NWRI GRADUATE FELLOW FINAL PROGRESS REPORT

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Project Title: A Novel Brine Precipitation with the Aim of Higher Water Recovery

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Introduction

Potable water scarcity has become an important issue over the last few decades due to changes in rainfall patterns and increasing population. Recent estimations demonstrate that more than 1 billion people do not have access to clean potable water, and approximately 2.3 billion people live in regions with water shortages [1]. Therefore, there is an increasing global trend toward using water more efficiently in urban and rural communities. In addition to novel water acquisition and management strategies, such as water transfers, banking and trading, municipalities are turning to water reuse to strengthen their water portfolios [2].

High pressure membrane processes, such as NF and RO, are commonly used to produce drinking water from brackish waters. The RO and NF processes are able to remove both organic and inorganic contaminants and produce clean water [3]. Two major limitations to these processes are membrane fouling and production of a concentrated brine stream [3, 4].

There are four main causes of membrane fouling:

1) Microorganism growth;
2) Colloidal material adsorption;
3) Mineral scale (most commonly divalent cations combined with sulfate and carbonate); and
4) Natural organic matter, such as humic and fulvic acids.

Options for concentrate disposal include: deep well injection, discharge to surface water/ocean, and evaporation [5]. Treatment of brine is a site-dependent issue, and the method usually depends on costs, which can be as high as 25% of the overall water treatment costs [6]. The high cost of brine treatment and adverse impacts of brine disposal on the environment are two variables that could be improved by using pretreatment methods that can increase the permeate water recovery and minimize brine generation.

The main goal of this research is to develop a new pretreatment technique for water treatment processes that use membranes. The proposed process consists of pretreatment techniques that will provide a cheaper water treatment option than currently used commercial processes and aims for zero brine waste generation.

The technology to be developed here will enable large-scale inland desalination using RO and NF, which are not commonly practiced in non-coastal areas due to the high costs of brine disposal. Decreasing the volume of brine production by one order of magnitude will make inland RO and NF cost-effective [7]. This will enable both municipally treated wastewater and brackish groundwater to be used as sources of potable/industrial water. These two new sources of water will improve economic development, which was limited by water scarcity in arid regions of the country.

Progress

During past 2 years, I worked on combining several treatment technologies (fluidized bed crystallization reactor, staged membrane processes, bipolar membrane electrodialysis and ferric chloride coagulation/flocculation) in order to achieve a zero-liquid discharge (ZLD) treatment for secondary wastewater. As previous versions of the project schematics were provided in previous reports, following schematics of the system is the most up to date version which has been improved according to the experiments done on the system.

