DESIGN AND CONTROL OF A LARGE ODOR TREATMENT COMPLEX USING FOAM BIOTRICKLING FILTERS FOLLOWED BY CHEMICAL SCRUBBERS AT THE ORANGE COUNTY SANITATION DISTRICT

Khalil Kairouz*[1], Doug Lanning[1], Walid Karam[1], Pam Koester[2], Ed Torres[2]
Carollo Engineers, P.C.
3100 South Harbor Blvd., Suite 200
Santa Ana, CA 92704

ABSTRACT

The Orange County Sanitation District (OCSD) owns and operates two wastewater treatment plants that treat approximately 240 million gallons per day (mgd). Each plant has extensive foul air collection and treatment facilities that treat over one million cubic feet per minutes (cfm). Odors must be controlled to levels that meet the emission requirements of the local South Coast Air Quality Management District (SCAQMD). In addition, because of the plants' proximity to residential areas, OCSD has voluntarily adopted a "good neighbor" policy that calls for no detectable odor at the plants' boundaries.

OCSD's current discharge limit to meet SCAQMD regulations is 1 ppm of hydrogen sulfide (H_2S). OCSD is currently designing a new headworks facility to replace the existing headworks facility at its Plant No. 2. The new headworks facility will require odor treatment of foul air. To minimize odors at the plant's boundary, the headworks' odor control facility is being designed to reduce hydrogen sulfide concentrations to 0.15 ppm. The selected odor treatment technology for the project is two-stage treatment: foam biotrickling filters followed by single-stage chemical scrubbers. A majority of the odors will be removed biologically through the biotrickling filter; remaining odors will be removed by the chemical scrubber. Hence, chemical usage and operating cost will be reduced substantially.

OCSD has been conducting research for a number of years to optimize a biological process to effectively control odorous emissions at an economical cost. Biological treatment would reduce OCSD's use of chemicals for odor control, providing savings in operating costs and increasing safety for plant staff and the community.

The research has led to the development of a foam biotrickling filter system that can be operated at very low gas retention times (2 to 4 seconds compared to 14 to 20 seconds for typical biotrickling filters). OCSD has converted five full-scale chemical scrubbers to foam biotrickling filters by replacing the plastic packing with open-pore polyurethane foam blocks, and replacing the large recirculation pump with a smaller pump. The test results indicated that the performance capabilities of the biotrickling filter are promising for reduction of hydrogen sulfide, reduced sulfur compounds (RSC), odors, and volatile organic compounds. Long-term operation of the biotrickling filter demonstrated its capability to reduce hydrogen sulfide concentrations ranging from 35 ppmv to 50 ppmv by up to 98 percent.

---

* Corresponding Author
[1] Carollo Engineers
[2] Orange County Sanitation District

The new headworks' odor control facility will be one of the largest biotrickling filter systems in operation in the United States, treating 188,300 cfm of foul air.

This paper discusses the design concepts to be used for two-stage treatment systems, including control capabilities to allow for flexibility and redundancy of biological systems.

KEYWORDS

Foam biotrickling filter, chemical scrubber, biological odor treatment, hydrogen sulfide, biotower, odor control.

INTRODUCTION

Odors generated at wastewater treatment facilities have historically been controlled using either liquid stream or air stream treatment technology. Liquid stream treatments involve adding chemicals to the wastewater stream to minimize odors before they can be emitted. Air stream treatments use some form of containment of the odorous area to capture the affected air and then ventilate the collected gases to an odor control unit for treatment.

