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# Electrochemical mineralization of chlorophenol by ruthenium oxide coated titanium electrode

Rohit Chauhan, Vimal Chandra Srivastava*, Ajay Devidas Hiwarkar

*Department of Chemical Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, Uttarakhand, India*

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ABSTRACT

Electrochemical oxidation of 4-chlorophenol (CP) was investigated (in terms of chemical oxygen demand (COD) and CP removal efficiencies) by using a dimensionally stable anode (DSA) namely ruthenium oxide coated titanium ($Ti/RuO_2$) electrode. Effect of process conditions such as current density ($j$), electrolyte concentration ($m$), initial pH ($pH_o$), time ($t$) and initial CP concentration ($C_o$) has been studied. Current efficiency (CE) and specific energy consumption (SEC) were also measured. Gas chromatograph-mass spectrometry (GC/MS) analysis was used to understand the CP mineralization mechanism which has been established on the basis of intermediates identified such as benzoquinone, hydroquinone and organic acids. Reaction kinetics was expressed by pseudo-first order kinetic model. Maximum COD removal efficiency of 96.7% and CP removal efficiency of 97.2%, respectively, was observed at $j = 222.22\ A/m^2$, $t = 180$ min, $pH_o = 5.2$ and $m = 400$ mg/l with SEC = 655 kWh/kg COD. Operating cost based on the studies performed on laboratory scale EC reactor has been calculated and compared with those reported for other pollutants degradation.



## 1. Introduction

Phenols and its derivatives such as 4-chlorophenol (CP) are discharged by many industrial units such as oil refineries, petrochemical, plastic, pharmaceutical, and food-processing plants [1,2]. Among various phenolic compounds, CP is one of the most toxic phenolic compounds which can enter the human body by ingestion, inhalation or dermal adsorption. Considering its hazardous and toxic nature, it is necessary to degrade CP present in the water by suitable methods [3–5]. Physical, chemical and biological methods of wastewater treatment are generally not efficient in removing CP. Advance oxidation processes which include electrochemical (EC) processes such as electro-oxidation, electrofenton, electrocoagulation, etc. can be used for oxidizing many organic pollutants present in the wastewater [6–10]. Electro-oxidation process uses electron as oxidation reagent and converts organic pollutants into $CO_2$ and $H_2O$ [11].

Amount of sludge produced in the electro-oxidation process is negligible because of the oxidation of organics and it does not produce secondary pollution as well [12]. During electro-oxidation, pollutants present in the water get destroyed (when they get adsorbed on the electrode surface) by the electrons generated by the electrode. Also, oxidants generated in the solution mineralize the pollutants [13–17]. Behavior of EC oxidation depends upon the nature of electrode material *i.e.* which metal is used as a support for coating of metal oxides. Dimensionally stable anodes (DSA) are highly stable and do not corrode in the wastewater. These coated electrodes show better efficiency for oxidation of organic compounds. Several types of DSA like boron diamond doped (BDD) [6,11,18], $Ti/RuO_2/IrO_2/TaO_2$-coated titanium and graphite anodes [10], $Ti/SnO_2$ and $Ti/IrO_2$ anodes [14], titanium based DSA electrodes [19], platinum electrodes [20], $PbO_2$ anode [21], etc. have been used in the literature for the treatment of various wastewaters. $Ti/RuO_2$ is one such DSA electrode in which $RuO_2$ is highly stable metal oxide even in strong acidic conditions and gives suitable oxidants which are used for oxidation of organic compounds [8,10,12,22]. Hou et al. [23] studied EC oxidation of bisphenol with the carbon aerogel electrode. Anand et al. [24] studied EC treatment of alkali decrement wastewater containing terephthalic acid using iron electrodes. Kumar et al. [12] investigated mechanism of EC oxidative degradation of p-nitro phenol by using $Ti/RuO_2$ electrode. Azzam et al. [7] studied the EC oxidation of CP solutions using a DSA, which was made of pure titanium sheet mesh coated with $Ti/TiO_2$ and $RuO_2$ film. The influence of current density, pH and initial CP concentration within 2 h was investigated. In this study, only CP destruction efficiency was studied, however, its complete mineralization was not investigated. Moreover, specific energy consumptions and mechanism of destruction was not studied.

* Corresponding author. Fax: +91 1332 276535.
*E-mail addresses:* rohitchn18@gmail.com (R. Chauhan), vimalcsr@yahoo.co.in, vimalfch@iitr.ac.in (V.C. Srivastava).

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Present study aimed to investigate mineralization of CP in terms of chemical oxygen demand (COD) and CP removal using Ti/$RuO_2$ electrode under various operating conditions. Reaction mechanism of degradation of CP has been proposed on the basis of intermediates identified during the reaction with the help of sophisticated instruments.

