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Review

Combination of Fenton processes and biotreatment for wastewater treatment and soil remediation

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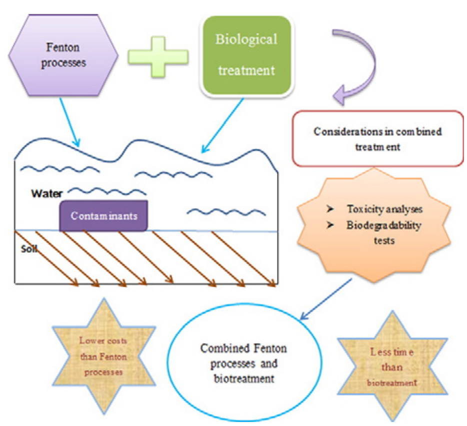
HIGHLIGHTS

- The combination of Fenton process and biotreatment is novel and useful.
- Toxicity and biodegradability tests are significant to design a combined system.
- No matter which technology at first stage, they would be called combined methods.
- Wastewater contains PPCPs or EDCs.
- Use of combination system in wastewater and polluted soil.

GRAPHICAL ABSTRACT



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ABSTRACT

There is a continuously increasing worldwide concern for the development of wastewater and contaminated soil treatment technologies. Fenton processes and biological treatments have long been used as common technologies for treating wastewater and polluted soil but they still need to be modified because of some defects (high costs of Fenton process and long remediation time of biotreatments). This work first briefly introduced the Fenton technology and biotreatment, and then discussed the main considerations in the construction of a combined system. This review shows a critical overview of recent researches combining Fenton processes (as pre-treatment or post-treatment) with bioremediation for treatment of wastewater or polluted soil. We concluded that the combined treatment can be regarded as a novel and competitive technology. Furthermore, the outlook

Abbreviations: AOPs, advanced oxidation processes; BaP, benzo[a]pyrene; BOD, biochemical oxygen demand; COD, chemical oxygen demand; DAF, dry-spun acrylic fiber; DOC, dissoluble organic matters; DCDE, dichlorodiethyl ether; EDCs, endocrine disrupting chemicals; EF, electro-Fenton; EOCs, emerging organic contaminants; HPAM, polyacrylamide; IBR, immobilized biomass reactor; LAB, linear alkylbenzene; LAS, linear alkylbenzene sulfonate; MBR, membrane bioreactor; MBBR, moving-bed biofilm reactor; MPG, α-methylphenylglycine; NXA, nalidixic acid; nZVI, nano zero-valent iron; PAHs, polyaromatic hydrocarbon; PCBs, polychlorinated biphenyl; PF, photo-Fenton; PPCPs, pharmaceuticals and personal care products; PYR, Pyrene; SBR, sequencing batch reactor; SBBR, sequencing batch biofilm reactor; SMBR, submerged membrane bioreactor; SMX, sulfamethoxazole; SOC, soluble organic carbon; SOM, soluble organic matters; TCDD, 2,3,7,8-tetrachlorodibenzo-p-dioxin; TEO, dichloromethane organics; TN, total nitrogen; TOC, total organic carbon; TP, total phosphorus; TPH, total petroleum hydrocarbon; UASB, Upflow Anaerobic Sludge Blanket; UV, ultraviolet; WW, wastewater; WWTP, wastewater treatment plants.

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Biotreatment
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for potential applications of this combination in different polluted soil and wastewater, as well as the mechanism of combination was also discussed.

Contents

1. Introduction

Water and soil pollution resulting from illegal discharge and incomplete treatment of waste has caused high concerns (Fu et al., 2014; Franco and Sarria, 2015). Various contaminants persisting in environment include pesticides, dyes, polycyclic aromatic hydrocarbon, polychlorinated biphenyl, heavy metals etc. (Ngah et al., 2011; Brito et al., 2015; Marina et al., 2015). All of these pollutants releasing into the environment pose a huge threat to ecosystem and human health (Freedman, 2008; Murthy and Ramesh, 2009; Trevors, 2010; Xu et al., 2012), making it critical to develop treatment technologies for removal of these pollutants from environment (Malarvannan et al., 2009; Bechmann et al., 2010).

