Catalytic/Adsorptive Carbon Testing for Odor Control at Indian River County, Florida

William F. McCain, P.E., Capital Projects Engineer
Indian River County

Richard L. Johnson, P.E., Principal Engineer
Montgomery Watson America, Inc.

Bradford H. O'Keefe, Water Superintendent
Indian River County

INTRODUCTION

Most of Central Florida withdraws water from the Floridian Aquifer by means of deep wells. The water that comes from both the inland fresh water wells and the coastal saline wells is typically high in total dissolved solids (TDS) and chlorides. Both the fresh water and saline water supplies usually contain elevated hydrogen sulfide concentrations. Indian River County is a coastal community on the East Coast of Central Florida, with Vero Beach its largest city and county seat. The county owns and operates two reverse osmosis (RO) plants and wanted to reduce construction and operating costs for these facilities while effectively removing hydrogen sulfide.

The county's two RO water production plants blend finished product water with raw water between a 3:1 and 4:1 ratio. The plants' combined finished water is stripped of hydrogen sulfide by forced draft aerators. The off-gas discharge of hydrogen sulfide has resulted in numerous odor complaints from area neighbors.

To control odors at regional facilities, Indian River County developed a program to study the various odor control systems to remove the hydrogen sulfide odor at the plant aerators. The South County RO Plant had a maximum finished water flow of 7.06 mgd/day with a 4 mg/L hydrogen sulfide concentration. The hydrogen sulfide load at the facility aerator is 236 lbs./day.

At the South County Water Treatment Plant, as well as other treatment facilities, odor complaints had escalated as development has 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 on treatment to remove the hydrogen sulfide odor in the vicinity of the water treatment plant. The county Utilities Department recognized the need to also initiate action to comply with pending US Environmental Protection Agency Clean Air Act legislation.

In 1995, Indian River County Utilities staff began looking at options for removing hydrogen sulfide from the product water and concentrate gas stream at the county water treatment plant aerators. The hydrogen sulfide removal options, the basis for moving forward with odor-control testing, were as follows:

- In-line oxidation system
- Two-stage wet scrubber system
- Catalytic/adsorptive carbon system
- Ozone dissolution system

IN-LINE OXIDATION SYSTEM

In early 1995, the Utilities Department received authorization from the Board of County Commissioners to conduct a pilot study of chlorine injection to oxidize hydrogen sulfide. The technology was piloted and hydrogen sulfide removal from the RO plant’s brine discharge was evaluated. 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 mixes air and chlorine directly into the concentrate stream to oxidize the hydrogen sulfide and increase the DO (Dissolved Oxygen). In 1992, the in-line oxidation system was installed at the Indian River County, North Beach Water Treatment Plant, a 2.5 mgd RO facility. The RO concentrate flows through the in-line oxidation system under residual pressure from the RO process. The system operated at 20lbs/square inch to increase the oxygen absorption. The increased concentrate pressure was accommodated by installing a CLA-VAL backpressure sustaining valve.

The existing South County RO plant has operated for 15 years, and the product water from the plant is aerated in degasifiers mounted on top of the ground storage tanks. The aerators are forced-draft packed towers designed to stop carbon dioxide and hydrogen sulfide before distribution to customers.

Chlorination

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 does produce turbidity, which is not a problem in the concentrate stream. To fully oxidize the hydrogen sulfide in the product water requires an increased chlorine dose. The pilot plant concentrate stream contained 3.0mg/L of hydrogen sulfide and required a 6.4 mg/L dose of chlorine to oxidize the hydrogen sulfide without air injection.

The RO product water contains a 4.72 mg/L hydrogen sulfide concentration that is higher than the concentrate. Laboratory analysis determined that a 10.0 mg/L dose of chlorine is required to fully oxidize the hydrogen sulfide. The difference in hydrogen sulfide concentration is attributed to well-to-well variance 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 regulation is 1.0 NTU, while 0.1 NTU is recommended. The only way to fully oxidize the hydrogen sulfide is to lower the pH of the product water is 3.0 with sulfuric acid. This low pH completely destroys the alkalinity and creates an extremely corrosive finished water-an unacceptable alternative.

