TO BOLDLY GO WHERE NO ONE ELSE HAS GONE – ODOR CONTROL AT WASTEWATER TREATMENT PLANTS USING HIGH-PURITY OXYGEN

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INTRODUCTION AND BACKGROUND
If you build it, they will come. If they come, they will smell. If they smell, they will complain. If they complain, you will respond – with odor control. Thus goes the story of many a treatment plant in the state and across the country and world. It is a given that wastewater can generate objectionable odors. But it is not a given that a treatment plant has to stink. Much effort and money have been spent on determining the most effective ways to neutralize wastewater odors at reasonable costs. Plant owners are faced with a responsibility of being a good neighbor to those living in the vicinity of the treatment plant and balancing that responsibility with being fiscally responsible to the citizens or customer cities funding treatment projects. To this end, the Trinity River Authority of Texas (Authority) has embarked upon a pro-active pursuit of odor control spanning more than four decades, in which they have continuously invested in odor control for the most significant sources at the plant, evaluated to determine the remaining most significant sources, and then implemented additional odor control. In 2003, the successful use of high-purity oxygen for odor control in pressurized collection system pipelines led the Authority and their consultant, Alan Plummer Associates, Inc. (APAI), to consider whether the use of high-purity oxygen would work for odor control in a wastewater treatment plant. Together, the Authority and APAI developed a pilot project to assess whether, in the limited contact time between the influent pump station and the first treatment processes (the aerated grit basins) there was enough time for the oxygen to work effectively for odor control in the preliminary and primary clarifier treatment units at the Central Regional Wastewater System Wastewater Treatment Plant (CRWS).

PILOT TESTING
CRWS consists of two parallel single-stage activated sludge nitrification treatment trains with effluent gravity filters and chlorine disinfection. The first train, constructed in the 1970s, is referred to as the Phase I/II plant or the north plant. The second train, constructed in the 1980s is referred to as the Phase III plant or the south plant. The 2003 pilot testing on the Phase I/II plant showed that oxygen injection reduced liquid total sulfides, dissolved sulfide, and dissolved hydrogen sulfide, and therefore reduced odors emitted from downstream treatment units. Superoxidogenation reduces sulfides by two mechanisms: (1) oxidation and conversion of sulfides to sulfate and elemental sulfur; (2) Maintaining aerobic conditions and precluding H2S reformation. H2S is the primary source of odors at the WWTP and in the collection system and has a low recognition threshold concentration. The presence of H2S also leads to corrosion of infrastructure. Reducing H2S formation improves odor and reduces corrosion at a plant. Oxygen was injected into the wastewater being pumped from Pump Station 6 (PS6) to the aerated grit basins (AGBs). Dissolved and total sulfides, dissolved oxygen, and other physical and chemical parameters were measured. Figure 1 shows the schematic of the high-purity oxygen pilot process and Figure 2 shows the sampling and testing points.
Figure 3 is a graph of the total aqueous sulfide concentration. Figure 4 is a graph of dissolved aqueous sulfide concentration, and Figure 5 is a graph of hydrogen sulfide (gas) emissions, as wastewater flows from PS6 through Primary Clarifier (PC) Nos. 1-4. As depicted in Figures 3-5, the pilot study showed that even at the low dosage and poor efficiency of the pilot test diffuser, increasing dissolved oxygen in the raw wastewater pipelines was effective at reducing aqueous sulfide concentrations and hydrogen sulfide emissions from the primary clarifiers.

Because of the success of the pilot study, in 2007, the Authority decided to pursue a full-scale demonstration project at the Phase III treatment train. The Phase III treatment train includes Pump Station 6A (PS6A), fine screening in Headworks Building B (HWB), vortex grit removal, and primary sedimentation in PC 5-8. The intent was to provide a positive dissolved DO oxygen concentration through the end of the primary clarifiers to reduce odor emissions from HWB and from PCs No. 5-8.

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FULL-SCALE DEMONSTRATION PROJECT

A high-purity oxygen system was installed at the Phase III plant area of CRWS in 2007. Additional bench-scale testing during preliminary design showed a target dissolved oxygen concentration of 11 mg/L in the influent wastewater would be sufficient for odor control. Figure 6 shows the oxygenation process schematically. The DO concentration of the raw wastewater is increased in a sidestream wastewater flow by pumping the sidestream to an oxygen dissolution cone. In the pressurized cone, oxygen is injected and absorbed by the wastewater. The highly oxygenated wastewater sidestream is then returned and blended with the mainstream flow. The oxygen dissolution cone or Downflow Bubble Contactor (DBC) superoxygênates the wastewater by injecting high-purity oxygen gas under
pressure into the pressurized wastewater. A layer of oxygen bubbles is formed within the contactor vessel through which the wastewater passes, causing significant contact between the oxygen bubbles and wastewater at an elevated pressure thus raising the DO of the liquid. Under pressure, water is able to absorb much more oxygen than at normal atmospheric conditions. The high DO sidestream mixes with the flow in the force main to achieve a target blended DO of 11 mg/L. Figures 7 and 8 are photographs of the oxygen storage and feed system and the dissolution cone vault, respectively.

