City of Wichita, Kansas' Odor Control Program – Continuing Optimization with a Cost-Conscious Approach

Rebecca Lewis – City of Wichita, Kansas
Mike Nelson – USP Technologies

ABSTRACT

This paper describes the evolving odor control program of the City of Wichita, Kansas from 2008 to 2015. In 2010, the City reduced odor control technology expenditure due to a reduction of revenues. The odors increased resulting in an upswing in citizen complaints as well as more corrosion in existing plant and lift station equipment. In 2013, the City re-evaluated their existing technology approaches to odor control and implemented optimized chemical dosing strategies to maximize cost-effectiveness and provide wide-ranging benefits. USP Technologies (USP) partnered with the City to implement state of the art chemical dosing controls to efficiently target sulfides with their hydrogen peroxide (H_2O_2) and peroxide regenerated iron sulfide control (PRI-SC®) treatment programs. Implementing the proper treatment technology and chemical dosing controls resulted in dramatically reduced sulfide levels in both the liquid and gaseous phases while providing more cost-effective treatment.

KEYWORDS

Odor control, cost-conscious approach, Wichita, hydrogen sulfide, PRI-SC®, peroxide regenerated iron – sulfide control, hydrogen peroxide, ferrous chloride, RFQ process, odor complaints, corrosion control

THE PROBLEM

Wichita, Kansas operates four wastewater treatment facilities, 59 lift stations, and 3,254 kilometers (2,022 mi) of sanitary lines within the sanitary sewer collection system. The collection system has a relatively flat grade and many areas have flow velocities of less than 0.6 meters per second (2 ft/s).There are many lift station that are oversized which are designed for future flows of a fully developed commercial/residential service area. Consequently, the low flow volumes result in sporadic pumping, forcemains with long retention times, and several inverted siphons. Furthermore, there are many industrial and commercial discharges of high BOD (biological oxygen demand) and high FOG (fats, oils, and grease) flows in the upper reaches of the collection system. All of these factors lead to anaerobic conditions that favor sulfide generation, causing corrosion, nuisance odors, and safety concerns spread out over a large area. The large majority of the flow (130,000 m^3 per day, or 35 mgd) is treated by the Lower Arkansas River Water Quality Reclamation Facility (Plant 2), which has historically seen high levels of sulfide entering the plant. There is a large seasonal pattern to the sulfide generation, with the highest levels experienced in August, September, and October. However, problematic levels of sulfide persist year-round and require constant mitigation.

Due to the long-acting durational sulfide control that iron salts provide, the City's main approach for sulfide control before 2008 within the collection system had been to use ferrous chloride dosing at key lift stations. This strategy provided odor and corrosion control over a wide area, but had limited success once the flows from these iron-treated lines combined. Within these combined flows, drops in pH below 6.5, especially during the warmest months, required frequent lime dosing. Below pH 6.5 iron sulfide (FeS) will not stay reliably bound, and thus sulfide can be released as H_2S. Furthermore, because the iron is fed via a gravity feed system and not metered, unreliable dosing control limited the effectiveness of this approach. The summary reaction of ferrous chloride binding with hydrogen sulfide is presented below.

$$H_2S + FeCl_2 \rightarrow FeS + 2HCl$$

Additionally, the Mid-Continent Water Quality Reclamation Facility (Plant 5) came online in 2010 with membrane bioreactors. The City and their plant design engineering firm had concerns that the high level of iron salt dosing required upstream to manage the sulfide generation occurring in the collection system could result in membrane fouling. The waste activated sludge (WAS) from this facility is pumped to Plant 2, approximately 13 kilometers (8 mi) away. This WAS is initially pumped through a dedicated forcemain through which it was observed that sulfide was being generated. It then discharges into a large interceptor with a drop of approximately 1 meter (3 ft), resulting in H_2S off-gassing at problematic levels.

With such a complex system comprising many problem areas, the City needed a more robust and comprehensive solution and sought to determine the most cost-effective approach. After the large increase in odor complaints resulting from the 2010 budget cuts to the odor control programs, the City decided to reevaluate their approach. The solutions chosen needed to be the most cost-effective options possible to provide the greatest value to the City and its residents.

The City sent out a Request for Proposal in the summer of 2013. Through the City's mandatory purchasing procurement process, the City initially selected a vendor which used a "biostimulant" product for odor control. The vendor was not able to meet contractual obligations for minimum H_2S levels, multiple feed sites, and monthly reporting requirements. The contract was not renewed in 2014, and through the City's procurement process USP Technologies was selected.