The amount of sulfide remaining in the treated permeate leaving the pilot unit was measured ranging 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 between the time of the original pilot plant for the concentrate stream and the pilot for the product water. Chlorine gas costs rose from $0.15 to $0.20/lb at the time of the RO product water pilot test. Projected costs for the in-line oxidation system were as follows:

IN-LINE OXIDATION SYSTEM COSTS

Annual Operation Costs:

Chemical	Cost ($/yr.)
Chlorine	$202,878
Caustic (Sodium Hydroxide)	$ 81,099
	$283,978

Cost/1,000 gallons $0.11

Estimated Construction Cost: $200,000

TWO-STAGE WET SCRUBBER

The county had a conventional two-stage scrubber at the North Beach RO WTP that was decommissioned in late 1997. Because of the results from the in-line oxidation system testing, an analysis of operation costs for a two-stage wet scrubber was conducted in June 1997 to determine the costs of a similar system at the South County WTP. The RO product water at the South County WTP degasifier had a 4.7 mg/L hydrogen sulfide average concentration and a flow rate of 7.05 mgd. The anticipated hydrogen sulfide load would be approximately 278 lbs./day with an air flow rate of 14,000 cubic feet per minute (cfm) coming out of the degasifier.

The anticipated chemical doses for a conventional two-stage wet scrubber are as follows:

Caustic (Sodium Hydroxide)	4.5 mg NaOH/mg H_2S 1,251 lbs./day
Chlorine	3.4 mg Cl_2/mg H_2S 945 lbs./day

The cost for sodium hydroxide at the time of the study was $1.20/gallon of 50 percent solution. Chlorine costs were $400 per ton container of $0.20/pound. Projected costs for the two-stage wet scrubber were as follows:

TWO-STAGE WET SCRBBER COSTS

Annual Operation Costs:

Chemical	Cost ($/yr.)

Caustic (Sodium Hydroxide)	$ 86,128
Chlorine	$ 68,797
	$155,106

Cost/1,000 gallons $0.06

Estimated Construction Cost **$350,000**

The two-stage wet scrubber has rated capacity to remove 95 percent, so five percent of 278 pounds of hydrogen sulfide will release 14 pounds into the air. This is a large reduction in sulfides entering the air, but the human nose can detect levels longer than instruments. The county decided that, even with 95 percent reduction, the neighbors may occasionally detect the sulfide smell.

CATALYTIC/ADSORPTIVE CARBON SYSTEM

In February 1996, Calgon Carbon Corporation approached Indian River County with a new Catalytic/Adsorptive Carbon product. The county reviewed the research data and agreed to observe a demonstration of Calgon Carbon's prototype Phoenix™ odor control system.

The Phoenix system utilized Calgon Carbon's Centaur activated carbon. Centaur HP Catalytic/Adsorptive Carbon enhances catalytic functionality by providing more catalytic sites for electron transfer. The carbon is not impregnated, yet it does possess 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.

In February 1997, the county pilot-tested a prototype catalytic/adsorptive carbon odor control system at the South county WTP. Calgon Carbon Corporation installed a Phoenix™ 6A odor control system that has 30 self-contained carbon canisters. The carbon canisters can be regenerated on-site with potable water, used as a backwash rinse that can be discharged into the county's wastewater collection system. The change-out of carbon canisters is a safe and simple operation because there is no actual handling of carbon media. Spent canisters are removed and shipped to Calgon Carbon facility for regeneration.

The county has operated the system for more than one year and has regenerated the carbon several times without having to return canisters for factory regeneration. The system is a skid-mounted package and required approximately three days to install because all utility connections were available.

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

A complete odor control system for the South County WTP would require two Phoenix™ 6000 systems. The annual water cost is based on a required 2,7000 gallons-per-day system at a cost of $0.001/gallon. Electrical cost is based on $0.12/1,000 gallons of treated water. Annual maintenance is based on work hours required to change spent canisters t a cost of $30/hr. The projected operations costs for the were as follows:

CATALYTIC/ADSORPTIVE CARBON SYSTEM COSTS

Annual Operation Costs:

Item	Annual Cost
Rejuvenation water	$ 2,000
Electrical	$ 8,500
Canister Replacement	$18,000
Maintenance	$ 1,000
	$56,000
Cost/1,000 gallons	$0.04
Estimated Construction Cost	**$185,000**

OZONE DISSOLUTION OF HYDROEN SULFIDE

The test data from the three different conventional process were compared with results of ozone oxidation at another Central Florida fresh water utility. The Orlando Utilities Commission (OUC), as part of their “Water Project 2000”, has been piloting and experimenting with ozone for the dissolution of hydrogen sulfide. Although the design criteria for OUC water treatment facilities provide for future disinfection credit, the core treatment use f ozone is strictly for hydrogen sulfide removal. The first constructed plant was an air-fed ozone generation system, but six subsequent facility designs use 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 counter-current ozone contactors or in-line ozone injection. The primary operational costs for ozone generations are LOX and electric costs for the ozone generators and air purging 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.

