Technical Paper

Electrodialysis Reversal at the City of Sherman

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Introduction

The City of Sherman, Texas is located about 60 miles north of Dallas, Texas and is near Lake Texoma. The city has about 35,000 residents and a wide industrial base ranging from food processing to wafer manufacturing. Until May 1993, the city relied exclusively on groundwater supplies for potable water. Thirty wells provided the city with approximately 14 million gallons per day (MGD) (53,000 m^3/day) of potable water. In the early 1970s, five wells were added to the system to meet demands. Due to further growth, six more wells were drilled during the early 1980s. These wells spanned outside of the city limits and required more capital and maintenance cost than had previously drilled wells. Eventually, growth in both residential and industrial demands began to exceed the safe limits of pumping from existing wells. The cost of drilling and transporting new groundwater sources outweighed the cost of treating surface water. The city was interested in expanding its water system but at the same time, wanted an abundant reliable source of water.

In the mid 1980s, the city began to look at Lake Texoma as a source of raw water to supplement the existing groundwater supplies. Lake Texoma was built in 1944 as a means to control flooding of the Red River. Several studies were conducted to determine the feasibility of treating Lake Texoma water for potable use. From the study, it was concluded that the lake water contained a significant amount of total dissolved solids (TDS). The high levels of TDS was attributed to the flow of naturally occurring salt deposits into the Red River and thus into Lake Texoma. The apparently high TDS and mineral content of the lake water became the basis for the need for demineralization technology. Demineralization would be needed to bring the levels of naturally occurring chlorides and sulfates to acceptable levels for drinking water.

Pilot Study

In the late 1980s, a pilot study was initiated to determine the effectiveness of demineralization technology on Lake Texoma water. Electrodialysis reversal (EDR) and reverse osmosis (RO) were piloted for six months. Both technologies performed well throughout the study. However, the performance of the RO system was limited by barium sulfate scaling which caused reduced recoveries and higher maintenance cost. EDR was selected as the demineralization technology based on its ability to achieve 85% water recovery, its tolerance to barium sulfate scaling and its tolerance to variations in feedwater quality.

Surface Water Treatment Plant

In May 1993, a 10 MGD (38,000 m^3/day) surface water treatment plant utilizing EDR was placed on-line to treat Lake Texoma surface water. The plant basically consists of two facilities; conventional and demineralization treatment plants. The conventional treatment plant utilizes preoxidation, rapid mixing, flocculation/sedimentation and dual-media filtration. Once the raw water has been conventionally treated, the treated water can either be demineralized, sent to distribution or blended to produce

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a finished water. Initially, the demineralization plant was designed for four three-stage EDR units. However, at start up, the demineralization plant only contained three two-stage EDR units installed on the same footprint as would be needed for four three-stage EDR units. The demineralization plant was capable of producing about 4.5 MGD (17,000 m^3/day). Also, the design of the demineralization plant allowed for further expansion and for necessary support equipment. Support equipment for demineralization plant includes five high-service pumps to deliver treated water to the EDR units, five cartridge filters to remove particles larger than 10 micrometers (µm) from the feedwater and support for electrical and chemical systems. In November 1996, the first expansion occurred, which involved installation of a fourth EDR unit. The fourth EDR unit had the same configuration as the EDR units that were installed in 1993. In order to maintain finished water goals, an additional third stage was added to each EDR unit in February 1998. The third stage included the use of a new high-performance membrane stack. These new generation stacks enable larger increases in desalting capability than would have been possible with conventional membranes. With four three-stage EDR units, the demineralization plant now is capable of producing 5.7 MGD of demineralized water.

Operation and Maintenance

The most important factor in the operation of the units is to supply acceptable feedwater to the EDR units. This includes good pH control, maintaining a slight chlorine residual and providing low turbidity water to the EDR units. Also, when using conventional treated water, one should always try to avoid clarifier upsets, filter surges and chlorine overdosing. If conventional plant upsets do occur, cartridge filters will provide a great deal of protection for the EDR units.

Operation and maintenance of the EDR units is fairly straight forward. Routine maintenance is usually accomplished through a series of cleaning procedures and daily monitoring.

