# Enhanced Chemical Treatment Calms Perfect Storm of Odor Conditions

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## ABSTRACT

The City of Tolleson, Arizona operates a 44.7 cubic meter per hour ($m^3$/hr) [17 million gallon per day (mgd)] capacity, wastewater treatment plant (WWTP). Several residential and commercial developments have been built within ½ kilometer of the Plant and odor complaints have increased. The Plant-wide odor control study was initiated in 2006 to determine the best long-term odor control approach. The initial results of the odor study, plus the urgency of the situation with adjacent neighborhoods, required immediate odor mitigation efforts – specifically by implementing an aggressive chemical addition program utilizing ferric chloride plus hydrogen peroxide. This chemical combination had been tried elsewhere, and had shown considerable success in reducing odors at trickling filters preceded by primary clarifiers. The test work demonstrated that the majority of sulfide reduction and odor control is accomplished with just ferric chloride. The addition of hydrogen peroxide produced approximately 30 percent reduction in sulfide and hydrogen sulfide emissions from the trickling filters.

**KEYWORDS:** Sulfide, ferric chloride, hydrogen peroxide, trickling filters, odor control

## INTRODUCTION

The City of Tolleson operates a 44.7 $m^3$/min (17 mgd) WWTP in the western suburbs of Phoenix, Arizona. The Plant operates at approximately 26.8 $m^3$/min (10.2 mgd). Flow originates from two major sources. The majority of flow 23.5 $m^3$/min (9 mgd) is primarily municipally based flow from the Cities of Peoria and Sun City, Arizona. This wastewater averages 365 mg/l biological oxygen demand ($BOD_5$). The City of Tolleson flow averages 3.15 $m^3$/min (1.2 mgd), and consists of a high proportion of wastewater from a meatpacker, beverage plant, and other industries. This wastewater averages almost 1000 mg/l $BOD_5$.

Since its construction, the Tolleson WWTP was largely isolated from any nearby facilities. **Figure 1** shows a 1999 aerial photo showing the plant largely surrounded by farmland. **Figure 2** shows a "close-in" aerial view taken in 2008. This shows schools and residential encroachment within ½ km of the Plant.