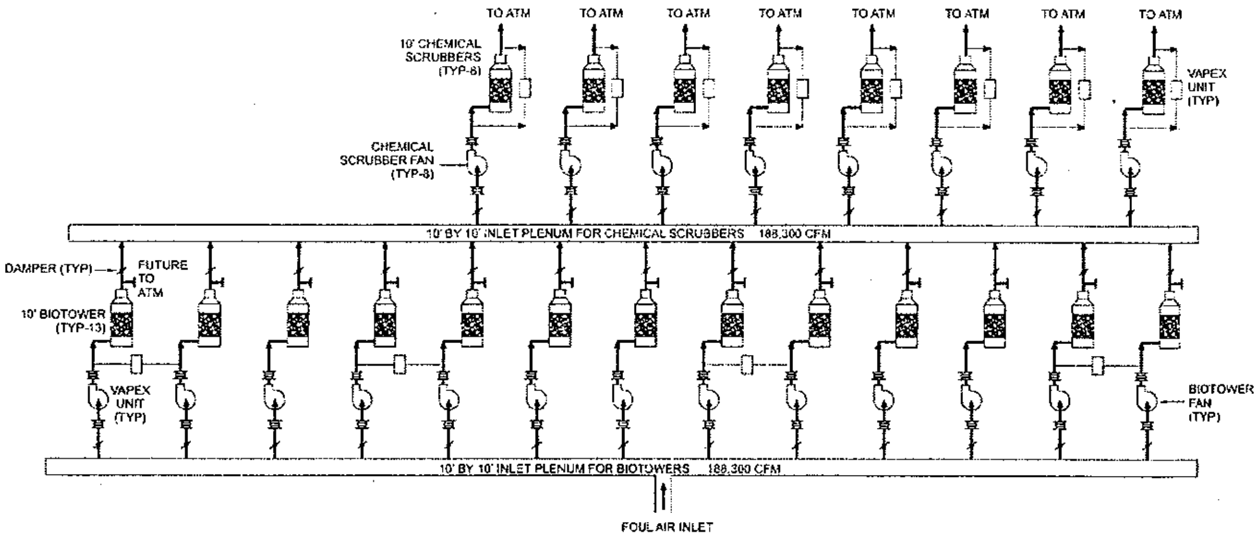
Typically, single-stage and multi-stage odor control systems are used to control odors. These include wet-packed chemical scrubbers, carbon adsorption, and biological soil filters or biofilters. While the industry-accepted techniques for treating foul air are effective, there are notable drawbacks. High operating costs and inherent dangers of dealing with hazardous chemicals and substances are but some of the negatives associated with chemical scrubber and carbon systems. Biological treatment offers potentially lower operating costs in relation to other odor control technologies, primarily because it requires no chemicals. However, the drawback is the residence time (30 to 90 seconds) and the large real estate requirements.

Upon considering such circumstances at OCSD, an alternative to the traditional methods of mitigating odor problems was sought. A pilot project was commissioned using biotrickling filters contained in cylindrical fiberglass packed bed towers. Pollutant degrading organisms were immobilized as biofilms in foam-type packed beds. Contaminants were effectively broken down producing acceptable emission levels established by the SCAQMD and OCSD wastewater treatment plant, i.e., hydrogen sulfide removal efficiencies greater than 98 percent. By using biotrickling filtering in stage one and chemical scrubbing in stage two, the benefits of both air-scrubbing methods would be realized. The following is a more detailed discussion of the design concept to be used in the two-stage odor control air scrubbing system with allowances for flexibility and redundancy in operation.

