

## **Mediated Electrochemical Oxidation (MEO) Process for the Total Degradation of Phenol : A bench scale study**

S. Balaji, S. J. Chung., T. Ramesh, I. S. Moon\*

Department of Chemical Engineering, Sunchon National University.

(ismoon@sunchon.ac.kr\*)

### **INTRODUCTION**

Mediated Electrochemical Oxidation (MEO) is an emerging and one of the most promising technologies for the destruction of organics as it is capable of completely mineralizing the organics into carbon dioxide and water, without emission of any toxic materials like dioxins [1, 2]. MEO process offer several advantages: First, the oxidation reaction takes place at ambient temperatures and pressures; second, the products of destruction are contained in the reaction vessel itself with the exception of gases, third, production of secondary waste is minimized and this avoids additional treatment methods.

In MEO process a metal ion in acid medium is oxidized from its lower oxidation state to higher oxidation state and this oxidized species destructs the organic compounds into carbon dioxide and water and get reduced. Therefore the metal ion is not consumed in the reaction and acts as a mediator. The mediator ion used is cerium. MEO process finds commercial applications for organic waste destruction and technical details of the processes have been patented [3-5]. A few research groups around the world are developing MEO process, with different metal ions, towards the commercial scale. However, there is still a strong need for detailed information on the destruction patterns and also the effect of various influential parameters.

Phenol is one of the most common pollutants found in the effluents of many industries and was chosen as the target organic species in the present study. The goal of the present work was to evaluate the systematic degradation of the target organic pollutant, phenol, by cerium(IV) mediator ion, in a batch reactor and to find the effect of operating parameters such as concentration of phenol, temperature, concentrations of cerium and nitric acid were studied.

### **EXPERIMENTAL**

The overall schematic diagram of the MEO system is shown in the Fig. 1.

#### ***Liquid phase analysis***

The samples at different time intervals were taken and analyzed for total organic carbon using TOC analyzer (Shimadzu TOC-5000A). The percentage of destruction was calculated

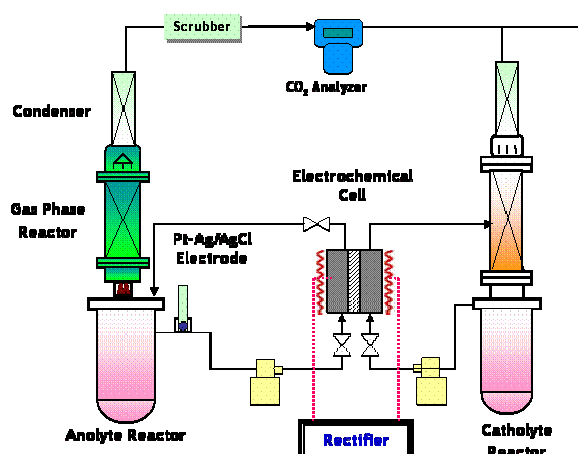


Fig. 1. Schematic diagram of the MEO process.

based on the initial and final TOC values. The concentration of cerium (IV) ion in the solution during organic destruction was measured from the redox potential. From the stoichiometric amount of cerium (IV) consumed, extent of organic destruction was calculated.



### *Measurement of carbon dioxide*

The concentration of carbon dioxide produced during the organic decomposition was measured continuously using a CO<sub>2</sub> analyzer (Environmental Instruments, Anagas CD 98). The flow rate of the carrier gas was kept constant throughout the experiment.

## **RESULTS AND DISCUSSION**

### *Effect of phenol concentration*

Fig. 2 shows a typical profile of variation of the TOC with phenol concentration at 80° C at a fixed Ce(IV) and nitric acid concentration. It was observed that degradation of phenol takes place quickly during the initial stages almost complete mineralization was achieved after 3 hr.

### *Effect of temperature on phenol destruction*

Fig.3 shows the destruction efficiencies vs. reaction time at various temperatures based on CO<sub>2</sub> at a fixed phenol concentration. In Fig. 3, the area under the curve should be proportional to the total volume of CO<sub>2</sub> formed and also the degree of mineralization. The pattern of the curve shows concentration of CO<sub>2</sub> goes through maximum within 5-10 min of reaction time and then decreases to zero and also the destruction was found to be temperature dependent.