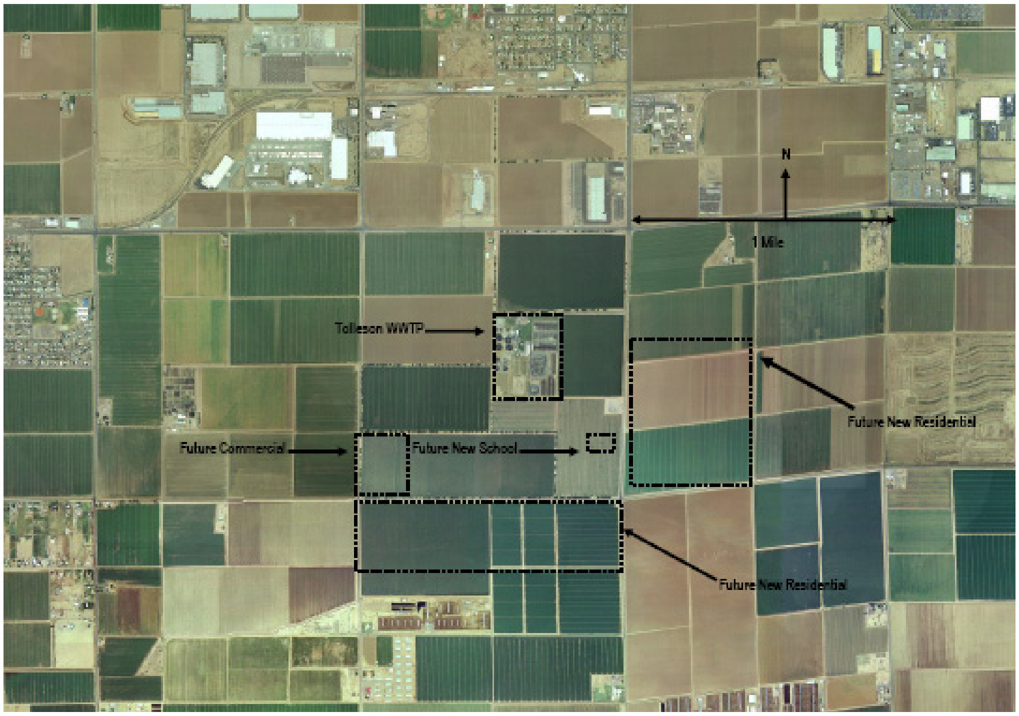

Figure 1: Tolleson WWTP and Surrounding Area – 1999

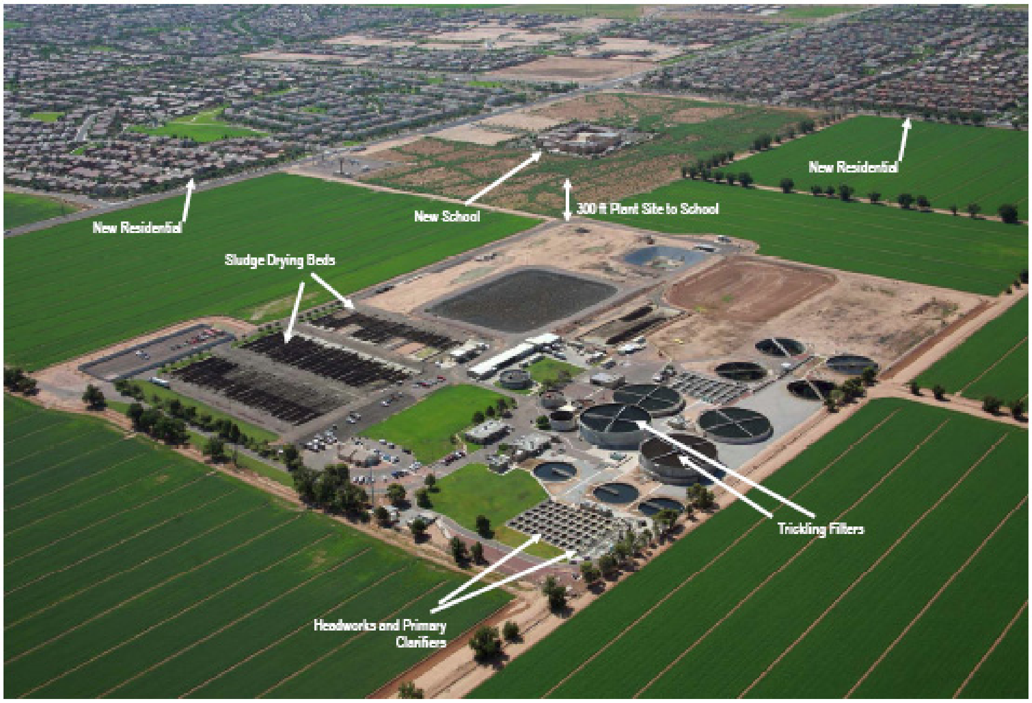

Figure 2: Tolleson WWTP and Surrounding Area – 2008

The Plant processes include screening, grit removal, trickling filters, solids contact tanks, intermediate clarifiers, final clarifiers, and chlorination/dechlorination. Solids are stabilized in anaerobic digesters. Primary solids are thickened within the primary clarifiers, and waste activated sludge is thickened on gravity belt thickeners. Digested solids are dewatered in belt presses, and further dewatered in sludge drying beds, prior to removal from the site. All processes are located outdoors. and none are covered nor employ any odor control.

These wastewater flows enter the plant through two different lines, from different directions. At the screen influent channel, flow from Tolleson enters from the south. and the Peoria/Sun City flow enters from the north. This produces stratification in which the higher strength Tolleson wastewater flows through the south screen and into the southern-most primary clarifiers. The Peoria/Sun City wastewater flows through the north screen and into the northern-most primary clarifiers. This stratification issue required testing both north and south primary clarifiers, as well as the combined primary clarifier effluent flow.

## INITIAL ODOR CONTROL EVALUATION

In 2006, the odor evaluation was begun and quickly showed the WWTP experiencing a “perfect storm” of conditions, causing an extremely high visibility odor problem. These conditions include:

- 3.1 $m^3$/min (1.2 mgd) influent high-strength waste from a nearby meat packing plant and beverage facility.
- Over 9 mgd of commercial/residential wastewater originating over 24 km (15 miles) from the Plant.
- Sewage temperatures exceeding 32 degrees Celsius during the summer.
- Outdoor screening, grit removal, and sludge dewatering facilities; and several acres of sludge drying beds.
- Increased regulatory scrutiny due to an impending air permit renewal.

The study quickly established that influent dissolved sulfide concentrations were between one and five milligrams per liter (mg/l), and increased an additional two to four mg/l through the primary clarifiers (PC). Dissolved sulfides at the PC outlet were routinely above three mg/l which were carried over to the trickling filters (TF), and produced gas phase hydrogen sulfide ($H_2S$) concentrations between 10 and 20 parts per million (ppm) at the TFs in the hot summer months. The combined PC and TF sulfide, and $H_2S$ data showed these processes were responsible for over 80 percent of the Plant odor emissions. The overall recommendations of the odor study focused on the following:

- Provide separate thickening facilities for PC biosolids to enable fast solids withdraw from the PC, and considerably less sulfide production.
- Provide PC covers and air phase odor treatment systems.
- Covers for the TFs were not physically or economically advisable. Thus, chemical treatment to minimize TF odors, as well as the above process modifications, were recommended.

Ferric chloride is used by numerous agencies for sulfide control in wastewater treatment and conveyance systems. This was a logical choice for Tolleson. Since the TFs odor emissions were also very high, hydrogen peroxide was considered as an adjunct to the ferric chloride with the expectation that overall odor control would be improved. In the early 1990s, the City of Wichita tested the combination of upstream ferrous chloride addition, combined with addition of hydrogen peroxide at their Plant 2 WWTP. This plant employs trickling filters after primary clarifiers. With these two chemicals, trickling filters odors were reduced significantly.

This chemical combination of ferric chloride and hydrogen peroxide is relatively well known in the industry, as it is utilized for the catalytic oxidation of sulfides and mercaptans in industrial waste treatment systems. It is also the foundation for the PRISC process, developed by U.S. Peroxide for interceptor sulfide control. The principal of the PRISC process is to convert previously added ferric compounds to an oxidized form that enables further sulfide control. In other words, ferric chloride added in the interceptor system can be re-oxidized at the Plant for further sulfide control through primary clarifiers.

## TESTING METHODOLOGY

Full-scale chemical addition began as an interim measure until odor scrubbers and primary clarifier sludge thickening systems could be funded, designed, and constructed. The study was divided into three phases; baseline (no chemical) testing, ferric chloride only addition, and ferric chloride plus hydrogen peroxide addition. Ferric chloride was added to each influent sewer approximately 120 feet upstream of the screen influent channel. Hydrogen peroxide was added to the inlet of each of the two grit tanks. Odor characterizations consisted of continuous and “grab” samples of both air phase $H_2S$ and liquid phase dissolved and total sulfide. Odalog continuous $H_2S$ instruments, Jerome $H_2S$ analyzers, and gas chromatography for reduced sulfur compounds were employed in the testing. The goals of the chemical evaluation were as follows:

- Characterize sulfide control from the Plant influent through the PCs.
- Determine $H_2S$ impact at the trickling filters arising from dissolved sulfide carry-over from the primary clarifiers.
- Monitor downwind fence-line $H_2S$ concentrations to document any fence-line impact to $H_2S$ concentrations.
- Understand the sulfide and odor reduction potential of the ferric chloride and hydrogen peroxide on liquid treatment and downstream processes, such as digested sludge dewatering.
- Determine the economics of this approach to chemically-based sulfide and odor control.