DISCUSSIONS

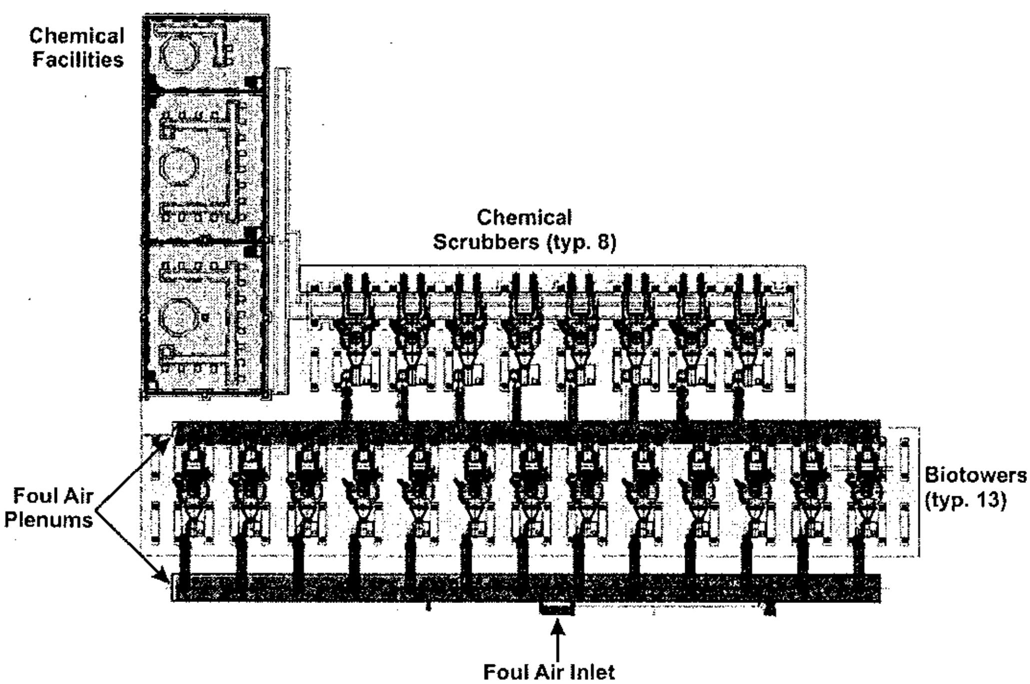
The proposed odor control facility will minimize odors from a new headworks facility to be constructed at OCSD's Plant No. 2. It treats 188,300 cfm of foul air and includes two-stage treatments. The first stage includes 13 single-stage foam biotowers (10 duty plus 3 redundant) followed by 8 single-stage chemical scrubbers (6 duty plus 2 standby) as the second-stage treatment. Figure 1 shows a process flow schematic of the headworks odor control facility.

Figure 1 - Odor Control System Schematic



A chemical facility will be included which provides storage and pumping of chemicals for the chemical scrubbers that are part of the headworks odor control facility. The chemical feed systems consist of sodium hypochlorite, sodium hydroxide (caustic), and hydrochloric acid. Each of these chemicals is stored in a tank. Sodium hypochlorite and caustic metering pumps dose each chemical to the chemical scrubbers. Hydrochloric acid is used for periodic cleaning of the scrubbers. Corrosion resistant fiberglass reinforced plastic pipes convey the foul air from the new headworks to the odor control facility. Figure 2 shows the proposed layout of the odor control facility.

Figure 2 - Odor Control Facility Layout



The following describes general design criteria and control concepts to be used in a two-stage system consisting of biotrickling filters followed by chemical scrubbers.