Clean in Place

The primary maintenance procedure is called the Clean-In-Place (CIP). The CIP will remove most scaling, organics and staining which have accumulated on the membranes during normal operation. The CIP cleans the unit without having to disassemble the stacks. Essentially the CIP involves circulating a hydrochloric acid (HCl) and sodium metabisulfate solution through each stack and allowing the solution to sit for a period of time. The solution is then recirculated and sent to waste and the stack is then neutralized and placed on line. A CIP is performed about every 450 to 550 hours and usually takes four to five hours to complete. The next cleaning procedure involves cleaning the electrode compartments in what is called the Electrode Clean-In-Place (ECIP). The ECIP is similar to the CIP except that only the electrode compartments are cleaned using an acid solution. An ECIP is performed every eight hours and takes about 40 minutes to complete. If heavy buildup is observed, the ECIP may be performed manually between normal ECIP cycles. Another type of CIP used is the salt-caustic CIP. This CIP is usually performed about three times per year. The purpose of this CIP is to remove organic fouling that occurs periodically. A high pH solution containing salt and sodium hydroxide is circulated through the stacks and is allowed to sit for a period of time. Depending on the organic loading, salt-caustic CIP can last up to several hours. Once the salt-caustic CIP is complete, the stacks are neutralized and placed back into service.

Monitoring

Secondary maintenance consists primarily of monitoring. Each stack is probed weekly to find "hot spots". A "hot spot" is an area within the membrane stack where the potential difference between adjacent cell pairs is greater than 20 volts. Once a "hot spot" is found, the stack is disassembled down to the problem area and the membranes are either cleaned or replaced. Similar probing is performed on the electrodes. In this case, a "hot spot" is defined as a potential greater than 10 volts between the electrode and the nearest cell pair. Finding "hot spots" before membranes become damaged will help to reduce overall maintenance cost and provide reliable unit operation. Another important part of the monitoring process is to maintain an adequate supply of anti-scalant. Anti-scalants will help reduce scaling, which could break off and obstruct flow within the flowspacers. It is important that the proper anti-scalant be selected because poor results can occur if the anti-scalant is incompatible with the concentrate stream.

Staffing

Successful operation of the EDR units depends on feedwater quality, routine cleaning operations and daily monitoring. Poor maintenance programs can lead to poor recoveries, high electrical cost and ultimately to stack failures. It is important to have qualified personnel who are able to properly monitor and maintain the EDR equipment.

When making staffing decisions it is important to keep in mind the following: first, the EDR units are very complex and require operators and maintenance employees to be able to tackle technical challenges: secondly, operators need proper training in recording data and understanding the significance of the data being taken. Maintenance personnel must be familiar with electrical, pumping and chemical systems in order to maintain the EDR units on a daily basis. Cross training between operators and maintenance personnel is needed so that communications can be made clear during the scheduling of maintenance work. Generally, a two-member team of maintenance employees is needed to properly maintain the EDR units. One of the maintenance employees should have a good knowledge of mechanical and electrical systems and be able to lead other team members. This lead person will need assistance from a employee with a general knowledge of mechanical systems to help disassemble stack components and to repair other supporting equipment. Currently, the City of Sherman utilizes three employees for plant maintenance. Their job is to take care of all the maintenance needs throughout the plant, but generally to spend most of their time in the demineralization building. The maintenance team is made up of a crew leader and two general maintenance employees. The crew leader is experienced in maintenance operations and is able to lead the overall maintenance crew. The other two maintenance employees have general backgrounds in maintenance and provide assistance to the crew leader. Both two-member and tree-member teams have been used in the plant. Based on experience, the three-member team is the most efficient because routine tasks can be delegated and more projects can be accomplished. As with most technical jobs, compensation is needed to keep well-qualified employees on the job. Since one of the maintenance employees will have a wide range of skills necessary to maintain the system, the employer must expect to provide more compensation to that employee. The City of Sherman offers various incentives and college tuition programs, which encourages employees to learn and grow into various job duties. The main issue of staffing is centered on finding good employees and training them to properly maintain and operate the EDR units. Since the demineralization equipment is expensive, it is important that the system be well maintained.

