Study on Electro-Oxidation Treatment of Industrial Paper Mill Wastewater

林逸汎、彭元興

E-mail: 9509726@mail.dyu.edu.tw

ABSTRACT

Large domestic industrial paper mills generally already comply with the environmental regulations after secondary biological wastewater treatments. However, due to the high electrical conductivity (> 2000 μs/cm) and amber-colored appearance of the effluents, reusing of the water often impact seriously on the wet-end chemical stability and cleanliness of the production system, which also foster slime growth as well. Thus the post-treatment effluents must be discharged. Beginning in July 2006, the EPA intends to surcharge water pollution and right of usage taxes, therefore causing hefty increases to the operational costs of the major water users. In this study, we designed and built a laboratory electro-oxidation treatment unit capable of high currents under low voltages that can be used to treat paper mill effluents to remove target effluent pollutants such as COD, electrical conductivity and color in a bid to supplement existing mill wastewater treatment facilities and reduce overall treatment cost. The phase I reactor was a designed to combine electro-dialysis and electro-oxidation. The reactor, however, encountered excessive electrical resistance that hinder the flow of necessary current. Thus, modification was necessary. In the phase II, we based design on the original reactor and filled the 2 cells with iron pellets to lower resistance. The same problem beset the phase I reactor recurred, however, after a few minutes of reaction time. A fixed-bed reactor design was then adopted for the phase III electrochemical unit, which had a reduced volume and forwent the dialysis membrane. We then tested paper mill effluents in the unit to examine the treatment suitability and feasibility. The reactor had a total volume of 400 mL, using 2 -vistainless steel (SS304) electrode rods which were wrapped with synthetic fiber mesh and the cell filled with 3 mm iron pellet to 80~95% of the reactor volume. The iron pellets were washed with dilute acid, and the electrodes sanded with emery paper before each treatment. The effluent treated in the study was from an industrial corrugating medium mill which produces 400 t/d of paper and discharges 3500~4000 m3/d of effluent. The post-DAF stage effluent was studied. The study was based on a 23 factorial experimental design with operational variables of electrode spacing 5 and 15 mm; current density 287, 3454 A/m2; hydraulic retention time (HRT) 57 and 180 s. In the semibatch experiment, the total reaction time was 2 hr. The inflow effluent had pH of 6.8. The results indicate that the long HRT of 180 s had the greatest influences on pollutant removals, while the efficacy was unstable. With regard to the factorial design, the ANOVA also suggested that the 180 s HRT was detrimental to all effluent parameters. Hence, we deleted the condition and adding an aeration and filtration unit to the reactor, and changed the design to a 22 factorial. The results indicate that the optimal conditions entail an electrode spacing of 15 mm, current density of 3454 A/m2, and an HRT of 57 s. Removal efficiencies under this condition were 23% for COD, 18% for electrical conductivity, and 27% for color. The overall reaction seemed to have reached end-point within 5 min in a recirculation mode. In addition, when we adjusted effluent pH using mineral acid or alkali to pH 3 and 9, respectively, before conducting the treatments, the results indicate that at pH 9, the above optimal conditions led to COD removal of 28%, conductivity of 15% and color of 93%. Our reactor system used cast iron as material for the fixed-bed. Under an alkaline condition, COD removal (28%) was superior to the neutral and acidic conditions. Conductivity removal was better under neutral and alkaline conditions than the acidic condition. Neutral condition gave somewhat better result (18%) than the alkaline one. Alkaline condition was needed for true color removal and removal rate of 90% or better could be achieved. The overall results suggest that electrocoagulation was the main mechanism of pollutant removal, while electrooxidation played an insignificant role.

Keywords : electrochemistry, electrooxidation, fixed-bed, current density, COD, conductivity, true color,paper mill effluents

