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# A novel vertical-flow electro-Fenton reactor for organic wastewater treatment

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## HIGHLIGHTS

- A vertical flow electro-Fenton reactor for organic pollutant efficient degradation was described.
- The effect of key parameters on pollutants degradation and mineralization efficiency was studied.
- The degradation performance was more efficient than that in traditional parallel flow reactor.
- The dependence of pollutant removal and energy consumption with cell numbers were investigated.

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## ABSTRACT

Degradation of organic pollutants using electro-Fenton has received great attentions in recent years, however, less efforts have been paid to sound reactor exploration. This study presented a novel vertical-flow electro-Fenton reactor, composing of 10 cell compartments using $PbO_2$ anode and modified graphite felt mesh cathode, which was found to be more complete and efficient in organic pollutants degradation when comparing with the traditional parallel-flow reactor, using tartrazine as the model pollutant. Under the optimal conditions of pH 3, voltage 4.0 V, flow rate 40 mL/min, $Fe^{2+}$ 0.4 mmol/L and aeration rate 80 mL/min, the tartrazine of initial concentration of 100 mg/L could reach near 100% removal and the TOC removal efficiency was 61.64%. The dependence of pollutant removal and energy consumption with the cell numbers were investigated, which would help to design vertical-flow electro-Fenton reactor for practical application.



## 1. Introduction

Nowadays, the decomposition of non-biodegradable toxic organic pollutants in water remains a problem to be solved. Conventional wastewater treatment plants cannot degrade the majority of biorefractory pollutants and generate large volumes of sludge, thus causing secondary environmental pollutants [1,2]. Over last 20 years, electrochemical advanced oxidation processes (EAOPs) have attracted more and more researchers' interests in the reclamation of wasters contaminated with non-biodegradable organics [3–5], because they are capable of generating strongly oxidizing radicals that can completely oxidize organic pollutants into $CO_2$ and $H_2O$ [6]. Among all the EAOPs, electro-Fenton (EF) has shown great effectiveness in the decontamination of pollutants and has great potential for practical application because of in-situ production of hydrogen peroxide by the reduction of oxygen on the cathode (Eq. (1)) [7]. Then it can be catalytically converted into highly powerful hydroxyl radicals in the presence of an iron catalyst (e.g., $Fe^{2+}$, $Fe^{3+}$, or iron oxides) (Eq. (2)) [8].

$$O_2 + H^+ + 2e \rightarrow H_2O_2 \quad (1)$$

$$H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + {\cdot}OH + OH^- \quad (2)$$

The cathode and catalyst are two key factors affecting the reaction rate and removal efficiency in the EF system, and thus many studies focused on these two aspects [9,10]. In comparison, there are not so many reports on EF reactor design, which is also vital to increase the degradation efficiency and reduce the treatment cost. Brillas' group reported a one-compartment filter-press electrolytic reactor to degrade phenolic pollutants [11]. Our recent work demonstrated that an electro-Fenton process using rotating disk reactor was capable of $H_2O_2$ generation without oxygen aeration and was effective for organic pollutant degradation [12].

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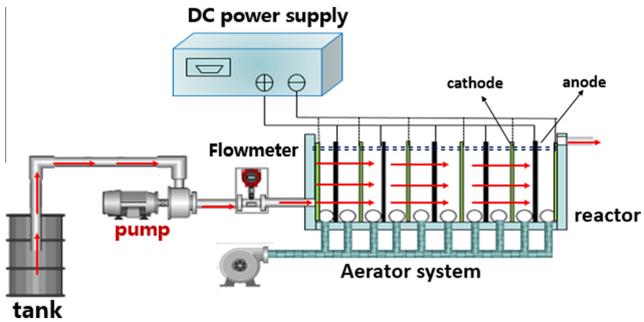


**Fig. 1.** The schematic diagram of the novel vertical-flow electro-Fenton reactor.

Zhang et al. developed a continuously stirred Fered–Fenton reactor for the treatment of landfill leachate at bench scale, where both hydrogen peroxide and ferrous ion were externally added into the electrolytic cell [13]. Rosales et al. designed a bubble EF reactor for the degradation of wastewater contaminated with synthetic dyes [14]. A pilot flow reactor in recirculation mode with a filter-press cell containing an oxygen diffusion cathode was studied to degrade aniline solution [15]. In summary, these reported EF reactor were either in intermittent flow in a single chamber reactor or a continuous parallel-flow system that the pollutants flowing parallel to the anode and cathode surface [7,16–18]. Unfortunately, the pollutant removal efficiency is still unsatisfactory due to the low space–time treatment efficiency and mass transfer limitation [19,20]. Therefore, it is very necessary to design an efficient EF reactor to overcome these weaknesses.