Testing specific to the planned chemical addition program began April 30, 2007. Baseline data was obtained throughout May and until mid-June. Ferric chloride addition began on June 11, 2007, at a rate of 102 liters/hour (l/hr) [27 gallons per hour (gph)]. As discussed below, the dosage rate proved inadequate and was increased to between 151 and 178 l/hr (40 to 47 gph). In late June, the Plant diverted the Peoria/Sun City flow, so that an in-plant pump station could be rehabilitated. At that time the ferric chloride was stopped until July 6th. Ferric chloride dosage was resumed at the 150 l/hr rate. On July 25th, the ferric chloride dosage was supplemented with hydrogen peroxide. The hydrogen peroxide feed rate was set by the supplier (U.S. Peroxide) at 32.7 l/hr (8.63 gph).

Ferric chloride plus hydrogen peroxide addition continued from July 25th, with only intermittent interruptions in chemical feed.

## RESULTS

### Liquid Phase Sulfide Evaluation

Table 1 summarizes sulfide typical concentrations in the influent interceptors and liquid stream processes. Dissolved sulfides in the 23.5 $m^3$/min (9 mgd) Peoria/Sun City line (serving mostly residential areas) are relatively consistent at approximately 1 mg/l. The sulfide loads in the 1.2 mgd Tolleson influent line are very high (typically 3 to 5 mg/l) due to the industrial discharge and high $BOD_5$ in this flow. Therefore, the Tolleson influent accounts for over 40 percent of the sulfide load but only 10 percent of the total Plant flow. Ferric chloride was initially tested at a total dose rate of 102 l/hr (27 gph) ("low dose"). This rate provided less than 40 percent sulfide control. Increasing the dose rate to a "high dose" between 151 l/hr and 178 l/hr (40 and 47 gph), provided over 75 percent sulfide control, compared to untreated conditions. Each ferric chloride dosing rate was then supplemented with 32.5 l/hr (8.6 gph) of hydrogen peroxide. Tables 2 and 3 summarize the dissolved sulfide reduction under the various chemical treatment combinations.

**Table 1: Liquid Phase Sulfide Concentrations**

| Sampling Point | Location | Dissolved Sulfides, mg/l | | |
|---|---|---|---|---|
| | | High | Low | Average |
| 1 | South Influent Channel | 4.0 | 1.0 | 2.7 |
| 2 | No. 6 Primary Clarifier Weirs | 7.2 | 4.0 | 5.2 |
| 3 | Primary Outlet Channel[1] | 4.7 | 2.5 | 3.8 |
| 4 | Intermediate Clarifiers | 0.0 | 0.0 | 0.0 |
| 5 | Trickling Filter Effluent | 0.0 | 0.0 | 0.0 |
| 6 | Final Clarifiers | 0.0 | 0.0 | 0.0 |
| 7 | Gravity Thickener Effluent | 0.0 | 0.0 | 0.0 |
| 8 | Belt Filter Press Filtrate | 2.8 | 2.0 | 2.3 |

[1] **Combined North and South PCs**

**Table 2: Dissolved Sulfide Reduction – Peoria/Sun City Interceptor**

| | **Peoria/Sun City Interceptor** | | | | |
|---|---|---|---|---|---|
| **Flow (mgd)** | 23.5 $m^3/min$ (9.0 mgd) | | | | |
| **BODs (mg/L)** | 374 | | | | |
| | Dissolved Sulfide Concentration (mg/L) | | | | |
| | Untreated | High Dosage Iron | High Dosage Iron plus Peroxide | % Sulfide Control - Ferric Chloride | % Sulfide Control - Ferric + Peroxide |
| **Interceptor Outfall** | 1.04 | 0.93 | - | - | - |
| **Primary Influent** | 1.04 | 0.78 | 0.15 | 25% | 75% |
| **Primary Effluent** | 3.11 | 1.5 | 0.9 | 52% | 71% |

**Table 3: Dissolved Sulfide Reduction – Tolleson Interceptor**

| | **Tolleson Interceptor** | | | | |
|---|---|---|---|---|---|
| **Flow (mgd)** | 3.15 $m^3/min$ (1.16 mgd) | | | | |
| **BODs (mg/L)** | 990 | | | | |
| | Dissolved Sulfide Concentration (mg/L) | | | | |
| | Untreated | High Dosage Iron | High Dosage Iron plus Peroxide | % Sulfide Control - Ferric Chloride | % Sulfide Control - Ferric + Peroxide |
| **Interceptor Outfall** | 3.95 | 4.67 | - | - | - |
| **Primary Influent** | 3.95 | 0.35 | 0.21 | 91% | 95% |
| **Primary Effluent** | 3.11 | 1 | 0.9 | 68% | 71% |

### Trickling Filter Air Phase $H_2S$ Emissions

Sulfide carryover from the primary clarifiers to the trickling filters (TF) is a major Plant odor source. Continuous $H_2S$ monitoring with data logging was the primary means of evaluating the effect of chemical addition on TF $H_2S$ emissions. The monitoring was accomplished with Odalog continuous analyzers, suspended from the handrail at the top of the TF. This placed the analyzer about 1.5 meters (five feet) above the edge of the media. Several Odalogs were produced in the course of the study. The following summarizes a small sample of the Odalog data that represent key data demonstrating the effect of chemical dosing on TF $H_2S$ emissions.

