

**ELECTROCHEMICAL METHODS FOR WASTEWATER
AND POTABLE WATER TREATMENT**
Session 3

DIVISION OF ENVIRONMENTAL CHEMISTRY
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Organizer: J.M. Farrell

Presiding: J.M. Farrell

Time	Paper
1:30 p.m.	Electrofoculation for particle destabilization and aggregation for municipal water and wastewater treatment. <u>A. Adin</u> and N. Vescan
2:00 p.m.	Regio-selective reduction of dinitrotoluene mediated by graphite in scrap iron. S.-Y. Oh, D.K. Cha and <u>P.C. Chiu</u>
2:25 p.m.	Reticle carbon and advances in capacitive deionization. <u>C.C. Nesbitt</u>
2:55 p.m.	Virus removal by electrocoagulation-microfiltration. <u>B. Zhu</u> and D. Clifford
3:20 p.m.	Intermission.
3:40 p.m.	Effect of the microstructure of an iron powder on its reactivity on trichloroethylene. <u>H. Nakamaru</u> , T. Ono, Y. Kato and K. Ogura
4:05 p.m.	Comparative study of electrochemical reduction of halogenated natural organic matter and resorcinol. <u>G.V. Korshin</u> and A.B. Velichenko
4:30 p.m.	Electrochemical treatment of wastewater generated from chemical mechanical planarization of silicon wafers. <u>S. Raghavan</u> , S. Tamilmani and J. Farrell
5:00 p.m.	Concluding Remarks.

ABSTRACTS

Electrofoculation for particle destabilization and aggregation for municipal water and wastewater treatment. Avner Adin¹ and Nicholas Vescan²; ¹Division of Environmental Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel, Fax: 972-2-563-5266, adin@vms.huji.ac.il; ²R&D Department, TreaTec21 Industries Ltd., c/o A. T. I.

Chemical coagulation-flocculation is an essential process in municipal water and tertiary or chemically enhanced primary wastewater treatment. A novel electroflocculation (electrochemical-flocculation, EF) technology has been under development, consisting of emission of aluminum or ferric ions supplied by conducting DC to metallic electrodes which also serve as static mixers (patented). Laboratory experiments comparing conventional jar tests and EF tests of raw and secondary effluents show pronounced destabilization and floc formation by EF leading to similar and occasionally better removal efficiencies of turbidity and suspended solids than the conventional. Disinfection effects also occur through hydroxyl ions formation; however, due to the low voltage (2-24 v) and current applied THMF potential is null. An EF-sand in-line filtration pilot-prototype treating polluted Jordan river water of 30 NTU produced turbidity of less than 1 NTU. EF vs. conventional flocculation shows up to 60% cost reduction.

Regio-selective reduction of dinitrotoluene mediated by graphite in scrap iron. Seok-Young Oh, Daniel K. Cha and Pei C. Chiu; Civil and Environmental Engineering, University of Delaware, Newark, DE 19716, Fax: 302-831-3640, pei@ce.udel.edu.

Mechanism and pathway for the reductive transformation of 2,4-dinitrotoluene (DNT) was investigated through batch experiments using high-purity iron powder and Master Builder scrap iron with the same surface area. The reaction kinetics, adsorption pattern and intermediate distribution contrasted sharply, suggesting that different mechanisms were involved in the two iron systems. We hypothesized that a major mechanism with scrap iron, which is absent in the pure iron system, is that exposed graphite serves as an adsorbent for DNT as well as a conductor to transport reductants from iron to reduce the adsorbed DNT. Additional experimental results support this hypothesis and indicate that most of the reducing equivalents transported through graphite was atomic hydrogen, which reacted with DNT primarily through reduction of the *ortho* nitro function. The implications of these findings will be discussed with respect to groundwater remediation and wastewater treatment applications involving scrap iron.

Reticle carbon and advances in capacitive deionization. Carl C. Nesbitt; Reticle Inc., 95 Main St., Suite 10, Los Altos, CA 94022, Fax: 650-948-8850, cnesbitt@mtu.edu.

With the recent advancements in the manufacture of activated carbon electrode material, Reticle Inc. has developed and patented a novel carbon electrode material that has created new opportunities in the field of capacitive deionization (CDI). The material has combined qualities of large surface areas ($> 1500 \text{ m}^2/\text{g}$) with low electrical resistivities and can be tailored during the manufacturing process to give a wide range of properties. This material has helped to propel CDI technology into a more efficient and less expensive water treatment process and has generated new process options in many other areas. To date, desalination and deionization experiments have been conducted which show the material's unique ability to remove ionized species from water at a very low cost. The energy consumption of the process has been demonstrated to be 0.36 Whr/L. This compares favorably to the current processes of reverse osmosis (9 Whr/L) and distillation (53 Whr/L). A broad range of novel uses for the material have also been explored including the recovery of metals from dilute solutions and the removal of trace elements from waste water. These results will also be presented along with background information on CDI and the results of desalination and deionization experiments showing the dramatic improvement with Reticle carbon are part of the presentation and discussion.

