Integrating Arsenic Removal with RO

Pilot testing determines which technology could best be incorporated into an existing RO treatment process.

Dare County Regional Water System is located on North Carolina's coastal Outer Banks. It provides drinking water for about 33,800 permanent residents and thousands of summer tourists through four distinct distribution systems on several islands. Dare County Regional Water System operates a total of five treatment plants. Four plants use reverse osmosis (RO) treatment and draw from brackish groundwater wells that are about 300 to 400 ft deep; the treatment process desalinates groundwater. The fifth plant uses ion exchange to soften water drawn from a well about ten ft deep.

The water system has experienced elevated levels of arsenic in the raw water sources at only one of its five treatment facilities, the five-mgd North Reverse Osmosis (NRO) plant, which draws from eight wells. This plant helps supply water to the largest distribution network, including wholesale service to the towns of Manteo, Nag's Head, Kill Devil Hills (each of which have their own distribution systems), and other unincorporated areas. Compliance testing from 1989 to 2001 showed that the arsenic levels in the wells averaged 60 ppb and treated water had average arsenic levels of 15.5 ppb. Speciation of the arsenic revealed that both arsenite—As(III)—and arsenate—As(V)—were present in equal parts in the source water treated by the NRO plant. Virtually 100 percent of the arsenic in the treated water from the NRO facility was found to be As(III), which is not readily removed by most treatment processes, including RO. In addition, because some of the raw water bypasses the RO treatment, the treated water also contained some As(V).

Adsorption system consists of six contactor vessels, configured with three in parallel and then placed in series with a second set of three contactors.

Five Technologies Tested

Dare County pilot tested five arsenic treatment technologies to determine which could best be incorporated into its existing RO treatment process. If time and financial resources permit, pilot testing is a good way to understand how various treatment options will perform under system-specific operating conditions and to identify any unforeseen issues that could arise with treatment installation.

At first, Dare County Regional Water System scaled back NRO plant operations and used another treatment plant (the Skyco plant) to provide up to 4.2 mgd. This helped to meet a significant portion of the annual demand. However, with the increase in seasonal demand, the NRO facility occasionally had to be operated near capacity. While this approach reduced treated water arsenic levels to less than ten ppb in all but the peak summer months, public notification was still required during each calendar quarter that arsenic levels at the entry point to the distribution system exceeded ten ppb.

Dare County Regional Water System investigated several options, such as using surface water with no detectable arsenic from either the Atlantic Ocean (located to the east of the treatment plant) or the brackish Albemarle Sound (located to the west of the treatment plant). This option was ultimately eliminated due to the estimated cost increases (energy costs, pretreatment costs, and construction costs for subsurface intake structures). The water system also determined that installing point-of-use or

point-of-entry treatment devices would not be cost-effective.

Ultimately, to find a permanent solution for the arsenic problem, the county selected the five treatment options for removing arsenic from the existing wells and conducted pilot testing in spring 2003. The treatment processes were selected based on cost (including residual disposal) and the ease with which the additional process could be integrated into the existing plant infrastructure.

Three piloted treatment technologies processed RO permeate (treated water) using a granular iron-based material to adsorb the As(III) and operated similarly to granular activated carbon. For these three pilot units, the media was placed in a pressurized treatment vessel to become a fixed bed "adsorber." Backwash was performed as needed to prevent compaction and remove any particulates in the supply. These processes required relatively minimal operator attention. Because RO treated water was applied to the adsorptive media, the level of ions competing with arsenic for adsorption sites was low. The media eventually becomes saturated with arsenic and must be replaced.

The fourth pilot treatment option processed RO permeate (treated water) using chlorine addition [to oxidize arsenite As(III) to arsenate As(V)] followed by nanofiltration—a membrane system similar to the RO membrane. The nanofiltration process removed the arsenate while operating at a high water recovery rate and low pressure. Unlike the other four processes pilot tested, the media used in this process did not have to be replaced and the process did not generate sludge requiring disposal. Instead, the waste stream was recycled to become part of the feed water to the existing RO plant.

The fifth pilot treatment option processed raw groundwater (feed water to the NRO plant) using manganese greensand filtration. Testing was conducted in two parts. In the first part of testing, a small amount of the iron salt, ferric chloride, was introduced along with chlorine, and the arsenic in the feed water was removed by manganese greensand filtration. In the second part of testing, only chlorine was added to oxidize the As(III) to As(V), so that all the arsenic could be removed in the existing RO plant. The flow through the vessel was set at 1.5 gpm. The disadvantage to this option is the space that the new treatment equipment and facilities would require.

Rear view of the filter gallery.

The pilot study results show that all pilot treatment units were successful in reducing arsenic levels below ten ppb, while the manganese greensand filtration, chlorine addition, and nanofiltration processes were effective in oxidizing or removing As(III).

Selected Compliance Strategy

Ultimately, the water system chose Siemens Water Technologies' (www.siemens.com/water) GFH® Adsorption System to treat RO permeate. The water system based its decision on many factors including space requirements, installation, operation and maintenance, residual disposal costs, disposal logistics, and most importantly, selecting the technology best suited for integration with the existing RO process. In January 2004, Dare County commissioners approved the selection and construction of the system. The system consists of six contactor vessels (each containing 377 cu ft of media), configured with three in parallel and then placed in series with a second set of three contactors. Additional space is available for future expansion. A small dose of chlorine is injected prior to the adsorption vessels to oxidize the As(III) to As(V), which enhances the media's ability to remove arsenic and keep the contactors disinfected. Plant operators monitor differential pressure across the contactors and briefly backwash the media to prevent compaction, as required.

Construction was completed in the fall 2005 and Dare County entered into a fixed-price, six-year renewable contract with Siemens Water Technologies for future media replacement. Siemens will be responsible for removal and disposal of the exhausted GFH media and the installation of new GFH media, which is expected to occur every five years.

The water system purchased an arsenic analyzer from Trace Detect (www.tracedetect.com) to monitor the performance of each contactor and the treated water and to predict the timetable for media replacement. Arsenic levels in the treated water to date are below detectable limits of one ppb. According to the system's 2005 Water Quality Report, arsenic levels at the entry point to the distribution system averaged six ppb. Based on the installation of treatment and arsenic compliance results below the MCL for two consecutive quarters, the Dare County Regional Water System was able to return to routine inorganic chemical monitoring in March 2006.

Funding Process

The total cost of the system (including a 5,700 sq ft building addition, arsenic adsorption equipment, and associated piping) was $3.8 million. Engineering, design, and construction management fees totaled $350,000. In addition, the system will pay $238,422 about every five years for media replacement and residual disposal. The project was funded entirely through loans. No customer rate increases resulted from the completion of the project and no increases are currently planned. GE

Courtesy of the U.S. Environmental Protection Agency.