First-Stage Treatment: Biotrickling Filter

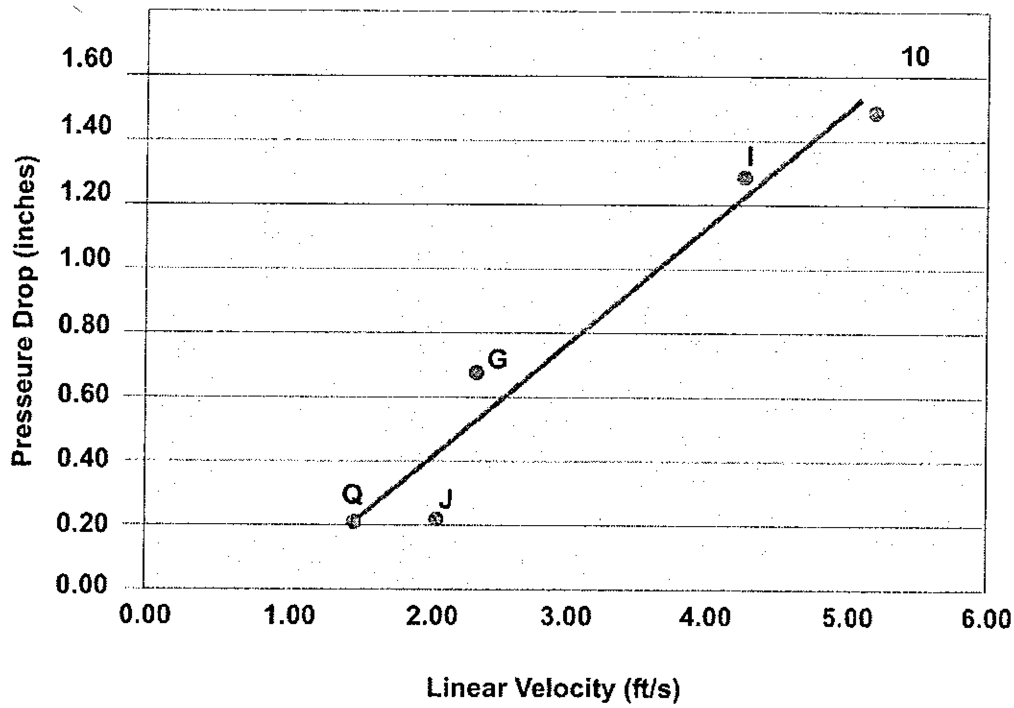
Based upon the test results of the converted chemical scrubber to foam biotower, OCSD established design and performance criteria for sizing the biotrickling filter. These design criteria include:

- Two seconds empty bed contact time (EBCT).
- Loading Rate Per Tower: 255 cfm/ft^2 cross-section.
- Water Recirculation Rate: 0.35 to 0.7 gpm/ft^2 cross-section.
- pH Operating Range: 2± 0.3.
- Media Type: Foam (manufactured by Zanders corporation, Germany) (see Figure 3).
- Pressure Drop: Figure 4 shows the pressure drop, which was established based on testing of the foam media.
- Make-Up Water Requirements: 1 to 5 gpm.
- One redundant tower for every four operating systems.
- Parting box gravity-type liquid distributor system.

Figure 3 - Foam Media

Figure 4 - Foam Media Pressure Drop Test Results

	EBRT	bed height	velocity	pressure drop	pressure drop per foot	
	s	ft	ft/s	inches	inches/ft	
10	1.5	7.7	5.13	10	1.30	actual height
I	2.38	10	4.20	11	1.10	
Q	6.6	10	1.52	2.4	0.24	
G	2.62	6	2.29	4	0.67	
J	7.31	15	2.05	3.2	0.21	



Using the above criteria, Stage 1 is comprised of 13 biotrickling filter foam towers. Ten units are sized to handle the total foul air flow, 188,300 cfm, with three redundant units. Each biotower is 10 feet in diameter and treats 18,830 cfm. The 10-foot-diameter tower was selected since OCSD performed testing of the foam media in a 10-foot-diameter tower and the design criteria were established around the results of the tested tower. A larger-diameter tower could be selected to reduce the number of the biotower units, however, there were concerns that a larger-diameter tower may not provide efficient liquid distribution over the media bed and could potentially affect the removal efficiency of the biotower system.

The biotrickling filters are designed so that under normal operation all 13 biotowers will operate continuously with any 10 towers designated as continuously operating or "duty" towers, and the remaining 3 towers designated as "redundant" towers. The redundant units will need to be operational to maintain the survival of the odor removal organisms, which populate in the foam media.

