



On-Site Treatability Study for Destruction of Sulfide Melbourne, Florida

Summary

A survey was conducted of total sulfides within Lift Station 23 in Melbourne, Florida's north end sewerage collection system. Pretreatment results over two weeks of testing indicated that hydrogen sulfide within the air ranged from 500 ppm to over 1000 ppm. Total sulfides within the wastewater column averaged from 9 ppm to 12 ppm over two 24 hour sampling events.

Flows into LS 23 range from 1.5 million gallons per day (MGD) to 2.1 MGD.

The calculated dosage of Ultra-S3/hydrogen peroxide necessary to achieve successful reduction of sulfides to less than 1.5 ppm within the water column and less than 200 ppm within the air was approximately 56 gallons per day (GPD). Actual treatment of the lines coming into LS 23 indicated that the actual dosage would be somewhat higher than this number at approximately 60 GPD.

The following Odalogger graphs depict before and after treatment results using the Ultra-S3 process at LS 23.

Figure 1: LS 23 Sulfide Concentration Before Treatment

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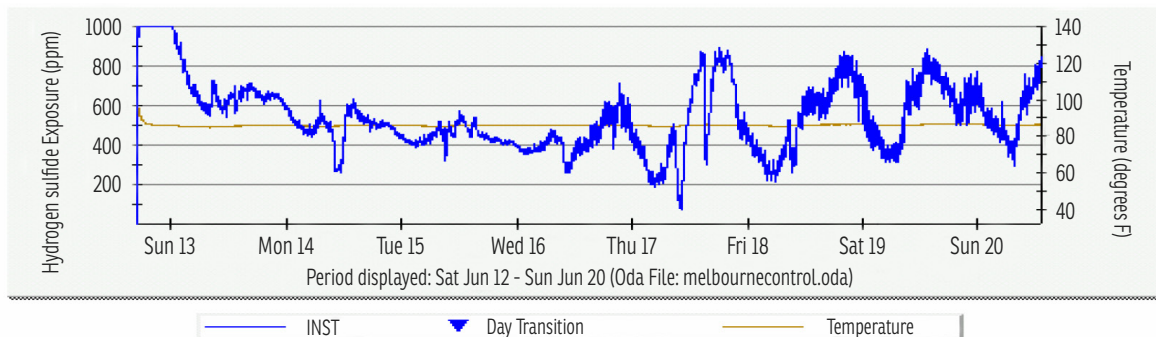
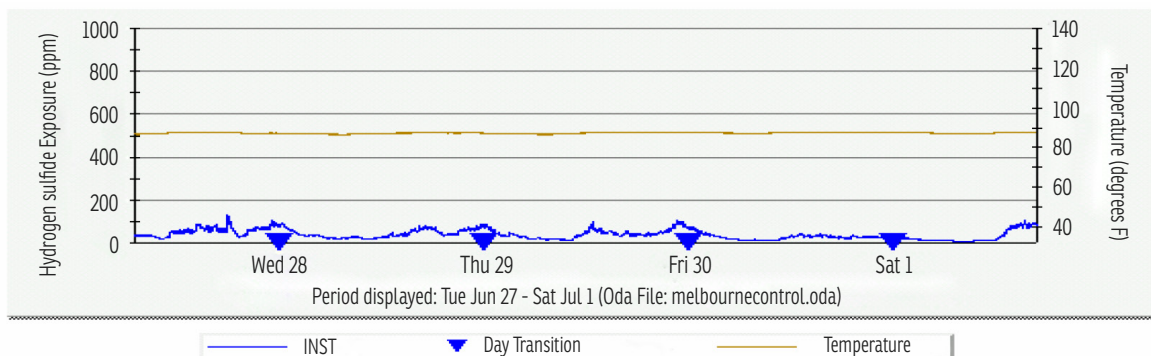


Figure 2: LS 23 Sulfide Concentration After Treatment

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Before and after treatment wastewater total sulfide levels are depicted in the following two figures.

Figure 3:

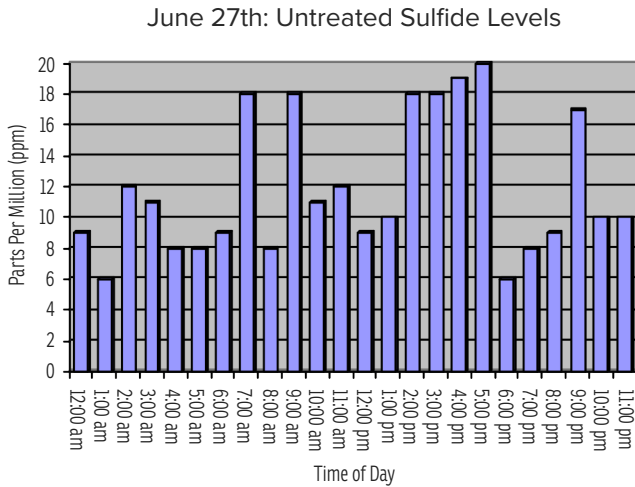
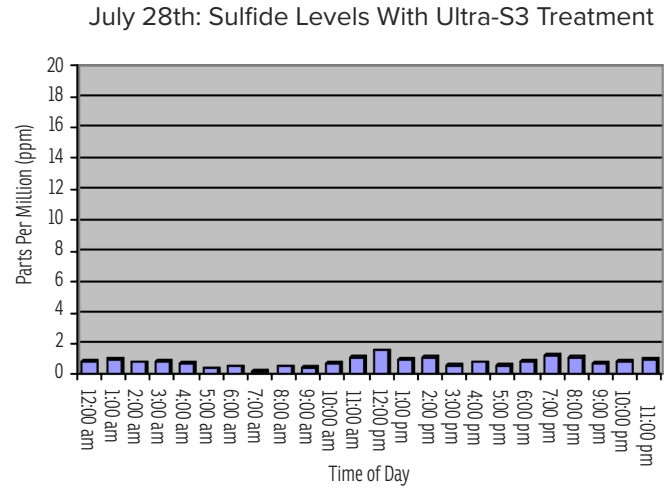


Figure 4:



Conclusions

The following conclusions are noted for the study:

1. LS 23 can be treated using approximately 60 GPD of Ultra-S3 treatment chemicals.
2. Ultra-S3 treatment at LS 23 can meet goals set by Melbourne for treatment efficiency.
3. No grease build-up was noted during the treatment.
4. Given similar sulfide levels at LS 6 and 15, approximately 120 GPD will be needed to treat all three stations.
5. Treatment of sulfides entering each station can be accomplished from the lift station grounds.
6. It is probable that lower dosages can be used during colder months.

Recommendations

While the objective of the treatments into the various lift stations within the Melbourne system is to reduce odor, it should be pointed out that Melbourne is undoubtedly experiencing significant infrastructure decay due to sulfide related corrosion. The corrosion brought on by sulfides is destroying concrete and metal throughout the system, including the wastewater treatment plant. A professional analysis of the costs associated with sulfide related corrosion at Melbourne will result in an understanding that significant amounts of money is being lost yearly to infrastructure decay, especially at the receiving wastewater plant. Such a study would justify a more aggressive approach for treating sulfides than plans call for at present.

Results of the Ultra-S3 Process Sulfide Treatment Pilot Study Conducted at Melbourne, Florida June/July 2004

Introduction

A pilot study was conducted by the City of Melbourne, Florida for the control of sulfides within a portion of the sewerage collection system in Melbourne.

The study was to establish base line information as to the nature and extent of sulfide prevalence within the designated portion of the collection system prior to treatment. Baseline studies were conducted which outlined the general flow patterns for the system over extended periods, retention time between the lift stations feeding the control point and sulfide concentrations within the wastewater as well as air within the lift station at the control point.

Once a general understanding was attained for the sewerage system, selected dosages of Ultra-S3 were administered to the system to attain the desired treatment goals over an extended period of time.

One of the benefits seen by the City of Melbourne for using the Ultra-S3 solution was the rapid treatment offered by the process. Because of the rapid treatment capability of the process, systems for treating a given lift station could be located at the lift station of concern. Locating systems on lift station grounds offers a significant benefit by not having to establish new satellite injection points for sulfide control using other less rapid techniques. Tests were conducted to determine the optimum dosages for rapid treatment of sulfides using Ultra-S3.