Capital and Operating Costs

The initial capital cost of the demineralization building and equipment totaled about US$3.6 million. During the expansion in 1996, approximately $950,000 was spent to add the fourth EDR unit. Again in 1998, an additional stage was added to each unit for an approximate cost of US$1.0 million. The total capital cost of the demineralization facility to date is about US$5.6 million. Treatment cost for the whole water system (which includes both ground and surface water) averages about US74 cents per 1,000 gallons (US¢/kgal). Usually, groundwater production cost runs a little higher than surface water treatment cost. The total surface water treatment cost averages about 69 US¢/kgal for the finished water. However, the surface water treatment cost is a combination of conventional treatment cost as well as demineralization treatment cost. The average conventional treatment cost is about 40 US¢/kgal, while the demineralization treatment cost is usually about 83 US¢/kgal. These treatment costs are based on operation and maintenance (O&M) cost as related to the water treatment plant and do not reflect distribution and other city administrative costs. In the end, the water user pays about 2.18 US¢/kgal for the finished water. These cost figures do not account for the unrealized cost due to the disposal of the concentrate stream. Typically, about 0.5 MGD of concentrate is sent to the wastewater treatment plant and represents an additional cost of about 1.97 US$/kgal or about US$360,000 annually.

Concentrate Disposal

One of the major issues facing the use of membrane technology is the disposal of the concentrate stream. There are several options available to properly dispose of the concentrate stream. Currently, the city discharges the concentrate stream into the city's collection system where it then goes to the wastewater treatment plant. This is not the most economical option but serves its purpose when discharge permits are virtually unobtainable. Currently, there are at least four options to consider when dealing with concentrate disposal. First, as mentioned above, the concentrate can be discharged into the waste collection system. This option represents a financial loss to the utility due to pumping cost, conventional treatment cost, loss in revenue, and causes undue loading on the collection system and wastewater treatment plant. The next option is to obtain a discharge permit to discharge the concentrate stream into a nearby creek or stream. Obtaining a discharge permit requires an enormous amount of effort and may prove to be unsuccessful. Even if a discharge permit is obtained, the unrealized treatment cost still exists with the exception of reduced loading on the waste treatment facilities. Another option is to pump the concentrate stream back to the surface water source. This may or may not be a viable option. For the city, this would mean installing an eight-mile discharge pipeline plus additional pumping equipment and discharge permits. The last option to look at is emerging technology. As technology improves, it may be viable to recover a portion of the concentrate to be used as potable water. This option has the advantages of reducing disposal cost, adding revenue and increasing production.

Planning A New Facility

For those planning ahead, the first thing to consider when evaluating EDR technology is to determine target goals such as TDS, water hardness and the amount of blend (conventional treated and demineralized water) for the finished water. Once these goals have been established, compare these goals with the capital cost of the EDR system, and try to achieve a good balance between the two parameters. Once these goals have been established, evaluate the conventional treatment plant and develop a good control strategy. Oxidants such as potassium permanganate can cause staining or even fouling of the EDR membranes. However, good pH control will eliminate these types of problems. Having a complete picture of the conventional treatment plant will enable the proper layout of the EDR system. Next, select a good Supervisory Control and Data Acquisition (SCADA) control package to monitor the EDR units. The SCADA system should be user friendly, easy to configure and adaptable to the EDR control system. The next decision should be made to determine if a service agreement or maintenance contract will used for the maintenance of the EDR units. This decision will probably be based on the size of the utility. For the City of Sherman, city employees perform all maintenance. In-house maintenance has been proven to be very beneficial. Finally, determine concentrate disposal needs. This is probably the most challenging aspect of deciding whether to use EDR or other membrane systems because it has to be dealt with in a manner that is beneficial to the utility. After all decisions have been made with determining the feasibility of demineralization technology, care should be placed on the design of the building that will house the EDR units. Basically, once the EDR units are installed, the building needs to be designed with maintenance and operation in mind. EDR stacks require equipment such as overhead cranes so that they can be easily moved around or repaired. Also, it is important that the building be large enough to allow adequate space between each EDR stack. Most of the time, one stack within a particular stage will need to be disassembled and adequate space is needed to perform the proper maintenance.

Conclusions

In conclusion, the EDR system has proven to be beneficial to the city and has been helpful in meeting desired finished water goals. The system is easy to operate and maintain, and is cost effective in reducing the level of TDS and hardness in the finished water. Successful EDR operation depends on the proper feedwater quality, routine cleaning programs and daily monitoring. Utilities should train operators and maintenance personnel to properly operate the EDR system and provide good compensation programs to their employees. Having a good maintenance and operation program in both the conventional treatment and the demineralization treatment plants can produce the desired finished water quality.