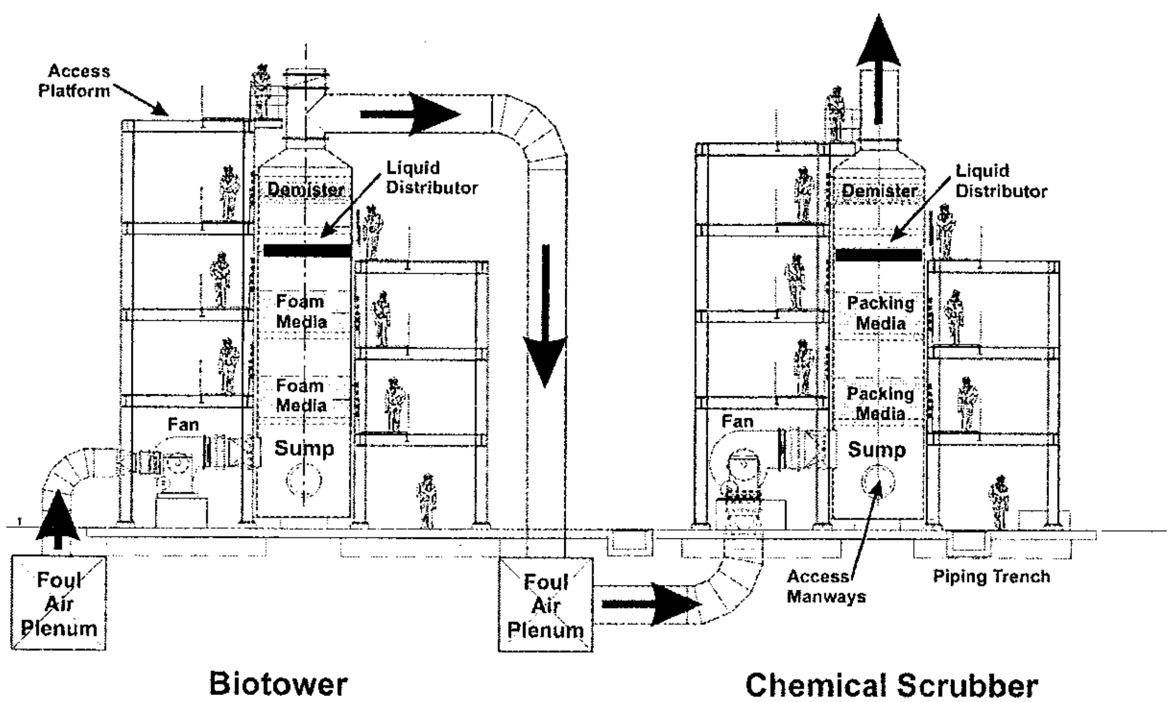
The biotrickling filters will be preceded upstream by a single common inlet header, followed by one dedicated blower fan per tower. The exhaust stacks on Stage 1 biotowers will be routed to another common downstream header. Every Stage 1 biotower fan will be controlled by a variable frequency drive. A flowmeter located on the fan inlet duct measures the flow rate and sends analog signals to the PLC which sums the flow rate of all biotowers and controls the fan's speed to maintain a desired total flow rate setpoint. Variable frequency driven fans are selected to provide accurate controls of the foul air to all biotowers since the pressure conditions among biotowers can vary widely depending on the fouled conditions of the foam media. Constant speed fans would require frequent adjustment of air flows with isolation dampers, which produces artificial back pressure at the fan and results in waste of energy.

The foul air flowmeter selected is a transit-time ultrasonic insertion type. The meter has been used very successfully in many applications involving dirty liquid and gas, and produces dependable, dirt-free, repeatable and accurate measurements, and responds quickly to changes in velocity, without impeding or obstructing the flow. The transducers are resistant to foul air condensate and corrosion, and require minimal maintenance and calibration. Other types of flowmeters could be used such as thermal mass type and others. However, previous experience with the thermal mass flowmeter at OCSD showed that this type of flowmeter can produce inaccurate readings due to condensate buildup on the sensors, which cause corrosion and frequent maintenance.

