sustainability

Techno-Economic Analysis of Electrocoagulation on Water Reclamation and Bacterial/Viral Indicator Reductions of a High-Strength Organic Wastewater—Anaerobic Digestion Effluent

Sibel Uludag-Demirer [1], Nathan Olson [1], Rebecca Ives [2], Jean Pierre Nshimyimana [2,3], Cory A. Rusinek [4], Joan B. Rose [2,5], and Wei Liao [1,5,*]

[1] Anaerobic Digestion Research and Education Center (ADREC), Michigan State University, 4090 College Rd, Lansing, MI 48910 USA; demirers@msu.edu (S.U.-D.); olsonna3@msu.edu (N.O.)
[2] Department of Fisheries and Wildlife, Michigan State University, 480 Wilson Rd, East Lansing, MI 48824 USA; ivesrebe@msu.edu (R.I.); nshimyim@mail.msu.edu (J.P.N.)
[3] Drinking Water Investigation Unit, Division of Environmental Health, Michigan Department of Health and Human Services, 333 S. Grand Ave, Lansing, MI 48909 USA
[4] Department of Chemistry and Biochemistry, University of Nevada, 4505 S Maryland Pkwy, Las Vegas, NV 89154 USA; cory.rusinek@unlv.edu (C.A.R.)
[5] Department of Biosystems and Agricultural Engineering, Michigan State University, 524 S. Shaw Ln, East Lansing, MI 48824 USA; rosejo@msu.edu (J.B.R.)
* Correspondence: liaow@msu.edu (W.L.); Tel: 517-432-7205

1. Introduction

The electrocoagulation (EC) is a promising technique for the recovery and reclamation of water from high strength wastewater. EC is very efficient to remove particulate matter related substances such as TS, tCOD, TP, and some biological indicators. However, it has difficulty to remove soluble compounds, particularly nitrogen-based substances (i.e., total ammonia nitrogen (TAN) of NH_3 and NH_4^+). It has been reported that complete mineralization of organics and removal of TAN in biologically pretreated coking wastewater produced in iron-steel manufacturing was successful using boron-doped diamond (BDD) employed EO (Zhu, Ni and Lai, 2009). The EO treatment of reverse osmosis brine was studied using BDD anode and the removal of organics and TAN have been found to be complete in addition to the removal of color. The BDD is very selective for electrogenerated hypochlorite production and has a high overall current efficiency compared to RuO_2 electrode. The major concern in this process is the formation of organochlorides because of EO reactions and they must be identified prior to reuse of reclaimed water. Therefore, electrooxidation (EO) technology using BDD electrodes was adopted to remove TAN and further clean up the water.

2. Materials and Methods

EO tests were also run in 0.5 L batch reactors using the EC effluent after 10 minutes of the Fe-Fe EC at 2 A and 10 minutes of settling. 5 BDD electrodes (2 anodes, 3 cathodes) were fabricated on niobium (Nb) substrates at Fraunhofer USA, Inc. Center for Coating and Diamond Technologies. The BDD on Nb electrodes were assembled in a parallel plate stack where they were spaced 0.3 cm from one another and connected to a Sorenson DCS 60-50 power supply. The surface area of the anode is 94 cm^2. The BDD parallel plate electrode stack was placed in a 0.5 L beaker and stirred to increase mass transport to the electrode surface. A 15 mL aliquot of the treated water was taken at 0, 30, and 60 min for sample analysis. In between the varied current density experiments, the electrode stack was disassembled and rinsed with deionized water and 5% acetic acid; a clean anode and cathode surface was generated for subsequent experiments.

3. Results and Discussions

The anaerobic digestion effluent studied in this test contained 690 mg NH_3-N/L, which was less than that in the effluent used in the main paper. After the EC treatment, the reclaimed water still

contained relatively high TAN at 455 mg NH_3-N/L. The corresponding tCOD and turbidity of the EC reclaimed water were 150 mg/L and 178 NTU, respectively. The EC reclaimed water was collected and then transferred to EO reactor. To understand the effect of energy input and removal efficiency for TAN during the EO process, different current levels were applied in a range of 75-125 mA/cm^2. Considering the minimization of energy consumption, maximum duration of EO was set to 60 minutes. The liquid samples at 30 minutes and 60 minutes of EO reactions were collected to be analyzed for turbidity, tCOD, and TAN. The results are given in Table 3. The turbidity levels were as low as 5 NTU in the first half hour of EO process regardless of energy input tested (75, 100, and 125 mA/cm^2), while TAN and tCOD concentrations reduced gradually with time and energy input. The concentrations of TAN reduced to 103 mg NH_3-N/L when 125 mA/cm^2 current applied for 60 minutes. The concentration of tCOD was negligible in a range of 14-34 NTU. The results clearly demonstrated that EO is a technology that can significantly remove TAN and further polish the reclaimed water.

Table S1. The effect of current density and reaction time of EO on the removal of TAN, tCOD, and turbidity.

		TAN (mg NH_3-N/L)	**tCOD (mg/L)**	**Turbidity (NTU)**
	EC effluent	455	150	178*
75 mA/cm^2	EO effluent (30 min)	406	34	5.4
	EO effluent (60 min)	238	16	5.4
100 mA/cm^2	EO effluent (30 min)	371	23	4.2
	EO effluent (60 min)	200	15	4
125 mA/cm^2	EO effluent (30 min)	304.5	18	5.2
	EO effluent (60 min)	103	14	5.6

*: The turbidity of the EC reclaimed water for the EO experiment was higher than it (30.2 NTU) of the EC reclaimed water in the kinetic study. It is due to the fact that a small portion of solids was re-dissolved during the sample transfer from EC to EO.

References

Zhu, X.; Ni, J.; Lai, P. Advanced treatment of biologically pretreated coking wastewater by electrochemical oxidation using boron-doped diamond electrodes. *Water Res.* **2009**, *43*, 4347–4355.