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Small Community of St. Johns Uses Creativity to Deliver Radium Treatment Project

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FOR THE PAST SEVERAL YEARS, the small community of the St. Johns, Arizona has been faced with the challenge of radium levels in their drinking water supply that exceeds Federal and State standards. Earlier this year, the City completed construction of a new treatment facility to meet these standards after several years of careful planning, testing, and budgeting. The project represents a successful partnership between City management, City staff, their construction contractor and engineering consultant, the Water Infrastructure Finance Authority of Arizona (WIFA), and the Arizona Department of Environmental Quality (ADEQ). The 3500 residents of St. Johns now receive drinking water that complies with the Safe Drinking Water Act.

St. Johns is a small community in northeast Arizona in Apache County, approximately 5 miles west of the New Mexico border. The drinking water is obtained from two existing wells located approximately 11 miles west of the City near Concho, Arizona. Water from these wells is pumped through a 10 mile-long, 8-inch pipeline into 2.6 million gallons (MG) of storage located in the Southwestern portion of the City's distribution system. Well 1 supplies 350 gallons-per-minute (gpm) and Well 2 supplies 550 gpm. When the wells are run together, their capacity is limited to 80 gpm due to hydraulic limitations in the 8-inch transmission line.

Well 2 supplies 550 gpm of water with a 90 percent radium level of 9.3 pico curies per liter (pCi/L). Well 1 supplies 350 gpm of water with a 90 percent radium level of 5.7 pCi/L. The radium level for the combined supply, 5.2 pCi/L, exceeds the Maximum Contaminant Level (MCL) of 5 pCi/L.

Further, adjusted gross alpha results often approached or exceeded the MCL of 15 pCi/L in samples taken at Well 2. This is a sign of elevated radium levels in the raw water as radium is an alpha particle emitter.

These water quality problems led to a Consent Order issued by ADEQ and signed by the City of St. Johns in September 1999. WIFA supplied a loan of $1.5 M and Technical Assistance Grants to the City to enable them to comply with the regulations. The final schedule called for a radium treatment study to be completed by 2002, preliminary and final design to be completed by 2003, and the treatment facility to be operational in 2005.

EVALUATION OF OPTIONAL WATER SOURCES AND TREATMENT METHODS

To further complicate matters, the City also needed an additional 200 gpm capacity to met future water demands and fire flow requirements. Several options were considered to meet these water quality and quantity requirements. These included: 1) A new larger well near the City that could deliver 1000 gpm and eliminate the pipeline capacity issues, 2) A new well in Concho and replacement of the 8-inch pipeline with a 12-inch line, and 3) A new well in Concho and use of booster stations to increase the capacity of the 8-inch pipeline. All of these options also included some level of treatment, for radium and/or other constituents.

Three existing privately owned wells were sampled to confirm treatment needs if a new well was constructed close to the City. These results indicated that additional treatment would be required for iron, sulfates, fluoride, manganese, and total dissolved solids, in addition to radium. It was determined that these treatment costs for a new well close to the City would far exceed the costs of upgrading the transmission line and installing radium treatment alone using the Concho wells. Therefore, the decision was made to proceed with evaluating radium treatment for the Concho wells, and upgrading the well field capacity and transmission pipeline capacity as a separate project in the future.

This decision was supported by the fact that co-occurring contaminants such as hardness and total dissolved solids (TDS) are much lower in the existing Concho wells than in locations closer to the City. This makes radium treatment and disposal of residuals much more feasible.

WIFA authorized the City to employ Narasimhan Consulting Services, Inc. (NCS) to perform a literature investigation and review of previous radium treatment research. This review indicated that there are five potential treatment technology alternatives that should be evaluated before performing any pilot-testing activities. These technologies include Ion Exchange (IX) using a carbon resin, Radium Selective Complexer (RSC), Lime Softening, Coagulation, and Reverse Osmosis (RO). These five technologies were screened using cost and non cost factors (operational, siting and environmental issues) to determine the most appropriate technologies for further consideration.

Ion Exchange Treatment Vessels

NCS and St. Johns decided to proceed with pilot testing of the three most promising (i.e., highest scoring) radium removal technologies: IX, RSC, and RO. The purpose of the pilot tests was to assess the feasibility of using each of the technologies to control finished water quality with respect to radium, predict full-scale operational costs and develop design criteria. Pilot testing of each radium removal treatment alternative was performed at the St. Johns water operations maintenance yard for 11 weeks starting January 15, 2002 and ending April 4, 2002.