THE SOLUTION

Peroxide Regenerated Iron – Sulfide Control at Plant 1

Plant 1 is a former treatment facility now used as a screening and pumping station. Historically there were four upstream ferrous chloride dosing sites used for odor control on flows entering Plant 1, with only two upstream sites left in use by 2015. While this ferrous chloride dosing provided excellent odor control at specific control points upstream of Plant 1, by the time these flows reached the bar screens of Plant 1 the pH levels frequently dropped below 6.5. A pH below 6.5 causes the FeS to dissociate, releasing H_2S under turbulent conditions such as at the bar screens and bell mouth. Besides presenting safety and corrosion challenges, this location is adjacent to Interstate 135, a busy urban highway where nuisance odors would be a source of complaints.

The flow leaves Plant 1 within a forcemain spanning 5.5 kilometers (3.4 mi) to a clarifier at Plant 2. At this point influent dissolved sulfide levels often exceeded 10 mg/L. The City was able to manage pH levels and thus FeS dissociation with heavy lime dosing at Plant 1, but ultimately the difficulty in doing this resulted in limited effectiveness of the downstream odor control strategy.

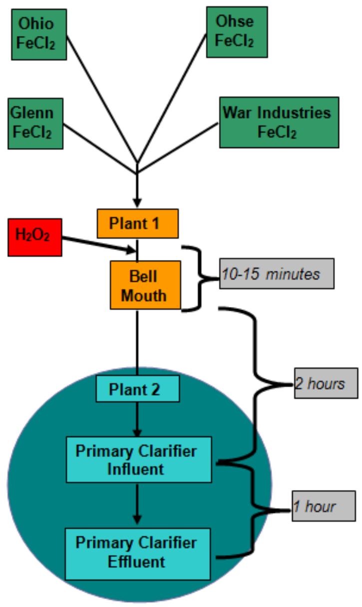

Figure 1. Schematic of Plant 1 to Plant 2 Chemical Odor Control

USP implemented a peroxide regenerated iron – sulfide control (PRI-SC®) program for Plant 1 in 2008 (shown in Figure 1). This involved using a hydrogen peroxide dosing system at Plant 1 to oxidize the dissolved sulfide and regenerate the iron sulfide, resulting in "free" ferrous iron that can then bind with the sulfide generated in the forcemain to Plant 2. These reactions are presented in the equations below.

$$\text{Step 1: } H_2S + FeCl_2 \rightarrow FeS + 2HCl$$
$$\text{Step 2: } FeS + H_2O_2 \rightarrow S_0 + Fe(OH)_2$$
$$\text{Step 3: } Fe(OH)_2 + H_2S \rightarrow FeS + 2H_2O$$
$$\text{Net: } 2H_2S + FeCl_2 + H_2O_2 \rightarrow S_0 + FeS + 2HCl + 2H_2O$$

This PRI-SC® program allowed for very effective control of hydrogen sulfide levels at Plant 1 and Plant 2 and diminished the need for heavy iron dosing. In 2013, when the entire odor control approach was being re-evaluated, the PRI-SC® program was rebaselined versus ferrous chloride alone. PRI-SC® provided better results at a lower cost than using iron salts alone (Table 1). Additionally, on an equivalent cost basis PRI-SC® provided far superior gaseous H2S results compared with $FeCl_2$ alone (Table 2).

Table 1. PRI-SC® Plant 1 to Plant 2 Segment Re-Evaluation Results

Condition	Date Range	Clarifier H_2S, Avg.	Costs
$FeCl_2$ Only	4/7 – 4/9/13	28 ppm	$560/day
PRI-SC®	3/20 – 3/22/13	8 ppm	$400/day

Table 2. PRI-SC® Plant 1 Re-Evaluation Results

Condition	Date Range	Bell-Mouth H_2S, Avg.	Costs
$FeCl_2$ Only	1/10 &1/13/13	38 ppm	$480/day
PRI-SC®	1/11/13 - 1/12/13	4 ppm	$480/day

Peroxide-Regenerated Iron – Sulfide Control and Sulfide Oxidation Using Hydrogen Peroxide for Plant 2

In 2013, with odors from the Plant 1 segments controlled, the City of Wichita issued a Request for Qualifications (RFQ) in order to address odors originating within the rest of the Plant 2 collection system. The City stipulated that the pH of the collection system must remain between 5.5 and 10.5 and that the product allows the City to maintain effluent iron concentrations at less than 0.3 mg/L. Average influent atmospheric H_2S levels were required to be 20 ppm or less. Finally, solids, fats, oil, and grease reduction benefits would be viewed favorably.