Each tower may be isolated using shut-off dampers located upstream at its fan's inlet and downstream in its discharge duct.

Figure 5 shows a typical section of the biotower system followed by the chemical scrubber.

Figure 5 - Odor Control Facility Section



The foam media is a proprietary-type foam manufactured by Zanders Corporation, Germany. OCSD tested the biotower with 10-foot media depth. Over time the media experienced compaction and formation of blocks of foam cubes attached to each other in the lower part of the bed, 1 to 2 feet. This was discovered during media replacement. To prevent media compaction, the new biotowers are designed with two media bed sections instead of the normal one media bed section. Structural platforms and 36-inch diameter manways are provided along the tower sides to allow for ease of accessibility to all internal components of the biotower. To provide ease of media replacement, manways are provided at each bed section located above the top level of the media and at the lower part of the media bed.

Each biotower is provided with two recirculation pumps (1 duty plus 1 standby). The pump continuously recirculates the liquid in the tower's sump to the top of the biotower where it is distributed over the media using a gravity type parting box distribution system. This type of distribution system is selected over the nozzle type distribution system since nozzles often plug and result in inefficient liquid cover over media and frequent maintenance. A pH-sensing element is also inserted in the recirculation line to monitor the pH of the recirculated solution. A continuous flow of plant makeup water is added to the sump to account for evaporation and to maintain favorable process conditions in the recirculation flowstream. Excess water in the sump overflows the sump to the drain. Testing results indicated that the pH of the recirculated solution should be maintained around a setpoint of 2 ± 0.3 to maintain the appropriate microbial population. Also, testing showed that at higher pH, different microbial population develops, in which the microorganisms don't grow as much, so that much larger residence times are required. Although the pH is not anticipated to vary drastically, provisions are incorporated in the design to maintain the pH with addition of makeup water to the sump as required, in case the pH drops below this setpoint.

The recirculation flow and the makeup water flow are monitored with magnetic-type flowmeters. OCSD currently uses in-line rotameters for flow monitoring; however, with time, algae and other fouling agents grow inside the rotameters, which become difficult to read and therefore affect the accuracy of the readings.

The inlet and discharge hydrogen sulfide concentrations of the biotowers are monitored with Vapex sentinel systems manufactured by Vapex, Inc., Florida. The Vapex system uses two hydrogen sulfide sensors. Hydrogen sulfide sample ports are located at the inlet and outlet of biotowers and connected to the two hydrogen sulfide sensors in the Vapex unit. OCSD has been using the Vapex system for several years in all their existing odor scrubber systems and are very satisfied with this type of instrument. The pressure drop across the foam media is monitored using a U-type differential pressure manometer. The water level in the sump is monitored by a site level gauge externally mounted to the tank.

Second-Stage Treatment: Chemical Scrubbers

The chemical scrubbers are designed using the following design criteria:

- Inlet Hydrogen Sulfide Concentrations: 10 ppm.
- Outlet Hydrogen Sulfide Concentrations: 0.15 ppm.
- Removal Efficiency: > 98.5 percent.
- Velocity: 400 ft/minute.
- Media Type: Packing, 3.5- to 4-inch size.
- Gas Loading Rate: 1,800 lb/hr.ft^2.
- Recirculation Rate: 8 to 10 gpm/ft^2.
- Make-Up Water: 5 to 30 gpm.
- pH Operating Range: 8± 1.
- One standby tower for every four operating.
- Ability to convert chemical scrubbers to biotowers.

Stage 2 chemical scrubber system is comprised of eight scrubbers. The system is designed so that any six are intended for continuous "duty" while any remaining two are "standby." As in Stage 1, each tower has its own fan and can be isolated from the rest. All stacks from Stage 2 chemical scrubber towers discharge to the atmosphere. Fans draw air from the biotower's discharge plenum and discharge the foul air upward through packed polypropylene media in the scrubber, while sodium hypochlorite and caustic solutions are distributed down through the media. The scrubber towers are designed so that they can be converted to biotowers.