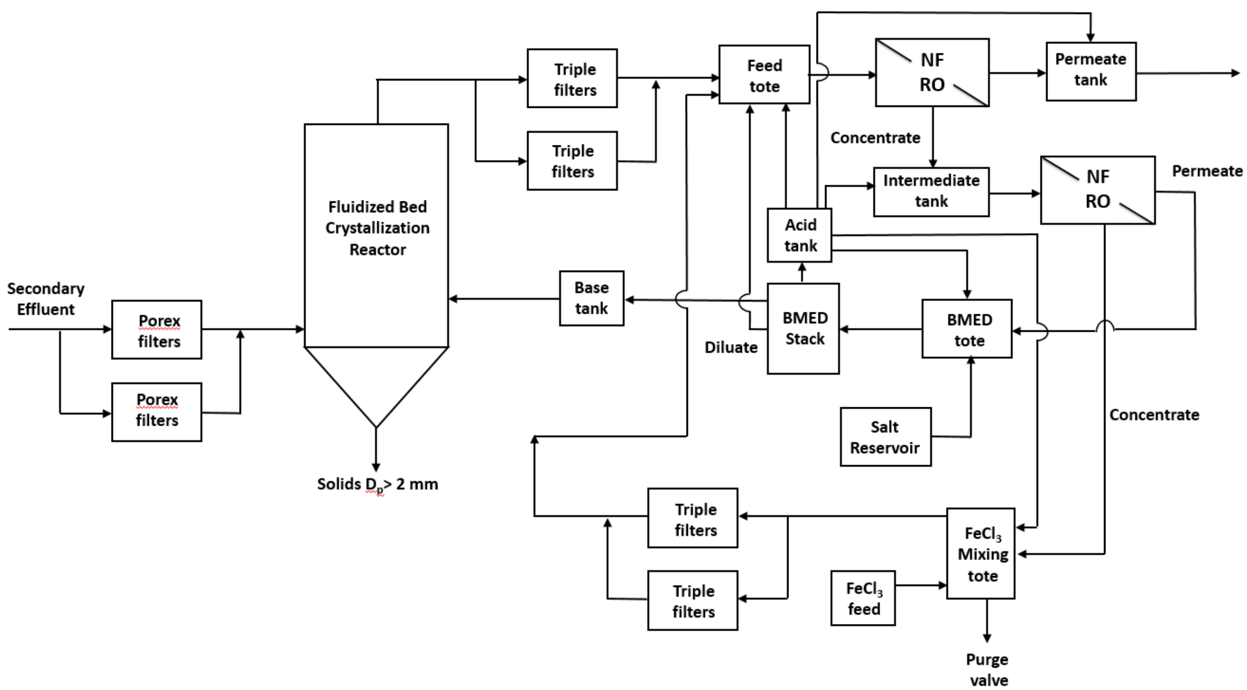

Figure 1 Project schematics

The pH value of the secondary wastewater is increased to 11.5-11.8 in the fluidized bed crystallization reactor (FBCR) and calcium and magnesium are precipitated as calcium carbonate and magnesium hydroxide on the garnet in the FBCR. In optimized conditions (bed is fluidized and pH is above 11.5), over 80% and 70% of the calcium and magnesium are removed, respectively.

The effluent of the FBCR passes through 10-20 micron filters (triple filters) in order to remove the precipitates that are carried over to the next stage. Then, this water enters to the first membrane (RO) and 99% of the monovalent and divalent ions are being removed at this stage. The permeate water exits

the system as clean water produced by the treatment train. The concentrate of this stage (20% of the initial feed volume) is fed to the second membrane (NF to remove the divalent ions. The concentrate of this stream which will be the dirtiest water produced will go to ferric chloride coagulation/flocculation step and the permeate flow will go to bipolar membrane electrodialysis (BMED).
Permeate flow of the secondary membrane enters to the BMED which will produce acid and base for the system. Based on the preliminary results, pH values of 1.4 for acid and 12.7 for base are achieved without any elaborate optimization of this stage; therefore, more concentrate acid and base streams are possible with better controlling of the flow and the applied current to the BMED.

According to the newly published research articles, ferric chloride's coagulation ability can be optimized with the pH. The authors of Racar et al. mentioned that ferric chloride had its highest organic matter removal at effluent pH of 5.58 and the iron (lll) concentration of 26.38 mg/L [8]. Therefore, the pilot plant design is optimized to include a pH sensor in the ferric chloride mixing tank and a pump for adding acid to the tank using the acid generated by BMED. TOC values will be measured for different pH values and iron concentration to optimize the organic matter removal in this specific wastewater in the next few months.

I have also worked on a controller system for the whole pilot plan to run the system on continuous mode. In order to achieve this goal, I have used multi parameter controllers to measure pH and level to control pump speeds and actuator valves which is discussed in the details of previous progress reports.

Conclusions

Even though there are several months of experiments left in this project, the preliminary results indicate that high inorganic contamination removal is possible using the FBCR. Furthermore, the amount of the acid and base made using the BMED will be sufficient to have a closed loop system, and we can avoid purchasing acid and base, which is one of the novelties of this system. Previous studies show the effect of pH and iron concentration in organic matter removal in ferric chloride mixing stage that needs to be investigated. However, if the results of these recently published articles can be reproduced, this system will be able to run continuously without early membrane fouling. For the next few months, these and several other hypotheses will be validated and more experiment data will be gathered in order to suggest this treatment system can be commercialized.

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