**Figures 3 and 4** reflect "Baseline" conditions with no chemical addition. These tests were conducted April 30 through May 11. $H_2S$ concentrations reflect moderate emissions that are less than 50 percent of mid-summer emissions. This is due to somewhat lower temperatures in the early May timeframe. Figure 2, in particular, is reflecting higher peak daily temperatures coinciding with high peak daily $H_2S$ concentrations.

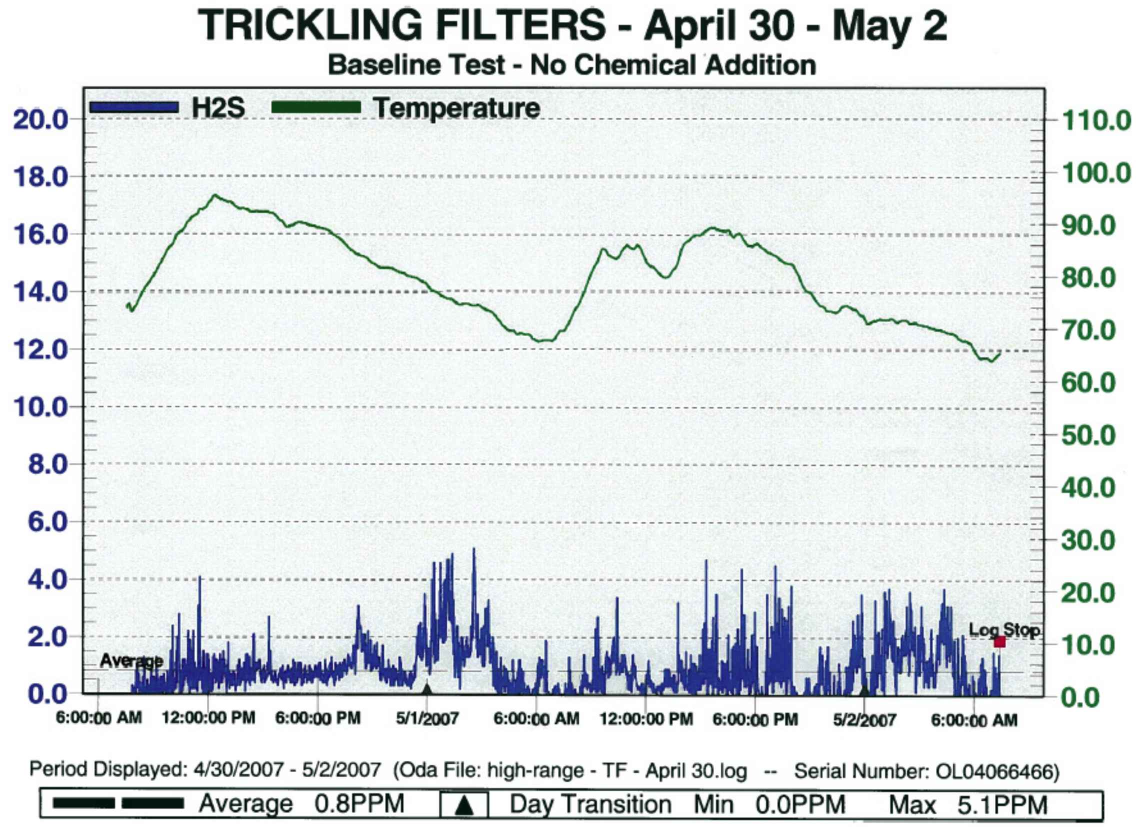

**Figure 3: Trickling Filter Odalog – April 30 Start**

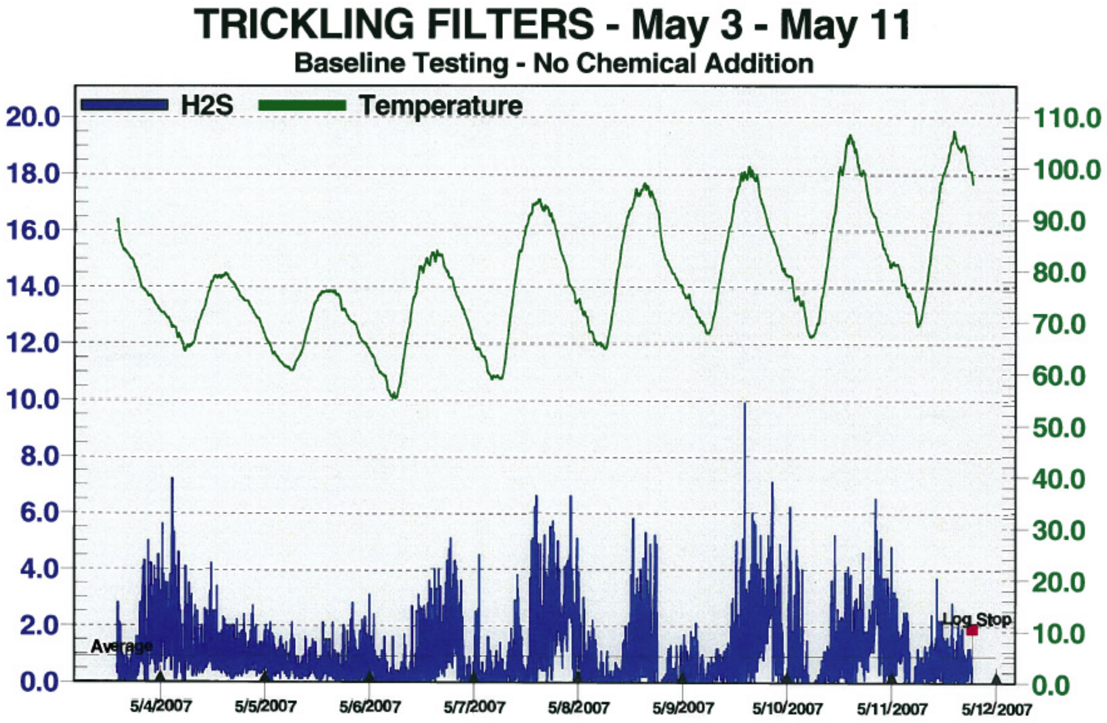

**Figure 4: Trickling Filter Odalog – May 3 Start**

**Figure 5** represents the start of ferric chloride addition beginning June 8th. Initially, ferric