Application Bulletin

Snuffing Out H_2S in Water and Air

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Dealing effectively with hydrogen sulfide (H_2S) in groundwater presented a major challenge for coastal Indian River County, Fla. Stripping the odorous substance from the water was only half the solution; keeping the smell from drifting through the air in the neighborhood was the other half.

Like most central Florida communities, Indian River relies on deep wells to withdraw water from the Floridan aquifer. The inland supplies are fresh water, and the coastal resource is typically high in total dissolved solids (TDS) and chlorides. Both the fresh and saline water supplies contain high concentrations of H_2S.

Indian River operates two regional reverse osmosis (RO) water production plants that blend finished product water with raw water at a ratio between 3:1 and 4:1. The plants' combined finished water is stripped of H_2S by forced-draft aerators. Indian River's South County RO plant has a maximum finished water flow of 7.06 mgd and a 4 mg/L H_2S concentration in finished water. The H_2S load at the facility aerator is 236 lb/d.

The off-gas discharge of H_2S caused area neighbors to complain of odors. In particular, at the South County water treatment plant odor complaints escalated as development encroached on the existing public treatment works. With the development of South County Park and South County Middle School, the Indian River County School Board insisted that treatment be installed to remove the H_2S odor in the vicinity of the water treatment plant. The county utilities department recognized the necessity to also initiate action to comply with pending US Environmental Protection Agency Clean Air Act legislation.

Considering Alternatives

In 1995, Indian River County Utilities Department staff began looking at options for removing H_2S from the product water and concentrate gas streams at the plant aerators. They identified the following alternatives:

- in-line oxidation system
- two-stage wet scrubber system
- catalytic/adsorptive carbon system

Why Not Use Ozone?

As part of Water Project 2000, the Orlando Utilities Commission experimented with ozone for the dissolution of H_2S. The Indian River County Utilities Department compared their test data from in-line oxidation, two-stage wet scrubber, and catalytic-adsorptive carbon with the OUC's results on ozone oxidation.

The purpose of ozonation is to oxidize the natural H_2S in raw water and provide the capability to meet primary disinfection requirements for the future Groundwater Disinfection Rule. Although the design criteria for OUC water treatment facilities provide for future disinfection credit, the core treatment use of ozone is strictly for H_2S removal. The first plant OUC constructed was an air-fed ozone generation system, but six subsequent facility designs used liquid oxygen (LOX) feed tanks. The LOX system uses bulk storage for LOX, an ambient air vaporizer, and a particulate after filter. The LOX is pumped to ozone generators that dielectrically convert the liquid to ozone gas. Gas transfer is by conventional countercurrent ozone contractors or in-line ozone injection.

The first five plants constructed used fine-bubble diffusion for ozone dissolution. Ozone is introduced into water through fine-bubble diffusers installed in the bottom of contact cells in a concrete ozone contactor. The contactors use over-under baffling to introduce ozone gas to water in a countercurrent contact of gas and water flow. Facilities that use pure oxygen typically have a supersaturated dissolved oxygen (DO) concentration as high as 25 mg/L after the contact process. Deoxygenation is required to lower the concentration to 7-8 mg/L. Air is introduced through fine-bubble diffusers into the water supersaturated with DO downstream of the ozone contact cells. The nitrogen content in the air reduces the partial pressure of oxygen, which allows the oxygen in the liquid to enter the gas stream. The water is thus deoxygenated.

OUC's Kirkman water treatment plant is a 15 mgd facility and the ozone dose required to oxidize H_2S is 9.0 mg/L. The utility's Lake Highland plant is a 33-mgd facility with a required 8.0 mg/L ozone dose. The projected annual average daily flow demands in the year 2000, as used for testing purposes, for the Kirkman and Lake Highland plants are 5.5 mgd and 16.6 mgd, respectively.

The primary operational costs for ozone generation are the LOX and the electricity for the ozone generators and air sparging systems. (OUC decided to change to the LOX option for the simplicity of operation. They operate their plants remotely, and LOX-fed systems have fewer maintenance requirements than prepared air systems).