## 2. Materials and methods

### 2.1. Materials

All chemicals used in the present study, were of analytical grade. Synthetic wastewater was prepared by dissolving appropriate mass of CP (commercially purchased by Loba Chemie Pvt. Ltd., Mumbai, India) into distilled water. Ti/$RuO_2$ electrodes were purchased from Titanium Tantalum Ltd. Company, Chennai, India.

### 2.2. Degradation of 4-chlorophenol using electrochemical method

Electro-oxidation of CP was studied in a lab-scale glass batch reactor with circular cross section having 1 l volume and 11 cm diameter. It was equipped with two Ti/$RuO_2$ electrodes as shown in Fig. 1. All the batch experiments were run with controlled action of current electrolysis process using a direct current (D.C.) source (4818A10). Configuration of electrodes was as follows: acquiring

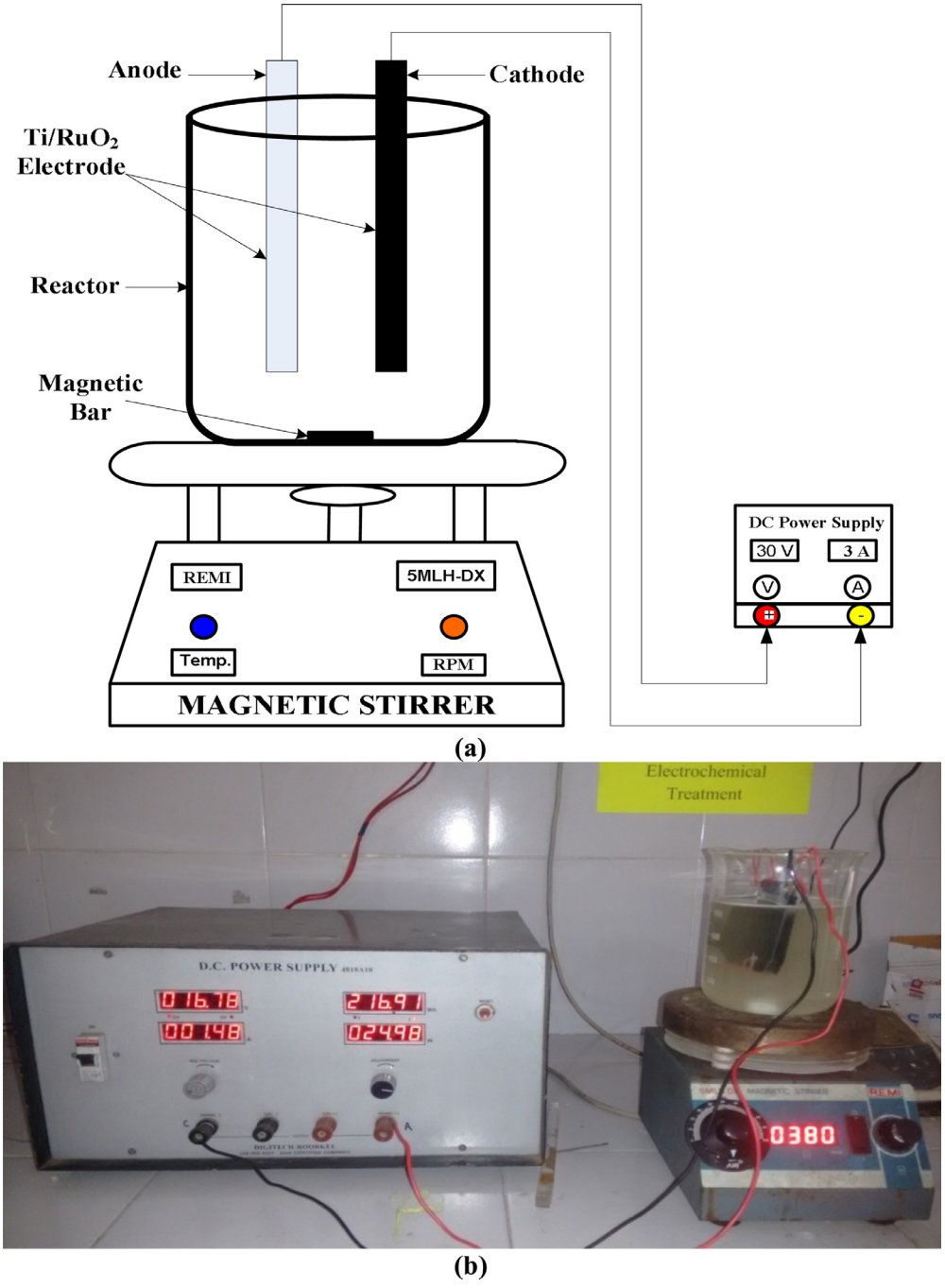


**Fig. 1.** (a) Schematic diagram and (b) actual photograph of the experimental setup.

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