

Progress Report #2
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Improving Recovery: A Concentrate Management Strategy for Inland Desalination

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To the University of Texas at Austin

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Progress continues on this new project, though we are still very much in a startup phase. We have been making progress on **Tasks 1a and 1b**, having to do with the oxidation by ozone or “peroxone,” the combination of ozone and hydrogen peroxide. This combination forms a relatively high concentration of hydroxyl radicals, the most powerful oxidants. At this stage, we have just completed the first level of startup—having a system in which we can apply an ozone dose at a known and controllable rate. We showed a schematic diagram of the apparatus in the previous report.

The ozone generator is Model OL80W/FM100V manufactured by Ozone Lab Instruments (<http://www.ozonelab.com/index.htm>). The built-in flow measurement device is a simple rotameter that does not give sufficient flow rate precision or accuracy; more importantly, it is insufficient to ensure that one can get the same flow rate in experiments on different days (*i.e.*, reproducibility). As a result, a digital mass flow controller manufactured by MKS Instruments (Model 1179) has been installed between the oxygen tank and the ozone generator; this mass controller gives excellent control and reproducibility of the oxygen supply to the ozone generator. Although the system has a built-in ozone destruction system after the reactor, the entire system is operated under a fume hood to minimize any risk of exposure to gaseous ozone.

In Figure 1, data obtained recently from that apparatus is presented; the input to the ozone generator is the oxygen flow and the output is a mixture of ozone gas and remaining oxygen. The ozone generator has an “intensity” setting that controls the electrical voltage applied to the influent oxygen stream and, thereby, controls the rate of ozone generation. The results shown in the figure are from an intensity setting of nine (on a scale of zero to ten); the interpretation that follows is based not only on the single set of data shown but also on data from other experiments performed at lower intensity settings. The data can be considered in three ranges. At low influent oxygen gas rates (less than 10 mL/min), the conversion to ozone is somewhat inconsistent, perhaps due to less turbulent flow in the generation chamber. At intermediate flow rates (10 to 60 mL/min), the conversion to ozone is nearly linear and quite reproducible. At high oxygen flow rates (60 to 200 mL/min), the efficiency of conversion to ozone dies off considerably, so that the mass production rate levels off to a nearly constant value at the highest oxygen flow rates. (The value at the highest flow rate shown from this one set of data is inconsistent with

this latter statement, but that point is considered an outlier based on other experimental data.) Because accurate control is necessary in the experiments planned in this research, we expect to operate in the best (most linear) region of this curve, which means oxygen flow rates in the 20 – 40 mL/min range. Since the primary reason to generate ozone in this research is to oxidize anti-scalants, the volume of the solution for that oxidation will be targeted with this range of ozone generation in mind.

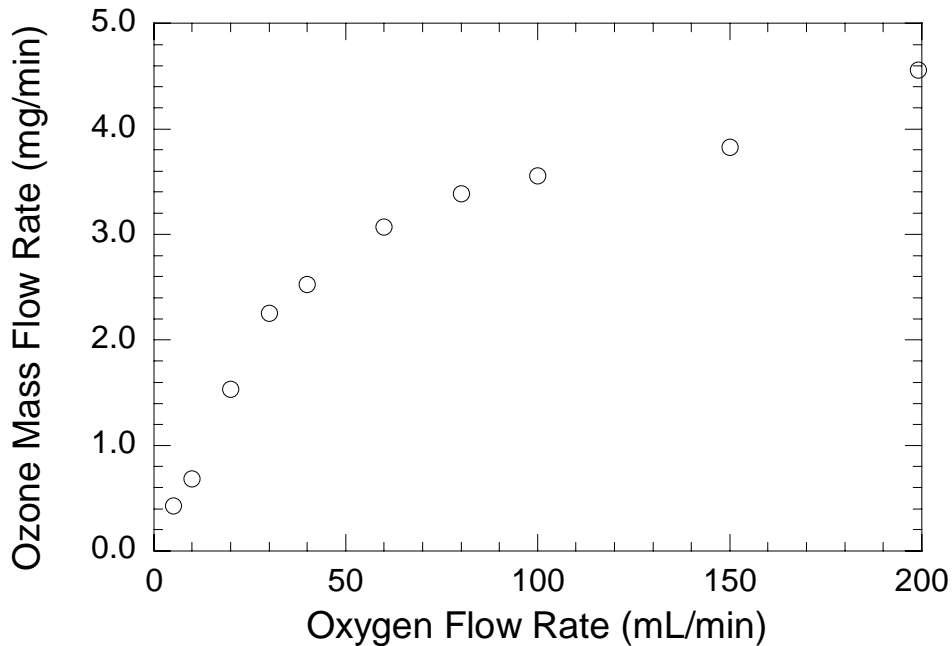


Figure 1. Ozone Generation from Oxygen Gas. (Intensity setting on ozone generator at nine)

