Electrochemical Coagulation & Ferrate

Overview. This short study represents a special collaboration between the University of Houston & the University of Massachusetts. It is aimed at comparing electrochemical coagulation, conventional coagulation, and ferrate pre-oxidation with conventional coagulation for the control of DBPs.

Background. Electrochemical coagulation is an alternative to conventional chemical coagulation for municipal and industrial wastewater treatment as well as drinking water purification. Its advantages include i) ability to be configured into portable units, ii) commercial availability of energy optimized modules, iii) reduced usage of corrosive chemicals, iv) lower labor costs because of the higher degree of automation and low maintenance. Additionally, in some instances (e.g. higher coagulant dosages) floc flotation can occur along with coagulation making it more appealing as a pretreatment step reducing mass loading onto downstream processes such as media or membrane filtration. Small-scale electrocoagulation units are already being extensively used for industrial wastewater treatment. The focus of our research has been adapting its use for surface water purification using it for microfiltration pretreatment to reduce fouling and increase virus removals [1-4]. However, to our knowledge the ability of electrocoagulation to control Disinfection By-Product (DBP) formation has not yet been evaluated.

Objectives. The primary objective of this research is to quantify reductions in DBP precursor concentrations following electrochemical and chemical coagulation treatment of surface water both with and without ferrate pre-oxidation. A wide spectrum of regulated and unregulated DBPs including trihalomethanes and haloacetic acids will be measured.

Experimental methods.

     Lake Houston water will be used as a representative surface water sample. This water has a near neutral pH. The hardness, conductivity, buffering capacity, and nitrogen concentrations are low but NOM concentrations and turbidity can be characterized as being moderate. A large sample of this water will be collected and partitioned into two separate, but identical samples. One (~20L) will be shipped to UMass for bench-scale testing and the other will be transported to UH for testing there.

     At the **University of Houston**, electrocoagulation experiments will be carried out in a custom designed cylindrical Perspex cell with a drain at the bottom. A single anode-cathode combination will be used where the anode (iron/aluminum) is mounted inside a porous stainless steel cathode. In each experiment, 450 mL of surface water will be electrochemically treated at a constant current density of 20 mA/cm^2 with an active surface area of 17.27 cm^2 in batch mode. The suspensions will be rapidly mixed during electrolysis (note that the rapid mix duration varies with dosage) and then slow mixed for 10 minutes. During iron electrocoagulation, the suspension will be air sparged to maintain dissolved oxygen levels to facilitate ferrous iron oxidation to insoluble ferric iron. After electrocoagulation, a 20 mL aliquot will be set aside for total metals analysis. The remaining volume will be filtered through

Whatman glass fiber filters (GF/F 1825-047, Fisher Scientific), stored in 500 mL media storage bottles, and shipped to the EWRE labs at the University of Massachusetts along with the small unfiltered sample.

Table 1. *Summary of electrocoagulation experiments*

pH	Coagulant	Dosage (mg/L as Al or Fe)	Electrolysis (rapid mix) time (s)
6.4	Aluminum	0 (control), 3, 6, 10, 15 and 20	From UH protocol
8.3 during electrolysis and 5.5 during flocculation	Iron	0 (control), 3, 6, 10, 15 and 20	From UH protocol

Total number of experiments = 10 (1 current density, 1 pH value, 2 coagulants, 5 coagulant concentrations)

At the **<u>University of Massachusetts</u>**, testing will be done on both the raw Lake Houston water and on the electrocoagulated samples from UH.

The raw Lake Houston water will be treated in accordance with the UMass standard protocol for ferrate process testing, as modified for this study (figure 1). The specific pHs and coagulant doses conditions listed in Table 1 (above) will be used in the UMass testing as well. As in Table 1, the alum and ferric coagulant doses are expressed as mg-Al/L or mg-Fe/L.

The dosed samples will be rapidly mixed for 1-2 minutes (with magnetic stir bar) and then slow mixed for 10 minutes at 20 rpm. After coagulation, samples will be filtered through Whatman glass fiber filters (GF/F 1825-047, Fisher Scientific), stored in 500 mL media storage bottles, and processed as indicted in Figure 1.

The high ferrate-dose, high ferrate pH will be used for direct comparison with the UH electrocoagulated samples. To facilitate comparison, UMass will use ferric chloride coagulant doses that result in a comparable total iron dose (ferrate + ferric) to those used at UH for electrocoagulation. Therefore the 50uM ferrate dosed samples will be treated with ferric chloride doses that are about 3 mg/L as Fe lower than those in the figure below. All other samples will be treated exactly as shown.