chloride was added at a 100 liter/hr (27 gph) rate. At this rate, $H_2S$ emissions were only decreased slightly compared to untreated levels. At this rate, dissolved sulfide control was poor, and significant dissolved sulfide increases were observed through the primary clarifiers.

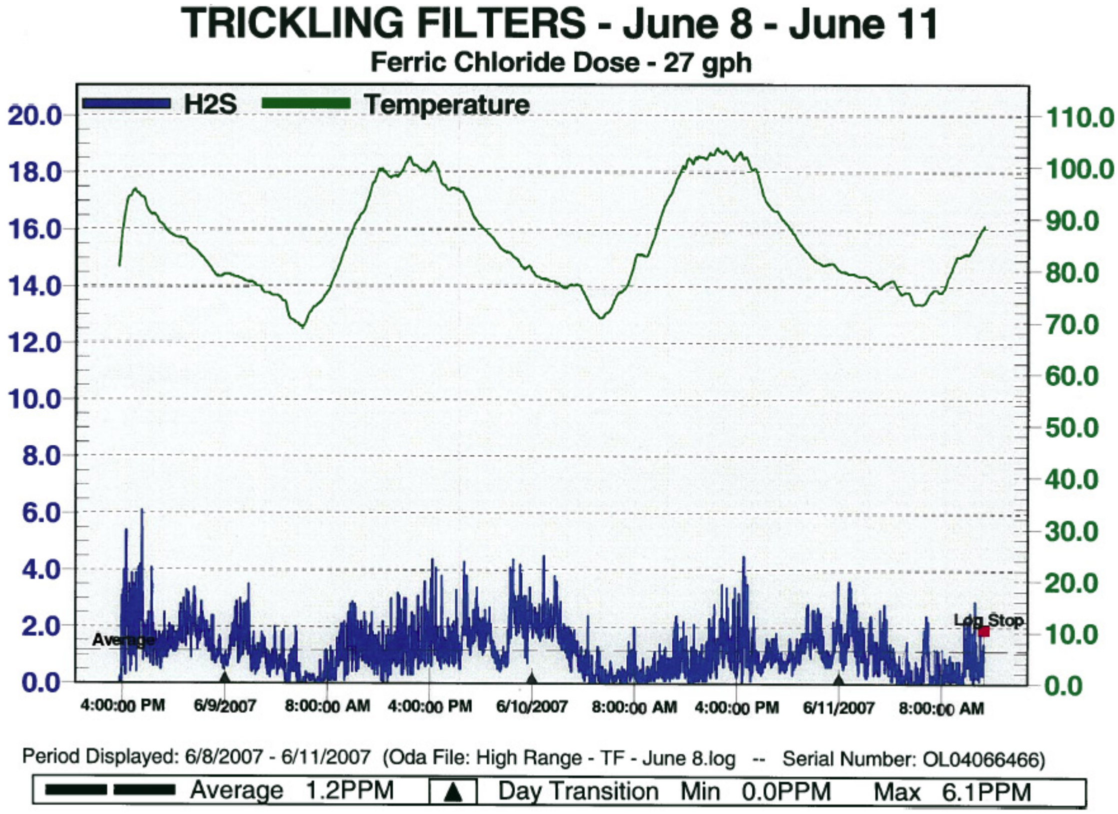

**Figure 5: Trickling Filter Odalog – June 8 Start**

**Figure 6** represents an Odalog reflecting a shut down of the chemical feed systems. This shutdown was necessitated by a major wastewater diversion to rehabilitate an in-plant lift station. It is clear that without the ferric chloride addition, TF $H_2S$ concentrations increased from below 5 ppm to between 10 and 25 ppm.