Virus removal by electrocoagulation-microfiltration. Bintuan Zhu and Dennis Clifford; Department of Civil and Environmental Engineering, University of Houston, Houston, TX 77204, zhubt@hotmail.com.

The use of membranes in drinking water treatment has a long history. Membranes can remove particles, turbidity, viruses, bacteria and other microorganisms from water and wastewater either completely or significantly. Among these, virus removal using microfiltration (MF) membranes is especially promising.

According to The Surface Water Treatment Rule (SWTR) requirements, utilities must provide at least 99.99 percent or 4 logs virus removal or inactivation along with a filtered water turbidity of 0.5 or less NTU. Microfiltration by itself cannot meet the virus removal requirement of SWTR even though the water turbidity requirement can be easily met.

Chemical coagulation (CC) with ferric salts followed by microfiltration had proven successful for soluble arsenic removal in previous studies at the University of Houston. Based on that experience, we conducted some CC experiments, which demonstrated that CC could improve the virus removal, too. We chose to study electrocoagulation (EC) in detail because when comparing these two methods, EC with ferric ions is reportedly more economical and efficient compared with CC. Moreover, the EC process

requires no pH adjustment and produces less sludge. Finally, in actual practice an EC plant requires less construction time, cost and space compared with CC.

This study was performed to evaluate the effect of EC-MF on virus removal. MS2 bacteriophage was used to measure virus removal; a 0.22mm hydrophilic Draper membrane made of modified polyvinylidene fluoride was used in this study. A 200mL active-volume EC unit with rod-shaped iron anodes and porous cylindrical stainless steel cathodes unit was designed and built by us.

The result shows that the EC unit provided a constant iron concentration when it reached steady state after about six reactor volumes. By adjusting the operating current and flow rate of source water to be treated, the desired iron concentration was obtained.

The data demonstrated that a bench-scale EC-MF system was capable of meeting the SWTR requirement of 4 logs virus removal when 10 mg/L Fe(III) was electrochemically generated into the water. The performance of chemical coagulation ahead of microfiltration was not as good as electrochemical coagulation. The mechanism of removal of MS2 virus was probably due to the absorption of negatively charged MS2 viruses onto the positively charged iron floc particles.

Effect of the microstructure of an iron powder on its reactivity on trichloroethylene. Hiroki Nakamaru¹, Tomoshige Ono¹, Yoshiei Kato¹ and Kuniaki Ogura²; ¹Technical Research Laboratories, Kawasaki Steel Corporation, 1, Kawasaki-cho, Chuo-ku, Chiba 260-0835, Japan, Fax: 81-43-262-2825, nakamaru@kawasaki-steel.co.jp; ²Iron Powder Sales Department, Kawasaki Steel Corporation.

Iron powder with a high reactivity in reductive dechlorination of trichloroethylene has been developed. It is well known that by depositing more noble metallic elements than iron, e.g., Pd, Ni, Cu, etc., on the surface of an iron powder, the reactivity of the iron powder for reductive dechlorination of chlorinated hydrocarbons is improved. However, the cost of using some noble metallic elements is so high, and some elements are so toxic in natural environments that an iron powder with the noble metallic elements is not suitable to use for the purpose of remediating a groundwater or a soil polluted by chlorinated hydrocarbons. In this article, an iron powder with high reactivity without any noble metallic elements will be introduced. The microstructure of the iron powder was controlled by using elements usually existing in an iron powder.

Comparative study of electrochemical reduction of halogenated natural organic matter and resorcinol.

Gregory V. Korshin¹ and Alexander B. Velichenko²;
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Electrochemical behavior of chlorinated and brominated NOM (Suwannee River hydrophobic acid fraction, HPOA) and resorcinol at pH 7 was studied using the method of rotating disc electrode. The potentiodynamic scans indicated that the EC activity of chlorinated HPOA was insignificant while that of brominated HPOA was notable at potentials < -0.6 V. Contrary to the behavior of NOM, both chlorinated and brominated resorcinols were EC active, albeit the dependence of the EC reduction current vs. halogen dose was non-monotonic. This was hypothesized to reflect progressive incorporation of halogen atoms into the aromatic ring of resorcinol accompanied by the progressive formation of halogenated phenols, hexenediones and their breakdown. The diminished EC activity of NOM was suggested to be caused by steric hindrance of charge transfer reactions of NOM. Despite the differences between the EC behavior of NOM and resorcinol, further EC studies of halogenated model compounds are expected to yield important information concerning the pathways of halogen incorporation into aromatic reaction sites.

Electrochemical treatment of wastewater generated from chemical mechanical planarization of silicon wafers.

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Wastewater generated during the chemical and mechanical planarization (CMP) of silicon wafers contains metal ions, oxidants, complexing agents and abrasives. This research investigated an electrochemical process to remove complexed copper ions and organic complexing agents from CMP wastewater streams. Boron doped diamond (BDD) film electrodes were used to oxidize the complexing agents and reductively precipitate copper ions from solution. At BDD anodes, the organic complexing agents could be completely mineralized to carbon dioxide and water. At the BDD cathodes, the copper ions were precipitated as metallic copper. The copper ion removal kinetics in flow-through and batch reactors were zero order in copper concentration and were independent of the solution pH value.