The IX, RO and RSC processes were tested using the higher radium level water from Well 2. The data provided a conservative estimate of facility performance during normal operations. A pilot trailer was constructed and installed by NCS; after the initial startup, City operations personnel monitored the RO and RSC units.

The pilot test results indicated that IX, RO, RSC all represented treatment options that could be implemented without significant side effects or complications. The IX system would have a run length of 300 Bed Volumes (BVs), or approximately 10 consecutive hours of operation. Radium would be removed to below 2 pCi/L in the treatment system under all conditions. Hardness would be reduced on average by approximately 75% with IX and no significant pH impacts would result. The water was not anticipated to be significantly corrosive after treatment.

The RO system could achieve an 85% water recovery rate and run for approximately eight weeks before cleaning would be required. In addition to radium removal, most TDS constituents would also be removed, rendering the water demineralized with a reduced pH value. Post-treatment to raise the pH and add alkalinity would be required to prevent corrosion in the distribution system.

The RSC resin treated over 50,000 BVs before the pilot plant operation was discontinued. The RSC treatment unit did not exhibit signs of sharp breakthrough when testing was halted and it was estimated that 100,000 BVs could be treated before the resin would be exhausted and have to be replaced.

The preferred radium removal process was identified as IX using a cation resin. The IX technology was preferred due to treated water quality, chemical handling requirements, and cost.

The RO process was rejected due to required chemical handling, reject water disposal problems, and post treatment requirements. The RSC resin was rejected because it was not yet NSF certified, was more expensive than the IX resin, and produced a Low Level Radioactive Waste when exhausted.

Pilot IX testing results indicated that a total empty bed contact time (EBCT) of 2 minutes is optimal. Under these conditions, 300 BVs were treated before regeneration was required. This is equivalent to 10 hours of continuous operation. A maximum effluent radium concentration of 2 pCi/L allows the use of four contactors operated in parallel.

DESIGN CRITERIA

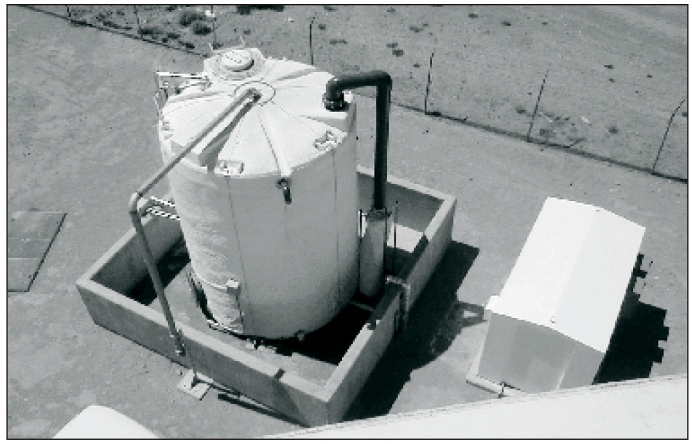
The operating parameters of an IX process consist of service, backwash, regeneration and rinse steps. Well water is pumped through the bed until the bed capacity for radium is nearly exhausted. Prior to regeneration, treated water is passed up through the resin bed to remove any accumulated debris. This backwash is sent to the equalization tank. Concentrated brine (saturated salt solution) is then passed down through the bed to exchange calcium, radium, and magnesium with sodium and sent to the equalization tank. Treated water is passed down through the bed to displace and rinse the remaining brine from the bed and piped to the equalization tank

The design of the IX radium removal facility was based on the use of four contactors (two operational, one regenerating, and one standby) operated in parallel with a peak design flow of 1.5 MGD. To meet the MCL of 5 pCi/L at the peak design flow, the treatment system flow in a split stream configuration is approximately 1.08 MGD. The treated stream flow is blended back with the untreated bypass flow from the wells to meet a combined maximum effluent concentration of 4 pCi/L prior to entry into the City's distribution system. Waste rinse water, regeneration, and backwash from the treatment plant are sent to an equalization tank prior to entering the City's sewer system.

The equalization tank was sized to hold the backwash, used brine regeneration and rinse water. The water is then either pumped or flows by gravity to the City sewer system at a rate that does not overload either the system or the wastewater treatment works.