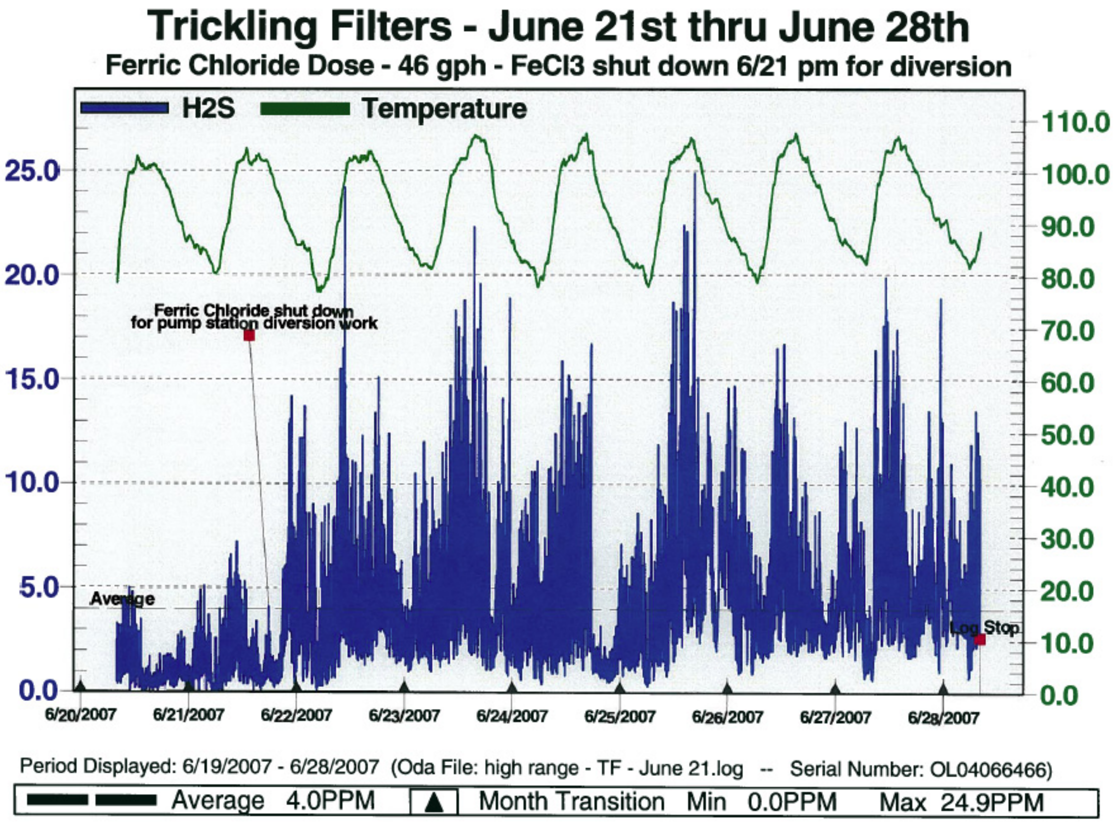

**Figure 6: Trickling Filter Odalog – June 21 Start**

**Figure 7** reflects the end of the ferric chloride outage and resumption of a 155 l/hr (41 gph) dosage. $H_2S$ concentration immediately decreased to less than 3 ppm from routine peaks of 10 to 15 ppm without adding chemical.

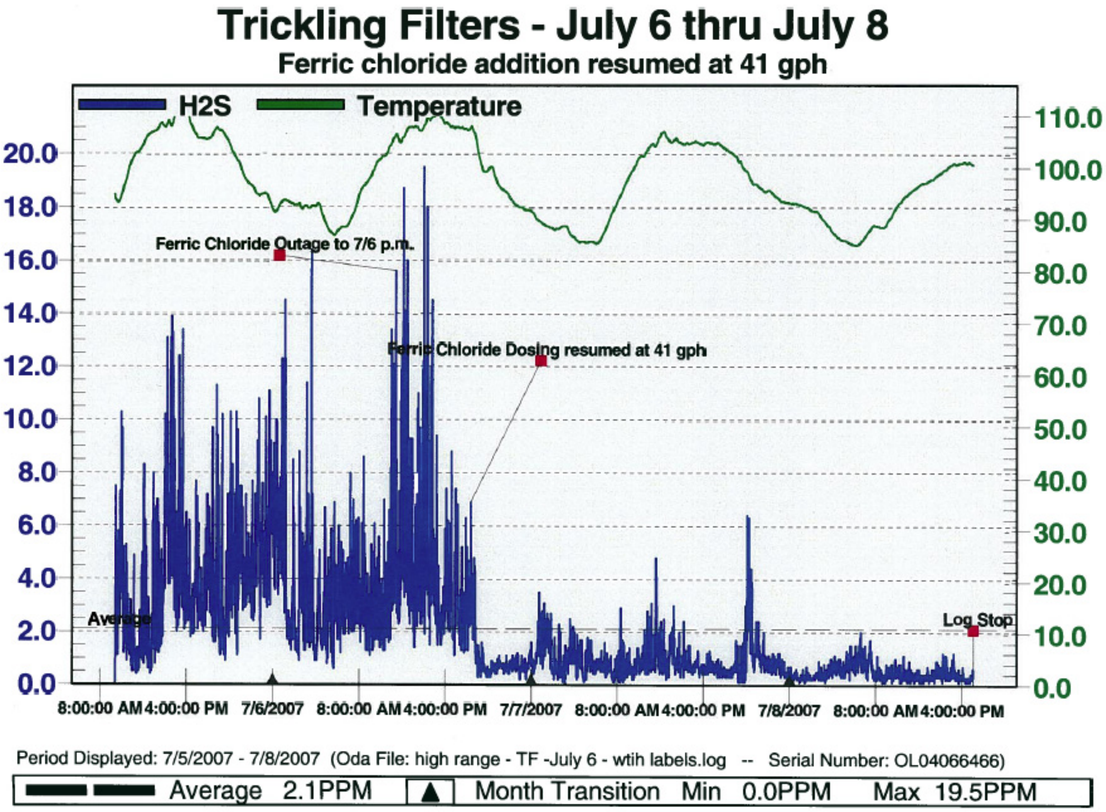

**Figure 7: Trickling Filter Odalog – July 6 Start**

**Figure 8** presents data at the beginning of hydrogen peroxide addition on July 25th. **Figure 9** shows continuation of the data through July 30th. Two events of interest are noted on these graphs. First, $H_2S$ concentrations decrease significantly when the meat processor is "off-line" on weekends. Second, a short ferric chloride outage resulted in an immediate spike up in $H_2S$ concentrations. When ferric chloride feed was re-established, $H_2S$ concentrations immediately decreased. The implication is that hydrogen peroxide at the dose rate selected would not be sufficient to provide good control of $H_2S$.