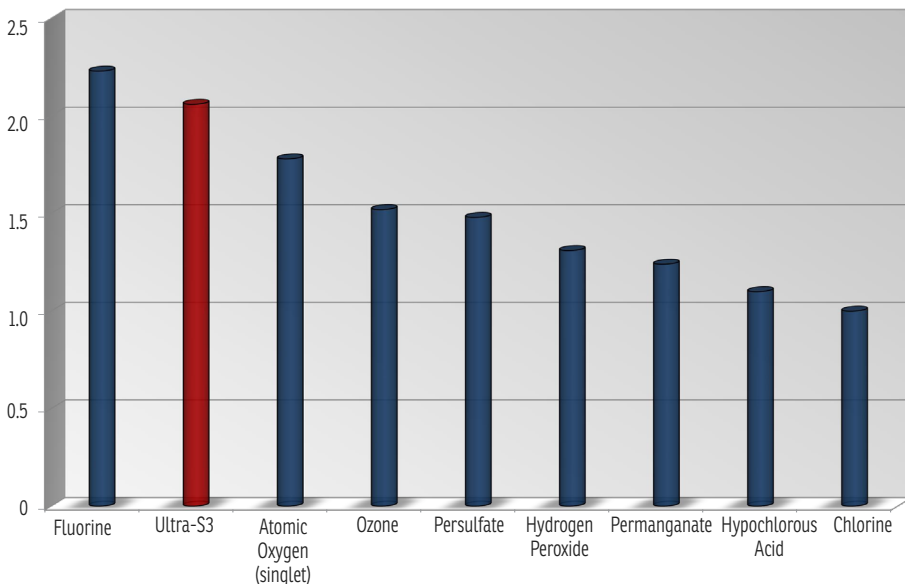
Description of the Ultra-S3 Process

The Ultra-S3 Process was originally developed to treat a variety of recalcitrant environmental contaminants, which are commonly found within soil and groundwater contamination. Initial test work focused on treatment of chemicals such as trichloroethylene, vinyl chloride, methyl tert-butyl ether (MtBE), benzene, and phenols among others. Ultra-S3 works extremely well to treat a variety of hard to treat chemicals.

The process works by combining a strong oxidizing agent, such as hydrogen peroxide, ozone, persulfate, etc. with an organo-metallic catalyst within a pH range of 5.0 to 8.5. The catalyst is environmentally safe and, in many cases, is consumed in the process. The catalyst is also easily biodegraded. The concentration of metal released from the degradation of the catalyst in sulfide treatment at sewage treatment plants will be in part per billion levels.

Figure 5 illustrates the relative comparison of commonly available oxidants (as compared to chlorine).

Figure 5: Relative Oxidation Power of Common Oxidants



It is widely understood that treatment of sulfide can be accomplished with hydrogen peroxide, hypochlorite, persulfate and many other oxidants. However, most of them are too costly or require too much contact time to be a viable alternative for rapid treatment sulfide at headworks of wastewater treatment plants.

Initial testing was performed to determine how quickly the treatment would yield desired results. Early testing indicated that, with effective mixing, treatment could be accomplished largely within the first five minutes of contact time (Table 1 and 2 below). Importantly, the testing also suggested that the amount of hydrogen peroxide needed to accomplish successful treatment within a very short period of time was below the published recommended dosage for peroxide alone. Hydrogen peroxide producers widely report that hydrogen peroxide dosage for treatment of sulfide within municipal wastewater systems approximate a range of 2.5 to 4.0 times the mass of sulfide present within the waste stream. The dosage of peroxide needed to accomplish treatment in wastewater using the Ultra-S3 process has consistently been in the range of 1.5 – 2.5 times the sulfide present. This has resulted in projections of cost of treatment below what is commonly available for all other competing treatment technologies.

Table 1. Percentage Destruction of Total Sulfides after 5 Minutes of Treatment

Treatment Level	H ₂ O ₂ Alone	H ₂ O ₂ /5xUltra-S3	H ₂ O ₂ /10xUltra-S3	H ₂ O ₂ /20xUltra-S3	H ₂ O ₂ /40xUltra-S3
1.5	18.6%	63.4%	54.0%	32.2%	28.8%
2.5	32.1%	92.5%	87.2%	81.6%	71.4%
3.0	33.6%	93.0%	91.4%	82.2%	71.0%
4.0	56.1%	99.0%	98.4%	97.9%	97.8%

Table 2. Percentage Destruction of Total Sulfide after 30 Minutes of Treatment

Treatment Level	H ₂ O ₂ Alone	H ₂ O ₂ /5xUltra-S3	H ₂ O ₂ /10xUltra-S3	H ₂ O ₂ /20xUltra-S3	H ₂ O ₂ /40xUltra-S3
1.5	62.2%	93.5%	86.5%	77.7%	70.6%
2.5	81.8%	97.3% ¹	98.8%	98.3%	97.0%
3.0	89.6%	98.4% ²	97.3% ³	97.3% ⁴	94.1%
4.0	93.9%	99.0% ⁵	98.4% ⁵	97.9% ⁵	97.8% ⁵

¹ After 15 minutes

² After 10 minutes

³ After 15 minutes

⁴ After 20 minutes

⁵ After 5 minutes

Cost Comparisons of Competing Technologies

The following chart, Table 3, illustrates a cost comparison of the most commonly used chemicals/technologies used in the treatment of sulfides. The cost information used in formulating the cost of the Ultra-S3 process is derived from data collected during actual treatment applications. The cost information for the additional accompanying treatment technologies is taken from information which is commonly available throughout the wastewater treatment industry.

Table 3. Approximate Comparative Costs for Chemical Treatment of Sulfide

Chemical Solution	Approximate Treatment Cost per lb. of H ₂ S Removed
Permanganate	\$ 4.99
Sodium Chlorite	\$ 6.40
Sodium Hypochlorite	\$ 6.18
Sodium & Calcium Nitrate	\$ 8.93
Ultra-S3	\$ 3.50



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Summary of Competing Technologies

Noted corrosion and odor control expert, Robert Bowker, P.E. (Bowker and Associates, Inc. Portland, Maine), produced the following table of advantages/disadvantages for the various available chemicals that control sulfides. Mr. Bowker's text is a recognized standard in the industry (Bowker, Smith & Webster, 1989).