Performance testing during commissioning of the demonstration system showed less odor control than anticipated, based on the pilot testing. The reasons for this were traced to two differences between the pilot test on the Phase I/II plant and the demonstration project on the Phase III plant. First, recycle streams from solids treatment were not part of the pilot testing. They were routed to the Phase III plant during the pilot test. The organics in the recycle stream exert a competitive demand on the oxygen injected, reducing the oxygen available for odor control. Second, a low strength, but high volume spent filter backwash stream was also included in the flow going to the south plant HWB, reducing the contact time available. Something was needed to make the oxygen sulfide reaction more efficient. A number of metals catalyze the oxygen sulfide reaction. Because the Authority was already adding iron into the collection system for odor control, it was decided to test the addition of a low dosage of iron at PS6A as a catalyst to speed up the reaction between oxygen and dissolved sulfides.

A full-scale demonstration test was conducted to determine whether the addition
of ferrous sulfate to the raw wastewater would improve the performance of the high purity oxygen system. Data showed (Table 1) that the iron alone was more effective than the oxygen alone. Subsequent testing showed that the iron could reduce emissions to levels similar to those achieved by the combined iron and oxygen. However, the dosage required for the iron was significantly higher than when used in combination with the oxygen. In the iron/oxygen combined situation, a low dosage of iron acting as a catalyst was all that was required. Air Dispersion Modeling results indicated high purity oxygen in conjunction with a ferrous sulfate catalyst fed at 2 gpm into PS 6A wet well is significantly less expensive and reduces off-site odor impacts better than an 8 gpm ferrous sulfate addition without oxygen.

### Table 1 – Odor Concentrations at the Phase III Headworks Building B and Primary Clarifiers with Oxygenation and Ferrous Sulfate Addition

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Odor Concentration (DT) Oxygen Only</th>
<th>Oxygen + Fe</th>
<th>Fe Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase III HWB</td>
<td>53,050</td>
<td>6,100</td>
<td>13,700</td>
</tr>
<tr>
<td>PC 6 CW</td>
<td>10,500</td>
<td>2,700</td>
<td>6,200</td>
</tr>
<tr>
<td>PC 6 MT</td>
<td>3,350</td>
<td>940</td>
<td>1,385</td>
</tr>
<tr>
<td>PC 6 EW</td>
<td>2,920</td>
<td>1,040</td>
<td>1,365</td>
</tr>
<tr>
<td>PC 1-41</td>
<td>9,500</td>
<td>2,850</td>
<td>4,700</td>
</tr>
</tbody>
</table>

1Extrapolated from laboratory results.
HWW = Headworks Building B. CW = center well. MT = mid-tank. EW = effluent weir.

The cost comparison (Figure 9) showed that the cost of oxygen plus ferrous sulfate addition was the most cost-effective solution. However, to implement high purity oxygen on the Phase I/II facilities, return flows that affect oxygen uptake must be handled in a different manner than they are currently. The figure shows four alternatives: (1) using high purity oxygen with an iron catalyst for both the Phase I/II and Phase III plants; (2) using iron only for both the Phase I/II and Phase III plants; (3) continuing to use oxygen on the Phase III plant but covering, scrubbing, and treating the foul air on the Phase I/II plant; and (4) covering, scrubbing, and treating the foul air on the both the Phase I/II and Phase III plants.

### Conceptual Design of Full-Scale System

Because of the success of the pilot and demonstration projects and the significant cost savings to be realized with the combined iron and high purity oxygen system, the Authority has tentatively decided to move forward with the full-scale implementation and expansion of the project to include high purity oxygen feed for the Phase I/II plant and a further expansion of the iron feed system at both plants. Prior to completion of the design of the full-scale facilities, however, a final controlled evaluation of the system will be performed to confirm the effectiveness of the system and refine the cost comparison. Further, the Authority is implementing projects to reduce the impact of the recycle streams on the effectiveness of the high purity oxygen. This is being achieved through two primary modifications to the current treatment processes. First, recycle streams from the solids management areas will be rerouted to the biological treatment system, saving costs for pumping and improving the performance of the primary treatment and high purity oxygen system. Second, the Authority is continuing its program of converting the effluent gravity sand filters to high efficiency, lower backwash AquaDiamond® cloth media filters. These projects reduce the organic demand competition for the oxygen and reduce the volume of flow through the headworks, thus increasing the contact time between the oxygen and the sulfides.

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