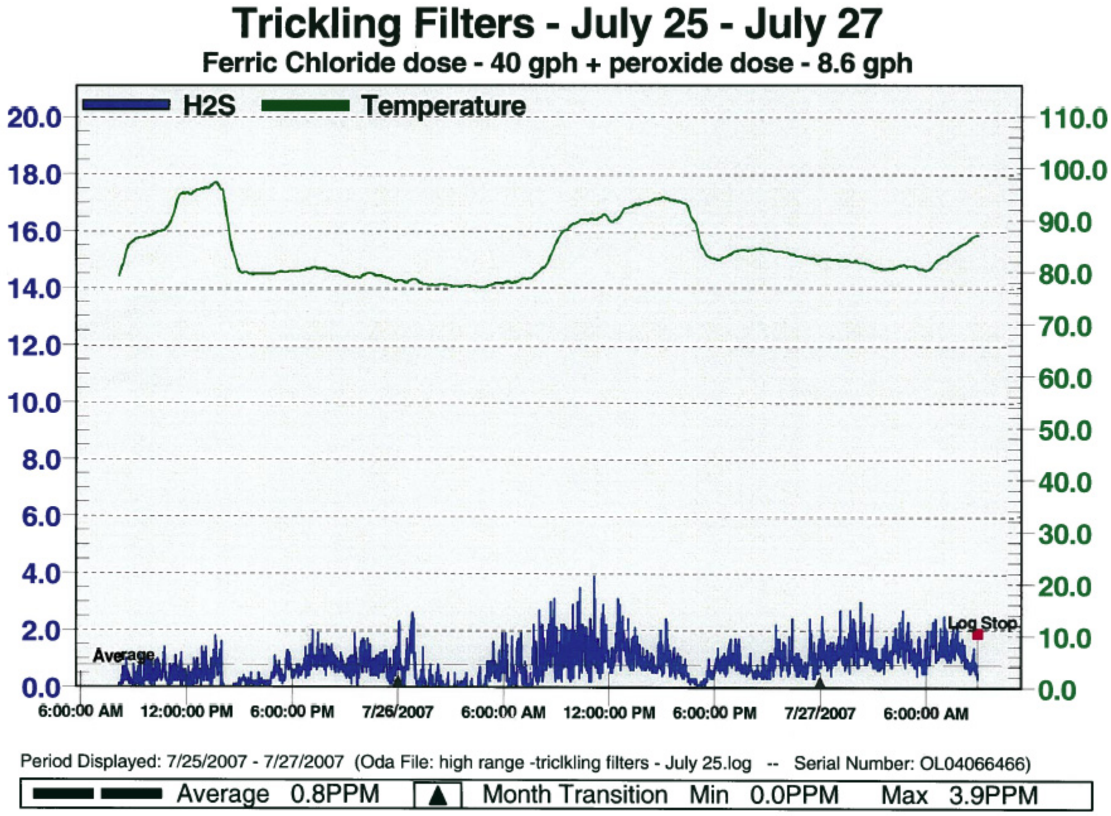

**Figure 8: Trickling Filter Odalog – July 25 start**

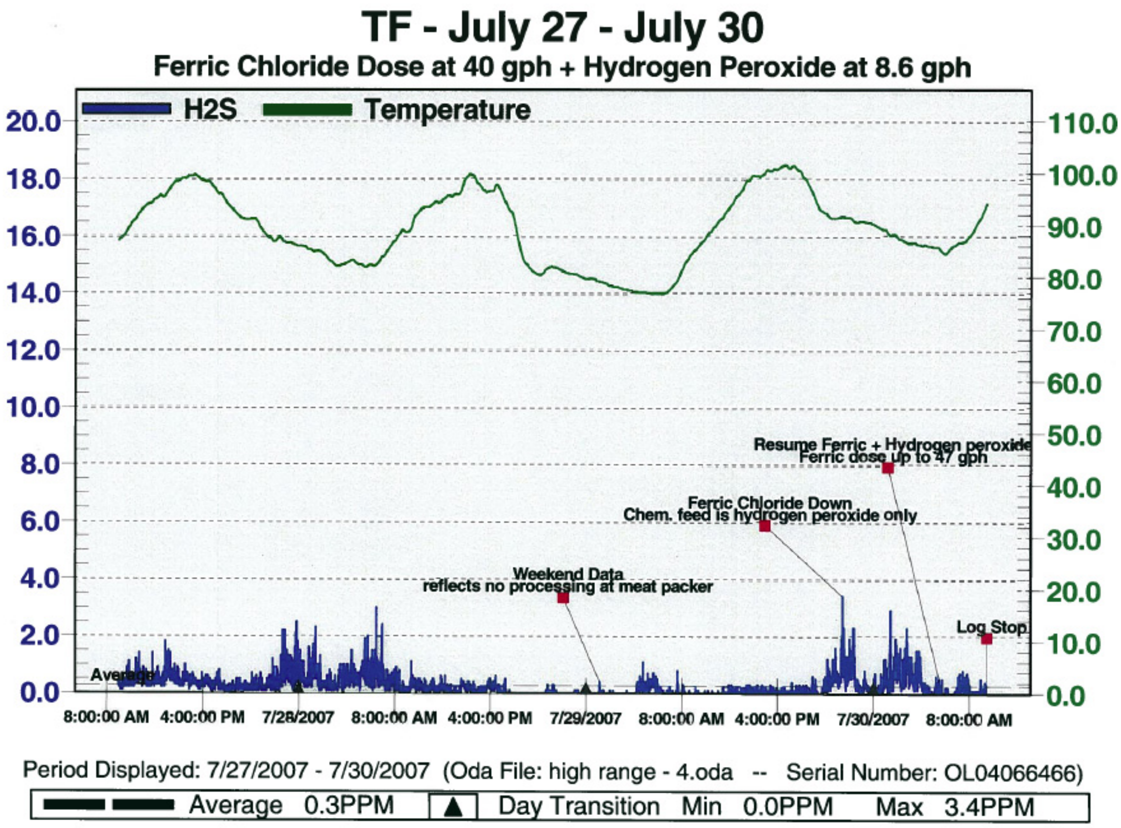

**Figure 9: Trickling Filter Odalog – July 27 start**

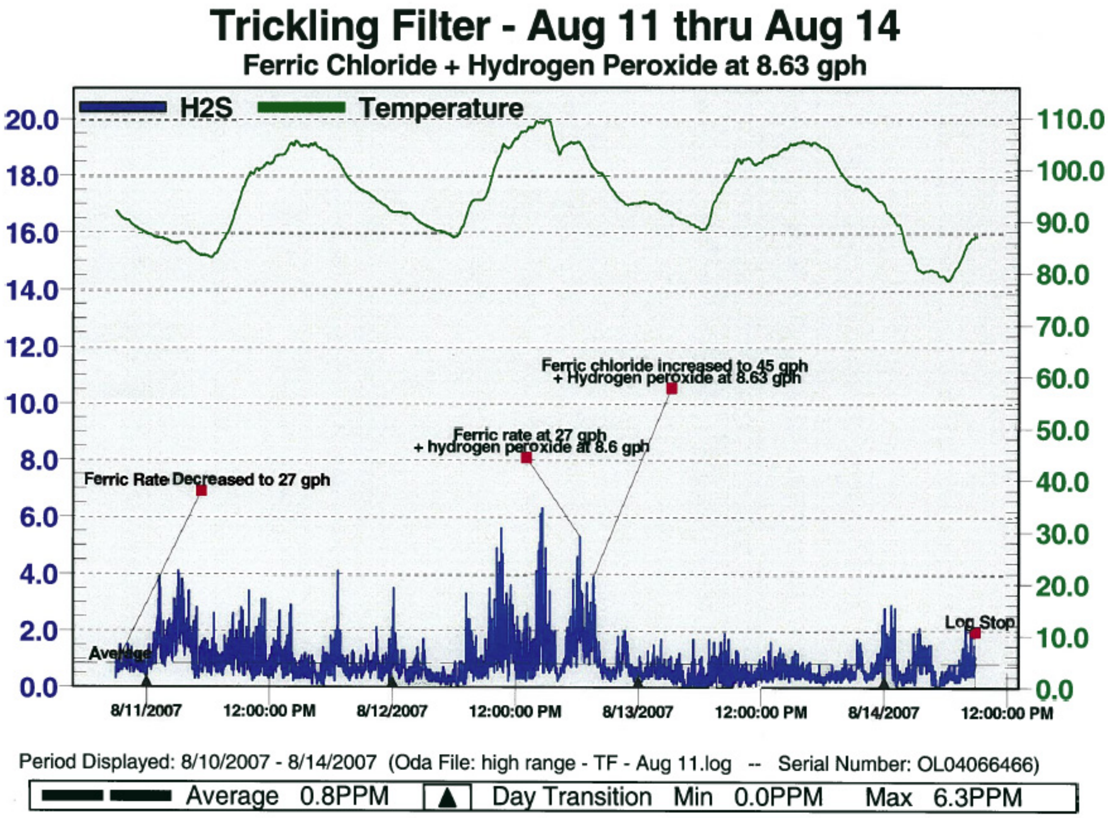

**Figure 10 – Trickling Filter Odalog – August 11 start**

**Figure 10** shows a period in which ferric chloride feed was temporarily reduced back to the 27 gph rate, while the 8.6 gph peroxide feed was maintained. Resumption of the "high rate" ferric chloride feed (45 gph) resulted in a pronounced reduction in TF $H_2S$ to below 2 ppm.

The implications of the air phase continuous $H_2S$ monitoring confirm the following:

- The data showed relatively poor control of TF $H_2S$ emissions at "low dose" ferric chloride rates of approximately 102 l/hr (27 gph).
- At the "high dose" rate 150 l/hr (40+ gph), $H_2S$ emissions were reduced significantly better.
- The addition of hydrogen peroxide did not appear to greatly improve $H_2S$ reduction from the TFs. It is possible that a much higher peroxide dose would be required to demonstrate a much greater $H_2S$ reduction.
- In most cases, chemical dosing maintain TF $H_2S$ emissions below 2 ppm. Without chemicals, concentrations are routinely between 10 and 20 ppm. In other words, chemical dosing reduces $H_2S$ emission by 80 to 90 percent.

## CONCLUSIONS

The most significant results and findings of this project were:

- High sulfide concentrations are primarily due to high $BOD_5$ influent in Tolleson interceptor and sludge thickening in the primary clarifiers.