While the operating cost of removing H_2S with ozonation is comparable, the capital cost is greater than any of the alternative technologies evaluated by IRCUD. It is important to note, however, that ozone generation does provide enhanced water quality features (taste and odor) as well as credit for primary disinfection.

In-Line Oxidation System

The next step was to compare the effectiveness of alternative technologies with on-site testing. IRCUD received authorization from the county commissioners to conduct a pilot study of chlorine injection to oxidize H_2S. The technology piloted and evaluated H_2S removal from the brine discharge of the RO plant. The brine concentrate discharges to the Indian River Lagoon, which is a class II surface water (Shellfish Harvesting Area).

The county pilot tested an in-line oxidation system that mixed air and chlorine directly into the concentrate stream to oxidize the H_2S and increase the dissolved oxygen. The system was installed in 1992 at the North Beach water treatment plant, a 2.5-mgd RO facility. The RO concentrate flowed through the in-line oxidation system under residual pressure from the RO process. The system operated at 20 psi to increase the oxygen absorption. The increased concentrate pressure was accommodated by installing a back-pressure sustaining valve.

At the South Country RO plant, in operation for 15 years, product water was aerated in degasifiers mounted on top of the ground storage tanks. The aerators are forced-draft packed towers designed to strip carbon dioxide and H_2S before distribution to customers.

Problems arose when the in-line oxidation treatment process incorporated the RO treatment plant product water. The concentrate treatment system had excellent sulfide removal because of the injected air. The air injection did produce turbidity, but it was not a problem in the concentrate stream. However, an increased chlorine dose was required to fully oxidize the H_2S in the product water. The pilot plant concentrate stream contained 3 mg/L of H_2S and required a 6.4 mg/L dose of chlorine to oxidize the H_2S without air injection.

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The RO product water contained a 4.72 mg/L H_2S concentration - significantly higher than the concentrate. Laboratory analysis determined that a 10.0 mg/L dose of chlorine was required to fully oxidize the H_2S. The difference in H_2S concentration is attributed to variances from well to well and perhaps over time. When the RO product water was piloted using injected air, the amount of turbidity was unacceptably high at normal pH and alkalinity levels. The turbidity readings ranged from 2.3 to 5.2 ntu. The maximum turbidity level allowed under the drinking water regulations is 1.0 ntu, and 0.1 ntu is recommended. The only way to fully oxidize the H_2S was to lower the pH of the product water to 3.0 with sulfuric acid. This low a pH completely destroyed the alkalinity and created an extremely corrosive finished water. This was an unacceptable alternative.

The amount of sulfide remaining in the treated permeate leaving the pilot unit ranged from 0.0 to 0.98 mg/L. (When the county measured 0.0 mg/L sulfide with a portable analyzer, the laboratory measured a higher residual.)

There was also a large increase in the cost of chlorine over the trial period - from $0.15/lb to $0.20/lb at the time of the RO product water pilot test. Project costs for the inline oxidation system are shown in Table 1.

Table 1

In-Line Oxidation System Costs

Chemical	**Cost ($/yr)**
Chlorine	$202,878
Caustic	$81,099
	$283,978
Cost / 1,000 gal	$0.11
Estimated Construction Cost	**$200,000**

Two-Stage Wet Scrubber

The county had an existing conventional two-stage scrubber at the North Beach RO plant that was decommissioned in late 1997. Because of the results from testing the in-line oxidation system, and analysis of operation costs for a two-stage wet scrubber was conducted in June 1997 to determine the cost of a similar system at the South County plant. The RO product water at the South County degasifier had a 4.7 mg/L H_2S average concentration and a flow rate of 14,000 ft^3/min coming out of the degasifier.