The treated water is then piped into the existing storage tanks and distribution system. This allowed the plant to be sited at the storage tank site where land was available. Due to the nature of the IX process and the type of equipment necessary to ensure proper operation of the IX system, and concerns associated with freezing conditions and vandalism, the entire treatment plant is enclosed in a masonry building.

The existing facility (1.5 MG peak design flow) will also accommodate future water system expansions and a new 1030 gpm well located in the area of the existing Concho well field with similar radium levels as Well 2.



Brine Handling Facilities

Other support facilities and design parameters for the St. Johns Radium Treatment Facility (RTF) are:

- Four carbon steel IX treatment vessels in parallel, each with an EBCT of 2 minutes and a maximum hydraulic loading rate of 9.7 gallons per minute per square foot (gpm/ft2).
- Four variable frequency drive booster pumps, one for each treatment vessel, adjust for variable flow conditions.
- Backwash and fast rinse water is supplied by two centrifugal pumps each operating at approximately 200 gpm.

- Slow rinse water is supplied by two centrifugal pumps each operating at 40 gpm.
- A 23,000 gallon waste equalization tank.
- Chlorination system - 5% sodium hydrochloride solution fed with a metering pump and stored in a 500 gallon tank

PROJECT DELIVERY AND CONSTRUCTION

The total project budget was limited to $1.5 million, including study, design, construction and equipment purchases. To meet this goal, the project delivery approach was customized and unique. The City, Fann Contracting, and NCS collaborated to come up with a solution to the meet the budget constraints. It was decided that the City would pre-purchase most of the equipment and use City personnel to complete certain aspects of the construction work and construction inspection tasks. The pre-purchased equipment included the treatment vessels, air compressors, pumps, meters, variable frequency drives (VFDs), treatment resin, brine maker, equalization tank, valves and valve actuators. The City forces constructed the yard piping and completed all the pre and post construction site work.

The contractor reduced the bid by the amount of contractor markup on the pre-purchased equipment but remained responsible for the installation. NCS trained City personnel to complete various construction inspection items, thereby eliminating a portion of the construction inspection and travel costs.

The flexibility of the contractor, owner, and consultant project team enabled the facility to be completed within both the budget and the Consent Order driven time frame. Construction of the treatment facility began in August 2004 and was completed in February 2005.

PLANT COMMISSIONING

The commissioning tests were conducted for six days (4/11/05 to 4/15/05 and 6/21/05). The commissioning protocol included operating Well 1 during Days 1-2, Well 2 during Days 3-5 and both wells 1 and 2 on Day 6. During the commissioning period, the operation of the facility was automatically controlled by the Control Panel. Once the well pump was switched on by an operator, the control panel automatically received well status signal and selected the trains for operation.

Field parameters such as iron, hardness, turbidity, treated and bypass flows, and influent and effluent pressures were measured during the commissioning period. Samples for radium were collected at the contactor influent and effluent, and at the entry point to the distribution system.

During initial startup, the treated water hardness increased gradually from 30 mg/L to 171 mg/L after eight hours of treatment operation. This is not uncommon as hardness levels typically increase during the end of an IX column run, since hardness has a higher selectivity than radium for a cationic IX resin and starts leaching out when the IX column capacity for radium is reaching exhaustion levels. The treated water radium level was found to be <0.3 pCi/L during all days of commissioning. Other water quality parameters were not found to have significant impact on finished water quality. The combined treated effluent radium level was found to be 2.1 pCi/L in all samples, which is below the compliance standard of 5 pCi/L.

In summary, radium was successfully treated from the raw water to below the maximum contaminant level using the split stream treatment approach.

KEYS TO SUCCESS

The key to the success of this project was the City of St Johns' trade off of time in order to save money. Their conscious decision for a "Hands On" approach to the project was instrumental in the timely delivery of drinking water that meets the radiological requirements of the Safe Drinking Water Act. The combined efforts by the City of St. Johns (Eric Duthie, Paul Ramsey, and Dana Waite), Fann Contracting (Mike Young, Jeff Sawyer, and Gary Steinmetz), NCS (Larry Hanson, Saqib Karori, Herb Durbin, Kenneth Miller and Sudheera Addepally), WIFA (Jay Specter, Jon Bernreuter), former WIFA personnel (Peter Miller and Greg Swartz), and ADEQ (Byron James, John Calkins, Mike Traubert, and Jeff Stuck) are appreciated.

Radium Treatment Facility Building