- High dissolved sulfide concentrations in the primary effluent cause high $H_2S$ release at the top of the trickling filters.
- Ferric chloride alone provides the majority of sulfide control. Hydrogen peroxide produces an additional 10 to 15 percent dissolved sulfide in the PCs. Hydrogen peroxide provide some additional $H_2S$ control at the TFs, however, ferric chloride is the more predominate odor control chemical.
- Chemical dosages are relatively high and will cost the City several hundred thousand dollars per year. Thus, the planned, long-term odor control improvements should be implemented. Faster sludge withdraw and air phase odor control at covered primary clarifiers will greatly minimize the need to add chemical at such high dosages. The cost of operating biological scrubbers will be much less than continued chemical addition.
- Maintaining chemical addition capability is appropriate. The trickling filters cannot be economically covered, and therefore, odor control from the filters must rely on process improvements plus the ability to add chemical as needed.
- This project has clearly demonstrated that chemical addition can be beneficial to TF odors and is a viable means of achieve lower TF odor emissions.

## BENEFITS

The results of this project have enabled the City to expediently address odor concerns and clearly demonstrate its “good neighbor” commitment to both regulators and the public. Characterizing $H_2S$ concentration with different chemical treatments enables the City to implement the most efficient and cost-effective treatment systems in the future.