The anticipated chemical doses for a conventional two-stage wet scrubber was:

Caustic (Sodium Hydroxide)	4.5mg NaOH mgH_2S 1,251 lb/day
Chlorine	3.4 mg Cl_2/mg$_2$S 945 lb/day

The cost for sodium hydroxide (NaOH) at the time of the study was $1.20/gal of 50 percent solution. Chlorine (Cl_2) costs were $ 400 per ton container or $0.20/lb. Projected costs for the two-stage wet scrubber are outlined in Table 2.

Table 2

Two-Stage Wet Scrubber Costs

Chemical	**Cost ($/yr)**
Caustic	$86,128
Chlorine	$68,797
	$155,106
Cost / 1,000 gal	$0.66
Estimated Construction Cost	**$350,000**

The two-stage wet scrubber had a rated capacity to remove 95 percent of the H_2S. Consequently, the remaining 5 percent of the 278 lb of H_2S would still mean a release of 14 lb of H_2S into the air. While this would represent a large reduction in sulfides entering the air, it wouldn't bar odor complaints, as the human nose can detect odor levels longer than instruments can measure them. The county concluded that even with 95 percent reduction, the neighbors might occasionally detect the sulfide smell.

Catalytic/Adsorptive Carbon System

In February 1996, IRCUD reviewed research data on a new product for H_2S odor control that consisted of multiple radial flow canisters that house catalytic/adsorptive carbon. These canisters are arranged in vertical chambers that permit physical separation from bank to bank.

Foul air enters and enclosed space known as a plenum located above the carbon canisters. The air is then directed downward in each bank of canisters, permitting flow to the outside of each individual canister. Air travels through the carbon zone where it is cleaned and returned to the exist air plenum through a manifold system.

The key to the design of the odor control product is the use of catalytic/adsorptive carbon, which was developed to convert high levels of H_2S to sulfuric acid in a small reaction zone, thus permitting the use of small amounts of carbon. The carbon is not impregnated, yet it possesses many of the properties associated with impregnated carbons. The catalytic/adsorptive carbon promotes a wide range of chemical reactions where conventional carbons are not effective. Because the carbon converts H_2S to $H_2SO_{->4}$, rather than converting it to elemental sulfur, it can be water rejuvenated. In February 1997, IRCUD pilot-tested a prototype system at the South County plant. A skid-mounted odor control system with 30 self-contained carbon canisters was installed in only three days because all utility connections were available.

The county operated the pilot for more than one year. The catalytic/adsorptive carbon was rejuvenated on-site several times with potable water, used as a backwash rinse that was discharged into the county's wastewater collection system. The change-out of spent carbon canisters was a safe and simple operation, because no actual handling of carbon media was required.

During operation, the system removed an average of 90 percent of the influent H_2S concentration of approximately 90 mg/L. In the first 1,000 hours of operation the removal efficiency was 95 percent or better. Operation protocol was established to rejuvenate the carbon every 1,000 hours of operation.

A complete odor control system for the South County plant would require two such systems. The annual water cost is based on a required 2,700 gpd per system and $0.001/gal. Electrical cost is based on $0.12 per 1,000 gal of treated water. Annual maintenance is based on work hours required to change spent canisters at a cost of $ 30/hour. The projected operational costs for the system are itemized in Table 3.

Table 3

Catalytic/Adsorptive Carbon System Costs

Chemical	**Cost ($/yr)**
Caustic	$86,128
Chlorine	$68,797
	$155,106
Cost / 1,000 gal	$0.06
Estimated Construction Cost	**$350,00**

Final Decision Making

ICRUD field-tested three different odor control systems: the catalytic carbon unit, a conventional two-stage wet scrubber system, and a conventional in-line oxidation with chlorine-air injection and mixing. The wet scrubber system would have cost $ 155,106 annually, while the oxidation system priced out at $283,978/yr. Clearly, the most cost-effective H_2S removal system was the catalytic/adsorptive carbon unit. The system also was effective with the county's raw water quality, achieving 95 to 98 percent H_2S removal efficiency, ultimately producing finished water quality that will meet future Safe Drinking Water Act trihalomethane formation levels for Phase 2 disinfection.

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