

中文摘要

本論文主要以電化學處理技術偵測氯酚化合物與去除水中五氯酚，採用 50 mL 的非分離式電解槽作為反應器，電解電壓由電化分析儀控制，連接三個電極：輔助電極為白金絲、參考電極為 Ag/AgCl 電極，工作電極為白金電極，實驗操作採用定電壓電解，實驗中電極上電流的量測使用 6 位半精密高階數位電表。

在偵測污染物的實驗之中，使用 0.3 V/s 做為線性掃描伏安法的最佳掃描速度，利用循環伏安法掃描可測得 4-氯酚、2,4-二氯酚及五氯酚水溶液中氧化與還原波峰，4-氯酚的氧化與還原電位為 1.218 與 -0.460 V、2,4-二氯酚之氧化與還原電位為 1.128 與 -0.448 V 及五氯酚之氧化還原電位為 1.037 與 -0.473 V。氯酚化合物以線性掃描伏安法進行分析測定，其濃度的線性範圍分別為：4-氯酚為 0.2~1

mg/L、2,4-二氯酚為 0.3~2 mg/L 及五氯酚為 0.1~4 mg/L。由本研究實驗證實應用電化學分析儀來測定微量的氯酚化合物是可行的，且為一種快速的檢測方法。以電解質 1.00 M KI 降解五氯酚實驗組中，在電解電壓 500 mV (vs. Ag/AgCl) 下進行電解實驗，五氯酚完全的被去除；但在相同的電解條件中，使用電極質 1.00 M KCl 與 Na₂SO₄ 對於五氯酚並沒有達到完成去除情形，可能的原因為電解質 KI 電解後產生 I³⁻與 I⁻氧化還原媒子反應，使五氯酚進行逐步脫氯反應。使用電壓 -1200 mV(vs. Ag/AgCl)之電解實驗，五氯酚去除率亦達 99%，因電解水生成氫原子會與吸附電極上之五氯酚進行脫氯反應，同時發現脫氯反應與五氯酚降解反應是同步在進行的，即吸附的五氯酚完成脫氯反應後，才會進行下一個五氯酚分子的脫氯反應。

以 KCl 為電解質之實驗組降解五氯酚之實驗中得知，以使用電解電壓-1.50 V(vs. Ag/AgCl)，電解質為 0.50 M KCl 為最佳電解條件，電解 120 min 後五氯酚可達到 99 % 以上的去除率，在相同的電解條件中使用電解質 NaNO₃ 與 CaCO₃ 其五氯酚沒有任何去除效果。在 pH 值 3.86 之條件下，120min 對五氯酚的去除率可達 99 % 以上；而 pH 值 9.97，電解 120 min 對五氯酚的去除率為 88%，由此可見，在低 pH 值條件下對五氯酚去除效率較佳。在本研究實驗中，五氯酚降解後生成之物種經由 GC/MS 鑑定後出現三種中間產物分別為 1, 2-二氯環己烷、順 2-氯環己醇及 3-HEXEN-1-YNE。

因此，在適當的操作條件下，可利用電化學技術使水中五氯酚有效地脫氯降解。

英文摘要

This study addressed the application of electrochemical technology on the detection of chlorophenols and the removal of pentachlorophenol in water. The reactor used in this study is a 50 mL double-jacketed glassware, which is established a Pt electrode as working electrode, a Pt wire as counter electrode, and an Ag/AgCl electrode as reference electrode. The electrochemical analyzer is employed to precisely control a constant potential during the experiments, and the current passing through the electrodes in the reactor was recorded by the 61/2 multimeter.

In the detection experiments, the scan rate is set at 0.3 V/s under the analysis of linear sweep voltammetry (LSV). On the cyclic voltammetry (CV) plot, each pair of clear redox peaks was observed for 4-chlorophenol (4-CP), 2,4-dichlorophenol (2,4-DCP), and penta-chlorophenol (PCP). The potentials of the redox pairs were 1.218 and -0.460 V for 4-CP, 1.128 and -0.448 V for 2,4-DCP, and 1.037 and -0.473 V for PCP. Based on the linear relationship between the concentrations of chlorophenols and the corresponding peak current, the suitable quantification ranges were 0.2~1 mg/L for 4-CP, 0.3~2 mg/L for 2,4-DCP, and 0.1~4 mg/L for PCP by the LSV analysis. The detection experiments demonstrated a quick measurement method to quantify the trace levels of chlorophenols in water by the electrochemical analyzer.

As using 1.00 M KI as electrolyte in the degradation experiments, a complete removal of PCP was achieved by the electrolysis at 500 mV. However, the same controls of degradation experiments did not result in a similar result as using 1.00 M KCl or Na₂SO₄. A possible contribution is ascribed to the formation of the redox couple I₃⁻/I⁻, which might play the role of mediator to initiate indirect oxidation. On the contrary, PCP can be completely removed for 1.00 M KI, KCl, or Na₂SO₄ by the electrolysis at -1200 mV. The possible mechanism is that the forming H atoms from water electrolysis might dechlorinate the adsorbed PCP on the electrode surface. Thus, the degradation of PCP synchronized with the dechlorination of PCP.

As using 0.50 M KCl as electrolyte in the degradation experiments, a complete removal of PCP was achieved by the electrolysis at -1500 mV. The same controls of experiment conditions did not result in a similar result as using NaNO₃ or CaCO₃. The removal of PCP is only 88% under the initial pH 9.97, while the removal efficiency is over 99% under the initial pH 3.86. As a consequence, the strong basic condition of initial pH is not favorable for the electrochemical degradation of PCP. Based on the analysis of GC/MS, the intermediates of PCP degradation are determined as 1,2-dichloro-cyclohexane, trans-2-chloro-cyclohexanol, and 3-hexen-1-yne. Accordingly, PCP can be successfully dechlorinated by a proper control of electrochemical treatment process.