THE IRON OXIDE WAY

By Rich Dennis

Treating arsenic to reopen wells in Oklahoma

ARTICLE SUMMARY

Challenge: When the U.S. EPA lowered the maximum contaminant level for arsenic in drinking water, the city of Norman, Okla., had to take 11 wells (one-third of its total well capacity) offline.

Solution: To bring its wells back into service, the city ran a one-year arsenic treatment pilot project using iron-oxide media.

Conclusion: Results validate that the arsenic treatment pilot plant has been a success, according to city staff.

Three 5-ft adsportion vessels at the city's Well No. 31, where arsenic levels had been measured between 40 and 70 µg/L.

The Garber-Wellington aquifer, a 280-million-year-old geologic formation in central Oklahoma, supplies municipal, industrial, commercial, agricultural and domestic water for that part of the state. All the major communities in the region, except Oklahoma City, rely either solely or partly on groundwater from this water source.

When the U.S. Environmental Protection Agency (EPA) lowered the maximum contaminant level for arsenic in drinking water to 10 µg/L in 2006, all noncompliant wells in the region were removed from service. The shutdown included 11 wells serving Norman, Okla.—one-third of the city's total well capacity. This reduced the average well production in Norman from nearly 5 million gal per day (mgd) to slightly more than 2 mgd.

"The new EPA arsenic standard really affected the Norman water system," said Geri Wellborn, the city's laboratory manager. "With 11 wells offline, we were limited in the number of wells we could use and, as a result, had to purchase more expensive water from Oklahoma City. We worked closely with the EPA and the U.S. Geological Survey to determine the level of arsenic in our aquifer before undertaking work to find the most cost-effective treatment system possible."

In an effort to bring their offline wells back into service, Norman officials decided to run a one-year demonstration project piloting an arsenic treatment system at one of its wells. The city received proposals incorporating the use of several technologies, including ion exchange and several adsorption media.

Solution Selection

Ultimately, a proposal from the team of Urban Contractors, Garver Engineers and Severn Trent Services using an iron-oxide media was chosen. Adsorption with iron oxide-based media does not require chemical regeneration or flocculation, making the arsenic removal process simple and reliable, minimizing labor.

Severn Trent Services offers an iron oxide-based media, Bayoxide E33. Used in conjunction with the company's SORB 33 arsenic removal system, it has proven to be an efficient treatment process in several regions of the U.S., though it had not been tested previously in Oklahoma. The Bayoxide media has been permitted for use by health and environmental agencies in 24 states—more than any other arsenic removal technology. Among its advantages is that the media adsorbs arsenate, as do other adsorbents, but it also adsorbs arsenite, which is beyond the capability of other adsorbents.

Michael Graves, project manager and Oklahoma water practice leader for Garver Engineers, touted three other advantages of the Bayoxide media and SORB 33 system: "First, the media is easy to manage and requires infrequent handling. The spent media is classified as nonhazardous, so it could be disposed of in state-approved, nonhazardous solid waste landfills. In addition, for Norman, Bayoxide demonstrated a longer-than-anticipated run time, and the arsenic breakthrough curves were very predictable, enabling the operations staff ample time to schedule media changeouts. Finally, the zero-waste-discharge aspect of the process was very advantageous given our treatment site did not have sanitary sewer utilities."

Garver Engineers worked with Severn Trent Services to install three 5-ft SORB adsorption vessels at the city's Well No. 31—one of a number of Norman wells where arsenic levels had been measured between 40 µg/L and 70 µg/L. In addition, the groundwater contained high levels of iron (500 ppb), manganese (50 ppb) and vanadium (160 µg/L).

Efficacy of Iron Oxide-Based Media

Arsenic has a high affinity for iron oxide-based minerals and can adsorb quickly to the surface of the media. This makes granular iron oxide excellent for arsenic removal. Other contaminants common to groundwater, however, also have a high affinity for iron-based minerals. This creates competition among ions, resulting in less arsenic being adsorbed per volume of treated water. Bayoxide E33 is specifically designed to adsorb arsenic while reducing competition with other ions, thus improving the arsenic-adsorbing potential of the media.

The full-scale SORB 33 system applies a pump-and-treat process that sends pressurized water through filter vessels containing the media. As water is forced through the fixed bed, arsenic is attracted to the media and the water is reduced to 8 µg/L of arsenic or less. This level is agreed on between the city and the Oklahoma Department of Environmental Quality for the pilot system.

The media—a dry, crystalline granular—is designed to adsorb a large amount of arsenic to achieve long operating cycles, reduce pressure drops and improve the operational cost. The media does not need to be replaced for six months to two years, and the spent

media is sent to a nonhazardous landfill.

The system was installed in Spring 2008 and began full-scale test operation in June 2008. Water from Well No. 31 flows directly to the system after first being pH adjusted. A groundwater's pH level is an important variable affecting the arsenic treatment media's adsorptive capacity. The groundwater from Well No. 31 had a pH exceeding 9. In order for the iron oxide media to be effective, water should be close to a pH of 7.

To address high pH levels, the Norman pilot system was installed with a carbon dioxide (CO_2) injection system, which effectively lowered the pH to between 7 and 7.5. If there is a failure with the CO_2 system, the treatment system has been programmed to shut down, preventing high concentrations of arsenic from entering the distribution system.

Novel Design

The three 5-ft vessels contain 170 cu ft of media designed to treat 230 gal per minute (gpm), or 115 gpm per vessel with two adsorbers running in parallel. A novel system design called "sequencing" was employed in Norman in which three pressure vessels with Bayoxide media were used in both parallel and series flow configurations. The sequencing mode of operation allows for the highest capacity of arsenic adsorption to occur during one media cycle, treating up to 40% more water before being replaced. The Bayoxide media used at the Norman pilot plant had a treatment capacity of 46,000 bed volumes—equivalent to 63 million gal of water being treated through the 170 cu ft of media and representing an expected life cycle of 12.5 to 15 months.

Initially, the flow is split to two adsorbers operating in parallel. Sixty percent of the water feeds the first adsorber and 40% is fed to the second adsorber, staggering the media life between the two. When the arsenic level exiting the first adsorber exceeds 4 µg/L, it is placed in series flow with the third adsorber, which has been in standby mode. By doing this, the first adsorber can continue to treat water, removing arsenic to an effluent level significantly less than the 8 µg/L limit without compromising treated water quality. The second adsorber continues in parallel flow treatment. The net result is maximum media utilization for arsenic adsorption resulting in lower water treatment costs. Treated water exiting the SORB 33 system flows into distribution.

When the blended effluent from the second and third adsorbers reaches 4 µg/L, media is changed out in the first adsorber, flow to the second adsorber is increased to 60%, the second adsorber is connected in series flow with the first adsorber and flow to the third adsorber is reduced to 40%. This cycle is advanced when the blended effluent reaches 4 µg/L with the media being changed out in the second adsorber.

The pressure differential (ΔP) through each adsorber is monitored. When the ΔP on either adsorber exceeds the high ΔP set point of 10 psi, an alarm sounds indicating high ΔP on that adsorber. After a 15-minute backwash is conducted to reclassify the compacted media, the adsorber is returned to service. The minimum time between adsorber backwashes is two days to allow enough time for backwash effluent to decant in the reclaim tank and to reclaim the backwash effluent into the system.

"After one year, our arsenic treatment pilot plant has been a success," said Wellborn. "The SORB system and Bayoxide media had the best track record of the solutions we investigated, and our pilot plant results have validated that record." WWD

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