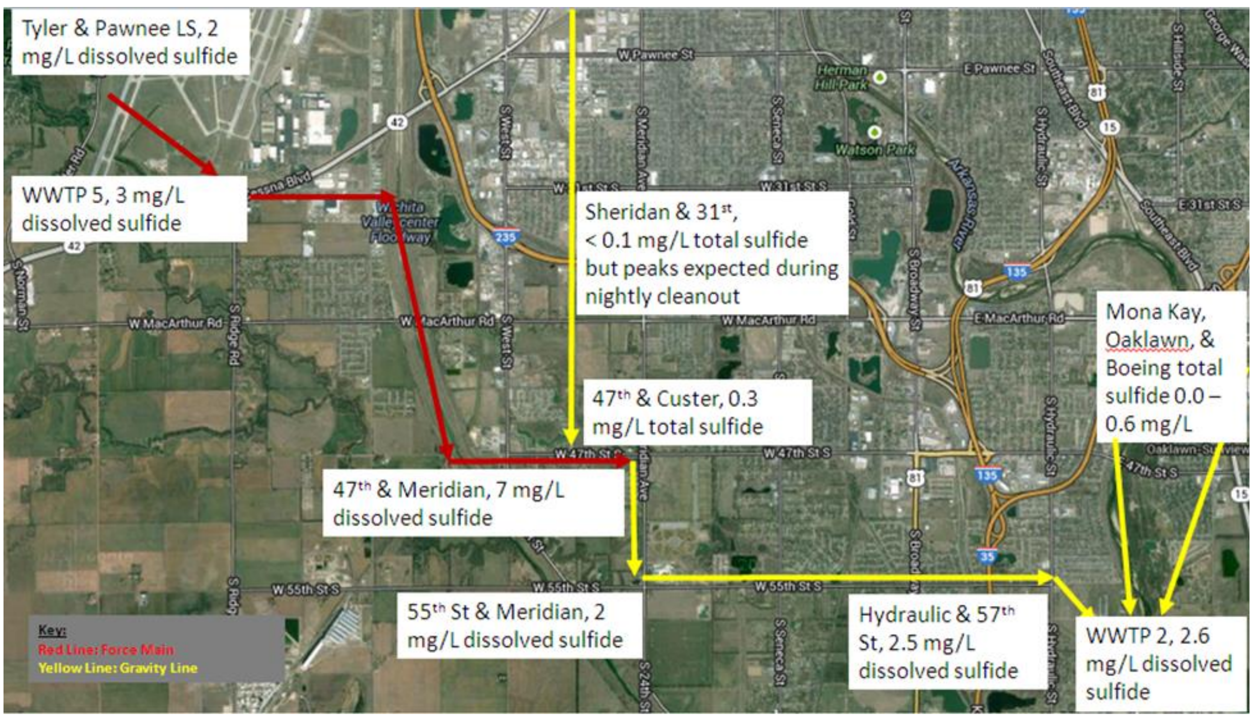

Figure 2. Diagram of Major Plant 2 Forcemains and Interceptors (Plant 1 Flows Not Shown)

USP conducted a survey in 2013 of the Plant 2 collection system and submitted a proposal for a program based on H_2O_2 and PRI-SC® chemical dosing aimed primarily at most cost-effectively controlling odors at Plant 2 while also providing odor, corrosion control, and safety benefits to large sections of the collection system (Figure 2). In this survey all large trunk lines were tested for sulfide levels and the major problematic sections were identified. Since iron salts could not be dosed upstream of Plant 5, 50% H_2O_2 was used instead. The impact on wastewater pH of the ferrous chloride dosing rates was also tested, demonstrating that even at excessive dosing concentrations the pH would stay above 5.5 (Table 3).