As one of the efficient technologies, advanced oxidation processes (AOPs), have been frequently used for remediation of polluted soil and water in recent years (Huang et al., 2015). AOPs include various technologies (Vilhunen and Sillanpää, 2010; Fernández-Castro et al., 2015; Cheng et al., 2016a) such as Fe^{2+}/H_2O_2 (Kallel et al., 2009), ozonation(O_3) (Esplugas et al., 2007), H_2O_2/UV (Moro et al., 2013), hetero-/homo-geneous Fenton-like process (Wang et al., 2016), photocatalysis (Elghniji et al., 2012), and other treatment technologies may contain electrify, ultrasonic, radiation (Luna et al., 2012; Zhang et al., 2013a; Huang et al., 2014). Fenton processes (Fe^{2+} / H_2O_2) are able to oxidize pollutants by producing hydroxyl radical (•OH) (Maezono et al., 2011; Wang et al., 2016). •OH is the major reactive intermediate responsible for organics' oxidation and is regarded as the dominant oxidant, which has been mentioned by some key publications (Georgiadis, 2008; Rd et al., 2012). On account of short reaction time, high efficiency of pollutants degradation and the wide diversity of target contaminants, Fenton processes have become the representative AOPs. Fe^{2+} is used as the catalyst and hydrogen peroxide is used as the oxidant in Fenton oxidation. On the other hand, biotreatment is regarded as an environmental friendly method for pollutants treatment, but the reaction conditions need to be carefully regulated (Ganigué et al., 2012; Wan et al., 2013; Xiao et al., 2015). In addition, biotreatment technologies might be not effective at high pollution level due to the limited resistance of microorganisms to toxicity (Kundu et al., 2012).

Combination of Fenton processes and biotreatment is developed to overcome the defects of Fenton technology (e.g., consumption of reagents and drastic reaction process, etc.) or the limitations of biotreatment (e.g., strict reaction condition and time-consuming, etc.). The combination system has been used in wastewater and contaminated soil treatment (Sirtori et al., 2009; Venny and Ng, 2012; Jho et al., 2014; Bing et al., 2015). The Fenton process in the combination system can improve the biodegradability of wastewater, which is beneficial to biotreatment, while biotreatment in the same combination system can stabilize the waste and reduce the use of Fenton chemicals. Fenton process or biotreatment is not only a pre-treatment or post-treatment, since the treatment would usually not finish unless the concentration of pollutants drop to 0. So far the review about the combination of Fenton process and biotreatment has not been reported.

This review describes the recent studies in adopting combined or sequential Fenton/biotreatment for wastewater and polluted soil treatment, and highlights the benefits of the combined treatment. The review firstly introduces basic information about single Fenton process and biological treatment, followed by the considerations in the combined treatment method. Meanwhile, the combined method is classified into (1). Fenton processes and then biological treatment, and (2). biological treatment and then Fenton processes. The outlook and future study in this promising field are also discussed. The structure of this review is illustrated in Fig. 1.

2. Fenton processes and biological treatment

Fenton processes (Fenton, Fenton-like and modified Fenton) and biotreatment have been frequently studied for pollutants removal. Below are the basic illustrations of practical application or experimental researches about single Fenton processes and biotreatment.

2.1. Fenton processes

Fenton technology is a promising and alternative method for remediation of soil or wastewater treatment. Laboratory, plant-scale experiments and practical application of Fenton technology were conducted by many researchers. Fenton process uses hydrogen peroxide as oxidant and ferrous ions as catalyst. The catalytic decomposition of H_2O_2 in the presence of Fe^{2+} involves a complex chain reaction. The critical reactions are listed below (Gu et al., 2012):

$$Fe(II) + H_2O_2 = Fe(III) + {}^{\cdot}OH + OH^- \quad (1)$$

$$Fe(III) + H_2O_2 = Fe(II) + H_2O + H^+ \quad (2)$$