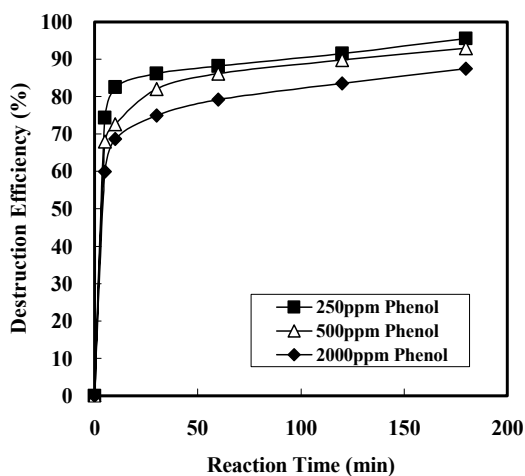


Fig. 2. Variation of destruction efficiencies vs. reaction time for different initial concentrations of phenol at 80° C (1 M [Ce(IV)]<sub>0</sub> in 3 M HNO<sub>3</sub>).

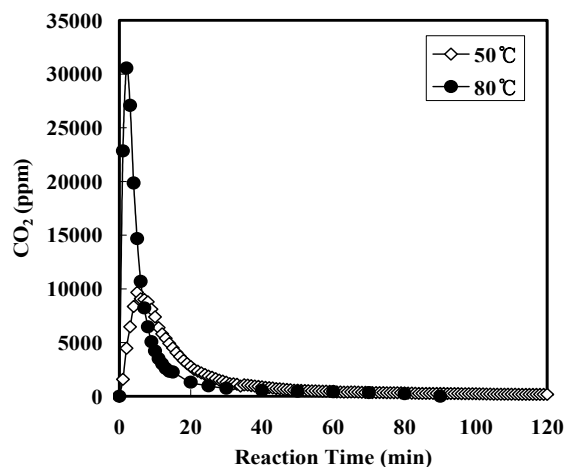


Fig. 3. Effect of temperature on the CO<sub>2</sub> evolution rate for 500 ppm phenol (1 M [C (IV)]<sub>0</sub> in 3 M HNO<sub>3</sub>).

#### ***Effect of cerium (IV) concentration***

The effect of Ce(IV) concentration on phenol degradation was determined. There was not much enhancement in the destruction efficiency between 0.5 M and 1 M Ce(IV) concentrations. The redox potential measured during the reaction time, was of similar pattern to the TOC, and CO<sub>2</sub> results. The destruction efficiency calculated from the amount of cerium consumed for the oxidation was compared with the TOC and CO<sub>2</sub> data and tabulated in Table 1.

#### ***Effect of nitric acid concentration***

The small variance in the destruction efficiency was observed within the range of nitric acid concentration studied. The organic oxidizing ability of the nitric acid medium would likely be the combined effect of both Ce(IV) and nitric acid and might not be solely from nitric acid, at least within the range studied.

### **CONCLUSIONS**

A bench scale study of the MEO process was successfully employed for phenol destruction in a batch reactor by taking the produced Ce(IV) and nitric acid as the mediator solution. Almost complete destruction of high concentration of phenol was achieved within the reaction time. Mineralization was found to be high at and above 70 °C. The increase in the concentration of Ce(IV) from 0.5 M to 1 M increased the destruction efficiency, though less significantly. Within the nitric acid concentrations

studied, it could be said that the oxidizing ability of the medium over the organics is the combined effect of both Ce(IV) and nitric acid but not solely from nitric acid.

Table 1: A comparison of Phenol destruction efficiencies from TOC, CO<sub>2</sub> and Redox measurements at different temperatures in the MEO process (500 ppm phenol, 1 M Ce(IV) and 3 M HNO<sub>3</sub>).

Temperature (°C)	Destruction Efficiency (%)		
	TOC	CO <sub>2</sub>	Redox
50	77.5	72.6	70.4
80	96.4	84.5	85.2
90	97.5	88.3	91.3

### **ACKNOWLEDGEMENT**

This work was funded by Core Environmental Technology Development Project for Next Generation (Eco-Technopia-21) of Korea Institute of Environmental Science and Technology (KIEST).

### **REFERENCES**

- [1] N.J. Nelson, "Handbook of Mixed Waste Management Technology", CRC Publishing, Boca Raton, FL (2001).
- [2] G.A. Steward, "Electrochemical Cell for Processing Organic Wastes", U.S. Patent 5,756,874 May 26 (1998).
- [3] J.E. Surma, G.H. Bryan, J.G.H. Geeting, R.S. Butner, "Apparatus and method for oxidizing organic materials", U.S. Patent 5,707,508, Jan. 13 (1998).
- [4] J. Varela, S. Oberg, T. M. Neustedter, N. Nelson, "Non-thermal organic waste destruction: Characterization of the CerOx system" 4, Environ. Prog. **20 (4)**, 261-271 (2001).
- [5] Il Shik Moon, "Electrochemical cell for hybrid mediated oxidation of organic wastes", Korea Patent 10-2005-0045983 May 31 (2005).