We have also made progress in setting up an electrodialysis (ED) system in the laboratory (**Task 3a**). In electrodialysis, alternating cation- and anion-exchange membranes are set in a parallel arrangement; the space between adjacent membranes is called a cell, and the entire arrangement of many membrane pairs is called a stack. An electrical voltage is applied across the stack, causing anions to move toward the anode and cations to move toward the cathode. Because anions can move easily through anion-exchange membrane but cannot pass through cation membranes, and vice versa for cations, alternating cells lose ions of both types (forming the *diluate*, the stream that is cleaner than the influent) while the adjacent cells gain ions of both types (forming the *concentrate*, the stream with higher concentrations of ions than the influent). Oxygen and/or chlorine gas is produced at one electrode, while hydrogen is produced at the other; because of this gas production, the electrode regions must be constantly rinsed with some solution to carry these gases out of the system. This *electrode rinse* can be done with the same influent stream (and two effluent streams, or the same stream can be sent from the effluent of one side to the influent of the other, creating a single electrode rinse waste stream. In a full-scale unit, where 200 to 500 cell pairs are in a single stack, the electrode rinse is a very minor part of

the overall system flow; however, in a laboratory unit (where only one or a few cell pairs make up the stack), the electrode rinse is a significant portion of the overall flow.

Because there are three streams involved, laboratory ED systems are complex and they also can be operated in several different ways. At this time, it appears to us that the two configurations shown in Figure 2 are the most fruitful for laboratory and small-scale research. In the batch-recycle configuration (Figure 2a), separate reservoirs for the three streams are set up; at time zero, the same solution composition is in the diluate and concentrate reservoirs, and the electrode rinse can be either the same solution or something different. When the voltage is applied and water is recycled through the system from all three reservoirs, ions are transferred through the membranes from the diluate to the concentrate, leading to a gradual separation of the concentrations of these two reservoirs. It appears that the best way to run this configuration is at a high flow rate with a detention time in each reservoir considerably longer than the detention time in the ED stack.

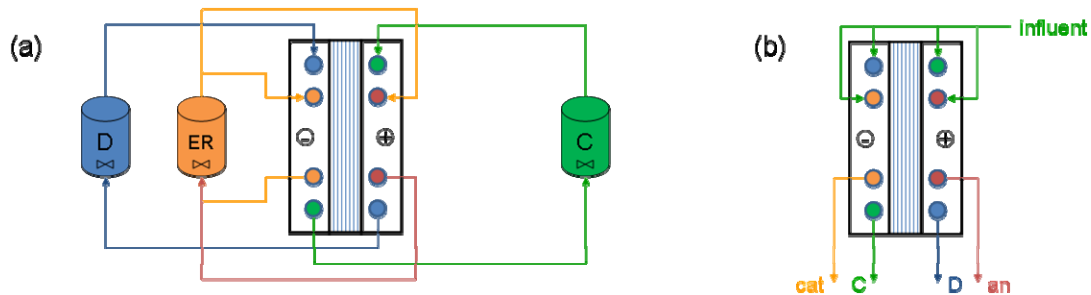


Figure 2. Schematics of experimental electro dialysis system hydraulic configurations: Part a is batch-recycle and Part b is single-pass. (D, C, ER, cat, and an refer to diluate, concentrate, electrode rinse, catholyte rinse, and anolyte rinse, respectively.)

The single-pass configuration (Figure 2b) emulates full-scale systems more exactly, and therefore is likely to be the configuration used much later in this research program when we do field studies. In this configuration, there is no recycle and so the residence time in the stack has to be sufficiently long to accomplish a reasonable separation. Because the size of the unit to be used in this research is quite small, the flow rate will be low.

Further development of the ED system for this research will be forthcoming in subsequent reports.