The purpose of the ozonation system is to oxidize the natural hydrogen sulfide in the raw water and provide the capability to meet primary disinfection requirements for the future Groundwater Disinfection Rule. OUCs system will use LOX feed and air purging for removing dissolved oxygen to a saturation concentration of approximately 7 to 8 mg/L.

The first five constructed water plants 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 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, allowing the oxygen in the liquid to enter the gas stream. The water is thus deoxygenated.

The capital cost for ozone equipment is greater than the other hydrogen sulfide removal systems evaluated in this paper, but it provides enhanced water quality features (taste and odor) and provides credit for primary disinfection. The authors were involved with the designs of two the OUC facilities, specifically the Kirkman WTP and Lake Highland WTP. The Kirkman WTP is a 15 mgd facility, and the ozone dose required to oxidize hydrogen sulfide is 9.0 mg/L. The Lake Highland WTP is a 33 mgd plant with a required 8.0 mg/L ozone dose. The projected year 2000 annual average daily flow demands for Kirkman and Lake Highland WTPs are 5.5 mgd and 16.6 mgd. respectively.

To compare the operation costs using ozone to the systems that Indian River County test-piloted, the annual average daily flow demands in 20000 are used for the Kirkman and Lake Highland WTP. Projected costs are as follows:

OZONE DISSOLUTION SYSTEM COSTS

Item	Kirkman WTP	Lake Highland WTP
Required ozone dose (mg/L)	9.0	8.0
Ozone required (lb./yr.)	150,683	406,692
Annual Operation Costs:		
Power cost ($/yr.)	54,259	149,062
LOX cost (4/yr)	24,130	74,531
Deoxygenation-air sparging (4/yr)	14,700	29,400
	$96,089	$249,047
Cost/1,000 gallons	$0.05	$0.04
Estimated Construction Cost:	$1,200,000(1)	$1,900,000(1)

(1) Cost includes ozone generator, LOX storage, ozone destruct system, and deoxygenation blowers.

CONCLUSIONS

The county field-tested three different odor control systems: catalytic/adsorptive carbon, conventional two-stage wet scrubber odor control system, and conventional in-line oxidation with chlorine/air injection and mixing for the purpose of process and economic evaluation. The most successful odor control unit was a catalytic/adsorptive carbon system that is not chemically discharged to the county's wastewater collection system. After the regeneration process complete, the catalytic sites within the carbon resume functioning as near virgin material. Hydrogen sulfide gas monitoring equipment detected 95 to 98 percent removals on the catalytic/adsorptive carbon system.

The authors also compared the operation cost for ozone dissolution from the Orlando Utilities Commission's Water Project 2000. The cost of operation for hydrogen sulfide removal is comparable to the other system evaluated. The capital cost for ozone generation and gas-to-water contact is greater than the three evaluated odor control systems. Each utility must make a comprehensive evaluation of water quality and treatment goals.

Indian River County determined that, for their given raw water quality, the most cost-effective system that removed hydrogen sulfide odors was the catalytic/adsorptive carbon system. The finished water quality will meet future Safe Drinking Water Act Trihalomethane formation levels for Phase 2 disinfection.

Estimated annual operation costs for each system are as follows:

IN-LINE OXIDATION SYSTEM COSTS

Chemical	Cost ($/yr.)
Chlorine	$202,878
Caustic	$81,099
Cost/1,000 gallons	$0.11

TWO-STAGE WET SCRUBBER SYSTEM COSTS

Chemical	Cost ($/yr)
Chlorine	$86,128
Caustic	$68,797
Cost/1,000 gallons	$0.06

CATALYTIC/ADSORPTIVE CARBON SYSTEM COSTS

Chemical	Cost ($/yr)
Rejuvenation water	$2,000
Electrical	$8,5000

Canister Replacement $18,000

Cost/1,000 gallons $0.04

OZONE DISSOLUTION SYSTEM COSTS

Costs	Kirkman WTP	Lake Highland WTP
Power Cost ($/yr)	54,259	149,062
LOX cost ($/yr)	27,130	74,531
Deoxygenation-air sparging ($/yr)	14,700	29,400
	$96,089	$249,047
Cost/1,000 gallons	$0.05	$0.04

REFERENCES

Suratt, William B., W.F. McCain, B.H. O'Keefe, T.G. into, Reverse Osmosis Concentrate Treatment In-Line Oxidation of Hydrogen Sulfide, American Desalination Association, Annual Symposium Proceedings, Baltimore, MD, 1995.

Ch2M Hill, Phase III OUC Water Quality Master Plan, September 1995.