Table 3. Jar Test Results of $FeCl_2$ Dosing Within Plant 2 Collection System

Condition	**pH Reading**
Control	6.89
16 mg/L Fe^{2+} Dosage	6.68
32 mg/L Fe^{2+} Dosage	6.51
48 mg/L Fe^{2+} Dosage	6.32
96 mg/L Fe^{2+} Dosage	5.98

The City awarded USP a contract for a full-service odor control program in 2015 encompassing the Plant 2 collection system. A map of the chemical injection site placement is shown below in Figure 3. Through the RFQ process a panel of City staff evaluated the proposals based on the ability to meet or exceed listed requirements, the staff qualifications, experience and expertise, the facility and/or equipment provided, and the thoroughness and completeness of the response.

Figure 3. Plant 2 Collection System Proposed Chemical Dosing Sites

USP installed two hydrogen peroxide dosing systems in April 2015. The ferrous chloride dosing system was installed and started in July 2015.

One hydrogen peroxide system was placed at the Tyler Lift Station. The flow from Tyler Lift Station, up to 11,300 m^3/day (3 mgd), is pumped by forcemain to the Mid-Continent Water Quality Reclamation Facility (Plant 5). This facility uses membrane bioreactors, the fouling of which precluded the dosing of ferrous chloride upstream. Any flow above 11,300 m^3/day (3 mgd) at Tyler Lift Station is pumped in a separate forcemain downstream toward Plant 2. This additional flow has averaged 7,700 m^3/day (2 mgd). The flow entering Tyler Lift Station contains a high percentage of commercial flows with high FOG, and routinely has baseline dissolved sulfide loadings of 2 mg/L or greater. Within the forcemains from Tyler Lift Station, sulfide generation is minimized by the residual hydrogen peroxide and boosted dissolved oxygen. Should the waste activated sludge leaving Plant 5 prove to be a significant problem, USP was prepared to provide an additional dosing system.

The PRI-SC® ferrous chloride system was placed at the Southlakes Sports Complex, allowing convenient access into the large Meridian Avenue interceptor. The forcemains from Tyler Lift Station and Plant 5 enter the interceptor just upstream of the ferrous chloride injection point. The Meridian Avenue interceptor carries flow from a food manufacturer that discharges relatively high BOD waste. This ferrous chloride site is approximately 5.6 kilometers (3.5 mi) upstream of Plant 2, and treats a long stretch of interceptor with evident corrosion that historically has caused many odor complaints.

The second hydrogen peroxide dosing system was placed near the headworks of Plant 2, approximately 200 meters (600 ft) upstream of the bar screens. This provides a final iron regeneration point by which the “free” ferrous iron can be used for sulfide binding at the bar screens and within the clarifier. Given the proximity to these control points, dosing from this hydrogen peroxide system was profiled to optimally address peak sulfide loading periods.

Plant 2 On-Site Odor Control

The City also upgraded the headworks biofilter system, replacing degraded wood chips with synthetic media. In a biofilter, the odor contaminants are solubilized from the vapor phase into an aqueous phase on the surface of an organic medium such as compost, mulch or peat. The compounds are then degraded by the bacteriological population on this media. Biofilters are very effective at removing sulfur-based odor compounds such as hydrogen sulfide, organic sulfides, and mercaptans. One major challenge in biofiltration systems involves the stability of the media. The woodchip media that was previously used in the biofilter was prone to breakdown. This resulted in the media bed settlement and compaction, increasing the headloss through the filter. A decrease in airflow and fugitive odor emissions developed from the air source. The City is addressing this problem through the application of an engineered or "manufactured" biofilter. Engineered biofilters typically address media stability and control issues and are provided with process guarantees.

RESULTS

Plant 2 collection system hydrogen peroxide dosing began on April 23, 2015. PRI-SC® ferrous chloride dosing started afterwards in July 2015 as the ideal location had to be secured and the site preparation finished. Baseline data was collected immediately before the program was started, from March 25 through April 22, 2015 (Table 4).

Table 4. Plant 2 Collection System Odor Control Baseline Data

Site	Average H_2S (PPM)	Dissolved Sulfide (mg/L)
Tyler Lift Station	11.0	2.1
Plant 2 Bar Screens	2.2	0.6
Plant 2 Clarifier Flume	36.8	0.9

Continuous vapor phase monitoring of hydrogen sulfide levels was conducted throughout the baseline and treatment periods. Dissolved sulfide levels were measured periodically by both City of Wichita staff and USP at different times of the day. Despite the seasonal increase in sulfide production, hydrogen peroxide dosing achieved significant reductions in average hydrogen sulfide levels (Tables 5 & 6).