Vertical-flow reactor has been applied to some water and wastewater treatment techniques, such as adsorption [21,22] and electrodialysis [23], which is supposed to accelerate the reaction rate and improve the treatment efficiency [24] because the mass transfer rate of the target pollutant molecules are accelerated and contaminants can be well enriched on the surface. As far as we known, there is no vertical-flow EF reactor was reported for organic wastewater treatment.

Therefore in the present work, a novel vertical-flow EF reactor was designed to test degradation and mineralization efficiency, using tartrazine, a model azo dye, as the target contaminant. After graphite felt mesh cathode modification by ultrasonic immersion and coating method, the electrochemical generation of hydrogen peroxide was greatly improved. The influence of applied voltage, tartrazine flow rate, initial pH, initial $Fe^{2+}$ ions, aeration rate and initial tartrazine concentration were systematically investigated, and the performance was confirmed to be much better than that in the traditional parallel-flow reactor account for the degradation efficiency and energy consumption.

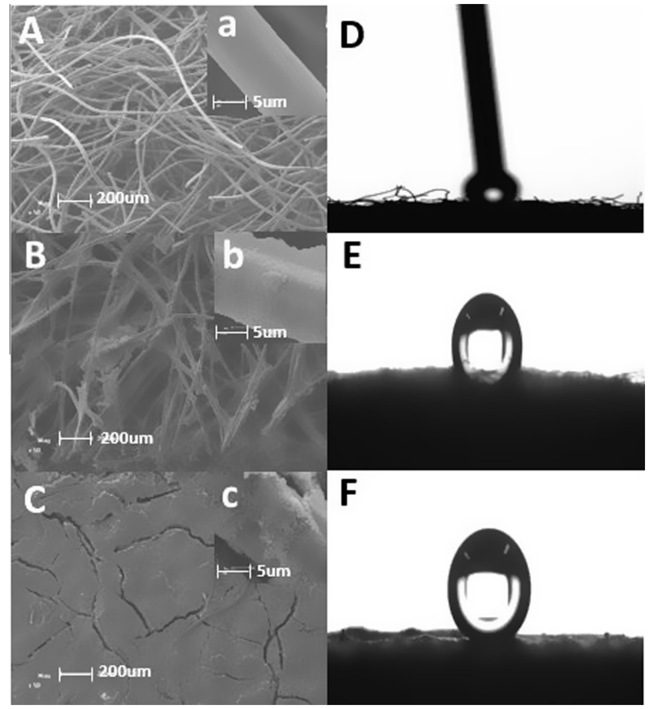


**Fig. 2.** The SEM and the contact angles of unmodified (A, D), ultrasonic immersion modified (B, E) and double modified graphite felts (C, F).

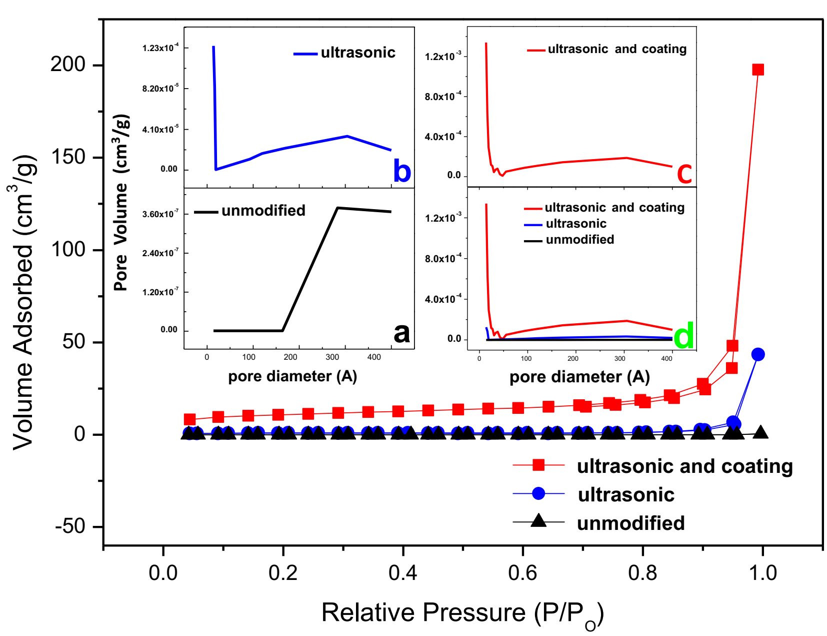


**Fig. 3.** $N_2$ adsorption/desorption isotherms and the pore size distribution of the unmodified, ultrasonic immersion modified and double modified graphite felts.