Table of Contents

REFERENCES

1. 彭元興、王益真、余世宗、史濟元、林逸汎、陳威存（2005），電氧化法應用在工業用紙廠廢水 之探討，第三十屆廢水技術研討會:136，中華民國環境工程學會，中壢。 2. Thompson G., Swain J., Kay M., Forster C.F.（2001）,“ The treatment of pulp and paper mill effluent : a review ”, Bio. Tech. 77:275-286. 3. Pokhrel D., Viraraghavan T.（2004）,“ The treatment of pulp and paper mill wastewater : a review ”, Sci. Total Environ. 333:37-58. 4. 彭元興、王益真、史濟元、張安毅、林逸汎（2004），工業用紙廠廢水回收再利用探討-先驅廠級脈衝電集系統的應用，清潔生產暨永續發展研討會:，經濟部工業區，台北。 5. 水污染防治法規(2003)，行政院環保署環保護人員訓練所編印。 6. Chen G. (2004),“ Electrochemical technologies in wastewater treatment ”, Sep. Pur. Tech. 38:11-41. 7. Chiang L.C., Chang, J.E., Tseng, S.C. (1997),“ Electrochemical oxidation pretreatment of refractroy organic pollutants ”, Wat. Sci. Tech. 36(2-3):123-130. 8. 詹士鴻（1998），製漿及造紙廢水再生利用技術之可行性研究，碩士論文，國立成功大學 環境工程系。 9. 何祖霆（1998），抄紙廢水再生利用技術研究，碩士論文，國立成功大學環境工程系。 10. 翁崑沅（1992），電解浮除（電化膠凝）處理粗紙製漿黑液之可行性，碩士論文，國立成功 大學環境工程系。 -91- 11. 張安毅（2005），脈衝電集法在工業用紙廠廢水之應用，碩士論文，大葉大學環境工程系。 12. 胡啟章（2002），電化學原理與方法，五南圖書出版股份有限公司。 13. Juttner K., Galla U., Schmieder H. (2000),“ Electrochemical approaches to environmental problems in the process industry ”, Elec. Acta 45:2575-2594. 14. 黃順興（1999），電聚浮除法處理氯苯之探討，碩士論文，淡江大學水資源及環境工程系。 15. Chiang L.C., Chang J.E., Wen, T.C. (1995),“ Indirect oxidation effect in electrochemical oxidation treatment of landfill leachate ”, Wat. Res. 29(2):671-678. 16. 呂明和、張祖恩（1999），電解法處理含重金屬垃圾滲出水之可行性研究，第二十四屆廢水 處理技術研究會:565-570，中華民國環境工程學會，中壢。 17. Abuzaid N.S., Alaadin A.B., Zakariya M.A.H.(2002), “ Ground water coagulation using soluble stainless steel electrodes ”, Adv. Env. Res. 6:325-333. 18. Xu X., Zhu X. (2004),“ Treatment of refectory oily wastewater by electro-coagulation ”, Chemosphere 56:889-894. 19. Hsieh S.Y., Cheng C.Y., Perng Y.S. (1983),“ Electrolysis of sodium silicate solutions using cation-exchange membranes ”, Sep. Sci. Tech. 18(9):821-829. 20. Elsheief A.E.(2003),“ Removal of cadmium from simulated wastewater by electrodeposition on spiral wound steel electrode ”, Elec. Acta 48:2667-2673. 21. Szpyrkowicz L., Grandi F. Z., Kaul S.N., Stern S.R. (1998),“ Electrochemical treatment of copper cyanide wastewaters using stainless steel electrodes ”, Wat. Sci. Tech.38(6):261-268. 22. Lin S.H., Shyu C.T., Sun M.C. (1998),“ Saline wastewater treatment by electrochemical method ”, Wat. Res.32(4):1059-1066. 23. Vlyssides A.G., Loizidou M., Karlis P.K., Zorpas A.A., Papaioannou D. (1999), “ Electrochemical oxidation of a textile dye wastewater using a Pt/Ti electrode ”, J. Haz. Mat. B70:41-52. 24. Bejankiwar R.S.(2002),“ Electrochemical treatment of cigarette industry wastewater: feasibility study ”, Wat. Res 36:4386-4390. 25. Saracco G., Solarino L., Specchia V., Maja M.（2001）,“ Electrolytic abatement of biorefractory orangics by combining bulk and electrode oxidation process ”,Chem. Eng. Sci. 56:1571-1578. 26. Rajkumar D., Palanivelu K. (2004),“ Electrochemical treatment of industrial wastewater ”, J. Haz. Mat. B113:123-129. 27. Hu K.H., Hu P.Y., Hu P.C. (2001),“ Electrolytic Wastewater Treatment Method and Apparatus ”, US Patent 6,274,028 B1. 28. Hu K.H., Hu P.Y., Hu P.C. (2003),“ Electrolytic Wastewater Treatment Apparatus ”, US Patent 6,554,977 B2. 29. Brillas E., Casado J.（2002）,“ Aniline degradation by Electro-FentonR and peroxi-coagulation processes using a flow reactor for wastewater treatment ”, Chemophere 47:241-248. 30. Feng C., Sugiura N., Shimada S., Maekawa T.（2003）,“ Development of a high performance electrochemical wastewater treatment system ”, J. Haz. Mat. B103:65-78. 31. Kraft A., Stadelmann M., Blaschke M.（2003）“ Anodic oxidation with doped diamond electrodes : a new advance oxidation process ”, J. Haz. Mat. B7103:247-261. 32. 陳鴻烈、鄭慧玲（1995），電解氧化法去除飲用水源中有機物影響因子之研究，農林學報，44 （4）:57-69。 33. 謝長原（2002），電解催化氧化氯酚之研究，碩士論文，國立成功大學環境工程系 34. 丁涴屏（2002），以電-芬頓程序處理含苯環類化合物廢水，碩士論文，私立嘉南藥理科技大學 環境工程衛生系 35. Kusakabe K., Nishida H., Morooka S., Kato Y. （1986）,“ Simultaneous electrochemical removal of copper and chemical oxygen demand using a packing-bed electrode cell ”, J. App. Elec. 16:121-126. 36. Simonsson D.(1984),“ A flow-by packed-bed electrode for removal of metal ions form waste waters ”, J. App. Elec. 14:595-604. 37. Fockedey E., Van Lierde A.（2002）“ Coupling of anodic and cathodic reactions for phenol ekectro-oxidation using three-dimensional electrodes ”, Wat Res 36:4169-4175. 38. Xiong Y., He C., Karlsson H.T., Zhu X.（2003）“ Preformance of three-phase three-dimensional electrode reactor for thereduction of COD in Simulated wastewater-containing phenol ”,Chemosphere 50:131-136. 39. 李士安、王擁軍、王治國、張守健（2002），“ 鐵床在高色度有機廢水處理中的應用 ”，環境 污染治理技術與設備，第3卷第8期:88-90。 40. 賈保軍、張愛麗（2003），“ 有機廢水處理中復極固定床電解槽的研究發展 ”，環境污染治理 技術與設備，第4卷第11期:21-25。 41. 歐陽玉祝、傅偉昌（2003），“ 鐵屑微電解-共沉澱法處理屠宰場廢水的研究 ”，環境污染治理 技術與設備，第4卷第8期:37-40。 42. 趙春霞、邱熔處、趙旭濤、劉發強（2004），“ 鐵碳微電解法處理拉開粉廢水的研究 ”，環境 污染治理技術與設備，第5卷第4期:73-75。 43. 施英隆著（2000），“ 環境化學 ”，五南出圖書出版。 44. 田中正三郎著，賴耿陽譯著（1923），“ 應用電化學 ”，復和出版社。