In order to conserve raw water volume, exploratory coagulation tests (those done solely for the purpose of finding the "optimal" dose) will use 250 mL total volume. Full "analytical" jar tests (those identified for full testing of DBP precursors, metals, etc) will be done in 500 mL volumes. These filtered samples will be combined with remaining filtrate from the corresponding 250 mL exploratory test to result in a total volume of about 700 mL.
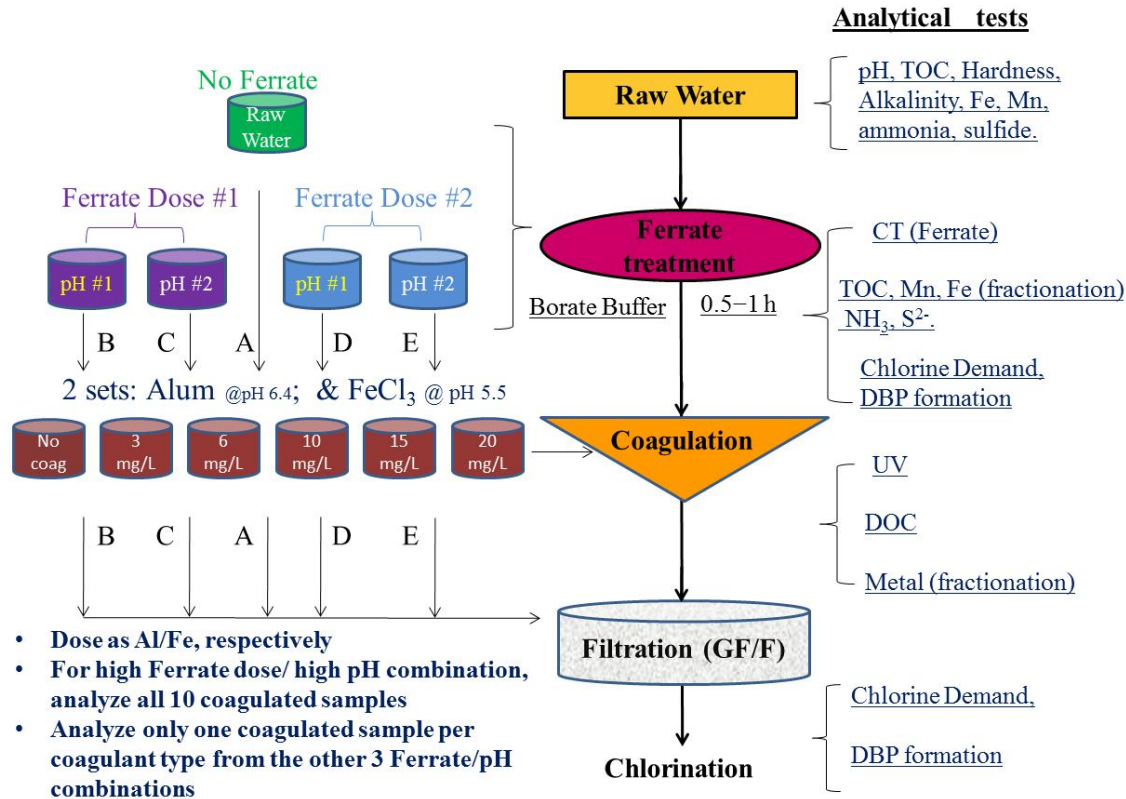
Figure 1. Experimental Design for UMass Laboratory Testing of Lake Houston Water

The 10 samples (plus controls) produced during raw water treatment (per Figure 1) along with the 6 treated at other ferrate/pH combinations will be subjected to the standard UMass chlorination procedure and analyzed for the full range of DBPs[1]. At the same time, the 10 electrocoagulated samples from UH will be treated in an identical fashion.

References
[1] A. Bagga, S. Chellam, D.A. Clifford, Evaluation of iron chemical coagulation and electrocoagulation pretreatment for surface water microfiltration, Journal of Membrane Science, 309 (2008) 82-93.
[2] N.P. Gamage, S. Chellam, Aluminum electrocoagulation pretreatment reduces fouling during surface water microfiltration, Journal of Membrane Science, 379 (2011) 97-105.
[3] N.P. Gamage, J.D. Rimer, S. Chellam, Improvements in permeate flux by aluminum electroflotation pretreatment during microfiltration of surface water, Journal of Membrane Science, 411-412 (2012) 45-53.
[4] C.T. Tanneru, S. Chellam, Mechanisms of virus control during iron electrocoagulation - microfiltration of surface water, Water Research, 46 (2012) 2111-2120.

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[1] We're planning to do TOX, Haloacetamides, haloketones, haloacetonitriles and possibly haloquinones in addition to the THMs & HAAs