Stage 2 is intended primarily to remove residual odor not treated in the biotrickling filter, comprised mainly of reduced sulfur compounds. This stage is arranged like Stage 1, and the design of the chemical scrubber tower is very similar to the biotower except the towers are chemical scrubbers using conventional packing with recirculating neutralizing reagent.

Each scrubber has a dedicated constant-speed fan. Constant-speed fans are normally used in chemical scrubber applications. Although it is expected that the flow rate will vary depending on the system pressure in each scrubber, variable frequency drives are not merited since any flow adjustment would be taken care of with the variable frequency driven biotower fans. As in biotower, two recirculation pumps (one duty plus one standby) are provided. The pumps continuously recirculate the sump solution and distribute the solution over the packing media using a gravity-type parting box liquid distributor. The recirculation solution is monitored for pH, chlorine, and flow rate. Caustic metering pumps are controlled to maintain an adjustable pH setpoint. Sodium hypochlorite pumps are controlled to maintain a chlorine residual setpoint. The Vapex unit monitors the inlet and outlet hydrogen sulfide concentrations of the chemical scrubber and controls the hypochlorite feed pump based on the vapor chlorine concentration in the discharge stack. The pressure drop across the media is monitored using a U-type differential pressure manometer. The water level in the sump is monitored by a site level gauge and pressure transducer externally mounted to the tank.

Abnormal Operating Conditions

It is critical to design the systems to provide continuous odor control at all times under normal conditions. Therefore, the odor control facility includes redundancies and safety controls. The following describes some of the control measures that are incorporated in the odor control facility.

If a biotower fan fails or a biotower is taken out of service for maintenance, the controls will continue to adjust the speed of the remaining biotowers' fans in service to maintain the total system flow rate setpoint.

If a flowmeter fails or is taken out of service for maintenance, the controls will continue to automatically adjust the speed of all running biotower fans to maintain a total flow rate that matches the flow rate setpoint. A flowmeter that has failed or is out of service will indicate zero flow to the PLC. However, the biotower system associated with the failed flowmeter will still remain in service. The PLC will determine total flow rate by adjusting the total measured flow rate as follows:

$$\text{Total Flow Rate} = \text{Total Measured Flow Rate} \times \frac{\text{Number of Biotower Fans in Service}}{\text{Number of Flow Meters in Service}}$$

All biotower fans will operate at the same speed. The PLC will vary the speed to maintain the total flow rate setpoint.

If a recirculation pump fails, the standby pump will automatically resume operation.

If a scrubber fan fails or a scrubber is taken out of service for maintenance, the standby scrubber will then be put in service.

CONCLUSIONS

The headworks odor control facility at OCSD will be the largest operating odor control system in the nation using two-stage configurations consisting of biotrickling filters followed by single-stage chemical scrubbers. The design provides hydrogen sulfide removal from 50 ppm to 0.15 ppm. The design incorporates features to allow for efficient liquid distribution through the media, ease of accessibility and maintenance of equipment, and accurate controls of air flow rate.

REFERENCES

Gabriel, D.; Cox, H.H.J.; Brown, J.; Torres, E.; Deshusses, M.A. (2002) Biotrickling Filters for POTWs Air Treatment: Full-Scale Experience with a Converted Scrubber; *Proceedings of Odors and Toxic Air Emissions 2002*; Water Environment Federation, Alexandria, VA.

Gabriel, D.; Deshusses, M.A. (2003) Performance of a Full-Scale Biotrickling Filter Treating H_2S at a Gas Contact Time of 1.6 to 2.2 Seconds, Environmental Progress, Vol. 22, No.2, 111-118.

Morton, R.; Caballero, R. (1996) The Biotrickling Story: LA County Sanitation District' Research Pays Off, Water Environment and Technology, June 1996, 39-45.