of 0.1–1 mg L^{-1} is hard.

Phenol is extensively used in various kinds of industries such as petroleum refineries, gas and coke oven industries, pharmaceuticals, explosive manufacture, phenol–formaldehyde resin manufacture, plastic and varnish industries. Phenol enters water during the manufacturing and processing steps in these industries. Phenol in a concentration ranging from 50 to 2000 mg L^{-1} has been reported by many researchers in industrial wastes [3,4]. Proper treatment of wastewater containing phenol is required before it is discharged to external environment because of its toxicity to living organisms. The permissible limit of phenol is 1 mg L^{-1} for industrial effluents to be discharged into inland surface waters (IS: 2490-1974) and 5 mg L^{-1} for discharge into public sewers (IS: 3306-1974).

2. Treatment of phenolic wastewater

There are two common methods used to eliminate the phenol contents in wastewater, i.e., physico-chemical and biological methods. However, most of the physico-chemical methods cause secondary problems in the effluents. Also, the physico-chemical method to degrade phenol usually involves high capital. Phenol is usually separated from wastewater through separation processes such as steam distillation, extraction, adsorption and membrane based solvent extraction. Phenol may also be abated in water solution through oxidation and bio-filtration [5].

Physical and chemical removal methods generate secondary by-products which eventually enter the environment as toxic aquatic pollutants. Chloro-phenols are generated if chlorination is used in the phenol degradation [6]. Physico-chemical methods used for treatment of phenol containing wastewater are ionization, adsorption, reverse osmosis, electrolytic oxidation, H_2O_2 and photo catalysis. The reason of using chemical processes along with oxidizing agents is to efficiently reduce the content of phenolic compounds in the wastewater. During the oxidation process, oxidizing agents transform these toxic substances to less harmful elements which are safe to be discharged to the environment.

Ozone is one of the strongest oxidants used for phenol degradation because of its availability, solubility and generation of less-toxic substances. Molecules of ozone react with electron-rich sites of the organic pollutant. Also hydroxyl radicals are generated from the reaction of ozone which acts as oxidants for pollutant molecule.

Adsorptive process using activated carbon is widely applied for removal of contaminants in wastewater [7]. Adsorption involves activities such as saturation, adsorption, desorption and regeneration. It has been reported that some of the phenols and its derivatives may get adsorb on activated carbon irreversibly, where the irreversibly adsorbed phenol cannot be desorbed in water [8]. This problem results in difficulty in the regeneration of adsorbent.

Chemicals such as hydrogen peroxide alone or hydrogen peroxide coupling with iron (II) salt (Fenton reaction) also have been used for phenol oxidation. Hydrogen peroxide (H_2O_2) is rich in oxygen content, low cost, acts as a strong oxidant. Researchers have reported alternative oxidation methods for the removal of phenol through oxidation by chlorine, chlorine dioxide and potassium permanganate [9]. However, these processes result in formation of secondary chlorinated organic compounds. Thus, the biological method such as activated sludge process has been used extensively in