The Removal of Nitrate from Reverse Osmosis Concentrate Stream

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Project Abstract

The new reverse osmosis (RO) water treatment system on the Cal Poly Pomona campus has a rate of return close to 80% with the brine waste stream, consisting primarily of nitrate, concentrated within 20% of the influent water. Because this waste cannot be reintroduced to the environment, Cal Poly Pomona has purchased a wastewater permit from the Los Angeles County Sanitation District and is required to pay disposal fees based on the amount of waste produced. The goal for this project was to develop a sustainable alternative that will effectively treat the concentrated nitrate waste produced by the RO plant. This method of treatment will benefit the University by reducing the amount of waste produced and save the campus money on hazardous waste disposal permits.

The proposed solution is a three-step treatment process that will utilize electrodialysis, ion exchange resin, and bioregeneration for resin restoration. The purpose of electrodialysis (ED) is to further concentrate the brine waste for biological treatment restoration stage as well as reclaim additional water from the brine stream. The highly concentrated waste stream generated by ED is then fed into an ion exchange (IX) system that will utilize resin beads to capture and retain the nitrate. After the resin has reached its saturated capacity and can no longer retain nitrate, the beads will enter a cleaning and restoration phase known a bioregeneration. The bioregeneration process incorporates the use of denitrifying bacteria that will naturally reduce nitrate into nitrogen gas that can be released into the atmosphere. The concentrated brine waste produced by ED will increase the rate of denitrification and ultimately decrease the amount of time required for the bioregeneration process. The water that is reclaimed from the IX stage of the treatment will undergo post treatment to remove any of the bacteria that may still be present from the bioregeneration process before the water can be used for irrigation purposes.
**Project Summary**

*Electrodialysis Summary*

The proposed solution will first utilize electrodialysis to generate a more concentrated brine stream from the RO waste effluent. A laboratory scale ED system was constructed and used to analyze its removal capabilities. The ED unit was designed using zinc sheet metal, ED membranes (CR67 cationic and AR204 Anionic), polyurethane spacers, and plastic plating all bolted together in an area of 31 in\(^2\). A DC power supply was used to provide a minimum and maximum voltage of 5 volts and 45 volts respectively.

A limiting current analysis was conducted to determine removal efficiencies of water samples under various electrical currents. The limiting current test is performed in order to determine the ideal current to maximize ED efficiency. The test was conducted using three different water samples: 1) tap water; 2) a sodium chloride solution with TDS concentrations that were expected of RO brine; and 3) concentrated well water obtained from a laboratory RO system with the appropriate nitrate concentration expected of the RO effluent. The results show that the ED unit has a limiting current of approximately 0.24 Amps, a maximum TDS removal of about 75%, and a maximum nitrate removal of 87%. Future construction plans include adding a second stage to achieve 87.5% removal, titanium-platinum sheets, and laser cutting materials.

*Ion Exchange Summary*

The concentrated nitrate effluent from ED will then enter the ion exchange resin tank in which the nitrate will be “exchanged” with the chloride ions on the resin bead. Nitrate will continue to be exchanged with the chloride ions until the resin has reached its full capacity upon which nitrate will pass through the system. This is known as the break point and can be determined through a breakthrough test. The breakthrough test was conducted in order to analyze the capacity of the resin beads under high concentrations of nitrate and to determine the ideal conditions for the IX system. A laboratory scale
IX column, approximately 15 inches high with a radius of 0.25 inches, was filled with approximately 20 mL of nitrate specific resin. To conduct the experiment, a highly concentrated nitrate solution was pumped into the column for approximately two hours at a constant flow rate while 10 mL samples were collected during the duration of the test. The samples were then measured for nitrate and recorded on a graph to determine the point at which the resin has reached its full saturation point. The results indicate that the resin reached its full capacity after approximately 1 hour and 773 mL of water, when the nitrate concentration in the effluent increased to 45 mg/L. Future work will consist of repeating the breakthrough curve test to confirm resins efficiency for the proposed system.

**Bioregeneration Summary**

Bioregeneration is the process of restoring the resin bead to its original state so it can uptake nitrate once more. Bioregeneration testing was conducted in two phases to analyze its restoration ability. The first phase of testing consisted of collecting and maintaining a denitrifying microbial culture for a laboratory scale bioreactor. Based on previous research, it was hypothesized that the resin would be restored close to its original capacity after the 10 day bioregeneration process. The test was conducted as a batch reactor in which the saturated resin from IX was placed into direct contact with the bioreactor for 10 days. During the test, the health of the microbial culture was monitored for pH, dissolved oxygen (DO), oxygen reduction potential (ORP), and temperature. Additionally, the bioreactor was dosed with carbon, supplemental nutrients, and alkalinity in the form of an enrichment solution. Dosage concentrations were adjusted based on the results obtained from ORP, DO, pH and temperature measurements. After the designated exposure period, the resin was removed from the reactor and placed in a sodium hypochlorite solution to disinfect the resin remove any biofilm remaining on the bead. Finally, the resin was soaked in a highly concentrated nitrate solution to analyze its capacity. The second phase of testing focused on comparing standard regeneration practice with bioregeneration to evaluate regeneration efficiency. The comparison analysis was performed by soaking nitrate saturated
resin in a highly concentrated sodium chloride solution then evaluating its capacity by exhausting it once more in a highly concentrated nitrate solution.

The results from testing confirm that the bioregeneration process is a feasible alternative to standard regeneration practice. The resin was able to absorb the same amount of nitrate as the initial saturation (approximately 97%). When compared to conventional regeneration, the bioregeneration process performed significantly better and did not generate a highly concentrated salt waste. Future work pertaining to the bioregeneration process will focus on determining the ideal time period for maximum nitrate removal.

**Conclusion**

The goal of this project was to design and test a more sustainable and economical solution to reduce costs associated with the disposal of hazardous waste generated by the RO treatment facility on the Cal Poly Pomona campus. The results of testing confirm the feasibility of the proposed solution and its ability to treat the highly concentrated nitrate waste generated by the RO facility. With the proposed system, costs associated with hazardous disposal will be significantly reduced and will provide the campus with an additional source of water. Furthermore, the proposed solution utilizes natural biological processes to significantly remove hazardous contaminants and eliminate the use of dangerous chemicals for nitrate removal. Future work across the entire project will consist of analyzing the system's ability to remove and treat perchlorate. Additional considerations such as the implementation of solar panels will also be considered to create a more energy efficient process.
References


State Department of Health Resources. 2012. *California Regulations Related to Drinking Water*.