Table 5. Plant 2 Collection System Odor Control Results (Achieved With Only Hydrogen Peroxide Dosing)

Site	Average H_2S (PPM)	Dissolved Sulfide (mg/L)
Tyler Lift Station	5.8	0.2
Plant 2 Bar Screens	0.0	1.0
Plant 2 Clarifier Flume	19.7	0.7
Plant 2 Clarifier Weirs	2.4	0.7

Table 6. Plant 2 Collection System Odor Control Results (Achieved With Only Hydrogen Peroxide Dosing), Percentage Reductions in Average Hydrogen Sulfide

Site	% Reduction of Average H_2S
Tyler Lift Station	47%
Plant 2 Bar Screens	~ 100%
Plant 2 Clarifier Flume	46%

Tyler Lift Station Results

The upstream hydrogen peroxide dosing system was installed at the Tyler Lift Station in order to address local problematic sulfide levels and the generation of more sulfides downstream. Hydrogen peroxide was injected into a manhole approximately 100 meters (300 ft) upstream of the lift station wet well, which provided sufficient mixing and duration to see the 47% reduction in average H_2S levels within the wet well head space. While the primary goal of the chemical dosing at this site is for downstream odor control, the benefits at Tyler Lift Station have been monitored.

Plant 2 Bar Screens Results

Sulfide levels at Plant 2 can be controlled using ferrous chloride dosing, hydrogen peroxide oxidation, or most cost-effectively with PRI-SC®. Having all three of these options available ensures that the City has reliable and robust odor control at all times. Ferrous chloride, injected far upstream at the Southlakes Sports Complex, is regenerated by hydrogen peroxide dosed just upstream of the bar screens.

Since USP's program began through August 6, 2015, sulfide levels within the headspace of the bar screens were consistently maintained at or below target levels, with average H_2S levels of 0.0 to 0.2 ppm (April 2015 baseline of 2.2 ppm).

Plant 2 Clarifier Results

The Plant 2 clarifier, since it is uncovered, presents one of the facility's most significant odor sources. USP monitored H_2S levels at two points at the Plant 2 clarifier, mutually agreed upon with the City. The first point, within the confined space of the Parshall flume on the clarifier effluent, offered a worst-case glimpse of the potential H_2S levels that could strip out and accumulate. The second point, over the weirs at an uncovered space near the inlet to the Parshall flume, monitored the levels released to the environment at what should be the most concentrated point. This second monitoring point was the point of greatest turbulence within the clarifier.

Baseline April 2015 H_2S averaged 36.8 ppm within the confined headspace of the Parshall flume, while after treatment with hydrogen peroxide through May and June 2015 H_2S averaged 19.7 ppm. Through May and June 2015 the H_2S emanating from the weirs and Parshall flume inlet averaged 2.4 ppm, with a treatment cost of $785/day.

Upstream ferrous chloride dosing began in July 2015, marking the beginning of the PRI-SC® treatment. This coincided with a seasonal increase in sulfide generation. At a treatment cost of $722/day, which is lower than the cost of treatment with hydrogen peroxide alone, H_2S levels above the Plant 2 clarifier weirs averaged 6.9 ppm.

PATH FORWARD

The City of Wichita and USP share the common goal of providing the greatest value to the citizens whose revenues support the odor control program. This goal guides the decision-making process from the highest level down to the daily dosing rate decisions. This requires a continuous optimization approach, never settling for the status quo but always finding ways to improve.

The City plans to explore a seasonal lime dosing program at Plant 1 that would maintain an ideal pH for sulfide binding with the ferrous iron. This is expected to also have beneficial impacts downstream as a source of alkalinity. As all of the decisions had been since the program began, this too would be subject to a rigorous evaluation against other options to ensure that it is the most cost-effective option for odor control.

Further automation of the hydrogen peroxide dosing systems, especially at Plant 1 and Plant 2, will be evaluated for its cost-effectiveness and overall performance improvements. Parameters for control which will be explored include gaseous H_2S levels, liquid sulfide levels, flow volumes and pH.

Finally, regular re-evaluations of the odor control targets, control points, dosing rates, budget, and overall strategies will be conducted. In the spring of 2016, a thorough re-examination of the ferrous chloride dosing strategy upstream of Plant 1 will be conducted, with cost-savings expected by the implementation of hourly dosing profiles to coincide with the observed pattern in sulfide loading.

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