Table 4. Advantages and Disadvantages of Various Chemical Controls

I. OXIDATION			
<i>Technique</i>	<i>Frequency of Use</i>	<i>Advantages</i>	<i>Disadvantages</i>
Air Injection	Low	Low cost, adds DO to wastewater to prevent sulfide generation	Applicable only to force mains; potential for air binding; limited rate of O ₂ transfer
Oxygen Injection	Low	Five (5) times solubility of air, high DO possible; economical for force mains	Applicable only to force mains; requires on-site generation or purchase as liquid O ₂
Hydrogen Injection	Medium	Effective for sulfide control in gravity sewers or force mains; simple installation	Costs can be high to achieve low (<0.5 mg/L) sulfide; safety
Sodium Hypochlorite	High	Applicable to gravity sewers or force mains; effective for broad range of odorants	Safety considerations; high chemical cost
Potassium Permanganate	Medium	Effective, powerful oxidant; good for sludge handling applications	High cost, difficult to handle
II. PRECIPITATION			
<i>Technique</i>	<i>Frequency of Use</i>	<i>Advantages</i>	<i>Disadvantages</i>
Iron Salts	High	Economical for sulfide control in gravity sewers or force mains	Does not control non-H ₂ S odors; sulfide control to low levels may be difficult; increased sludge production
III. pH ELEVATION			
<i>Technique</i>	<i>Frequency of Use</i>	<i>Advantages</i>	<i>Disadvantages</i>
Sodium Hydroxide (shock dosing)	Medium	Intermittent application; simple, little equipment required	Does not provide consistent control; safety considerations
Magnesium Hydroxide	Low	Maintains pH at 8 – 8.5; adds alkalinity; economical for high (>5 mg/L) sulfide levels; safe	Requires mixer to maintain slurry in suspension; cost is independent of sulfide concentration.
IV. PREVENTION			
<i>Technique</i>	<i>Frequency of Use</i>	<i>Advantages</i>	<i>Disadvantages</i>
Nirate Formulations	High	Can be used to prevent sulfide generation or oxidize sulfide in gravity sewers and force mains; safe to handle	Dosages vary depending on use; prevention vs. removal
Anthraquinones	Low	Prevents sulfide generation biochemically by disrupting sulfur cycle	Not well developed; results inconsistent and difficult to predict



An Overview of Sulfide Generation in Sewerage Systems

The economic impact of hydrogen sulfide not only involves concrete. Hydrogen sulfide is also an aggressive corrosion agent for electrical components and metal surfaces. Most wastewater facilities spend a significant amount of money to coat metal surfaces with paints designed to resist the corrosion impact of hydrogen sulfide. It is well understood that a drastic reduction in sulfides in the collections system as well as headworks of municipal wastewater plants will result in significant long-term capital expenditure savings over time.

The following is an excellent summary of sulfide generation within sewerage collection systems (Pomeroy & Parkhurst, 1976).

Production and effects

Hydrogen sulfide, H_2S , is a gas that is widespread in nature, and well known because of its odor. It can arise from the decay of some kinds of organic matter, especially albumins. An example is the white of an egg, an albumin that can release large amounts of H_2S . The odor of H_2S is most commonly described as the odor of rotten eggs.

Physical-chemical properties of hydrogen sulfide

H_2S also occurs in many ground waters. Its presence in such waters is due not so much to breakdown of organic matter as to the bacterial reduction of sulfate. By this it is meant that certain bacteria are able to split oxygen from the sulfate ion, SO_4^{2-} , a common constituent of natural waters, and use it to oxidize organic matter. The sulfur is then left in the form of the sulfide ion, S^{2-} , which immediately changes by reaction with water to a mixture of H_2S and HS^- (read H S ion).

H_2S is a gas slightly heavier than air. It condenses to a liquid only at the low temperature of $-62^\circ C$. It is fairly soluble in water. At $20^\circ C$, it can dissolve in pure water to the extent of 3850 mg/L, or 2.7 liters of H_2S gas per liter of water. The solubility decreases about 2.5 % for each degree increase of temperature. The stated solubility is the amount that will dissolve when the pure gas is brought into contact with pure water. From H_2S diluted with air, it will dissolve only in proportion to its concentration in the gas mixture. Thus, for example, air in which the concentration of H_2S is 0.1 % (1000 ppm) by volume of H_2S will, if brought to equilibrium with pure water at $20^\circ C$, produce a solution containing 3.85 mg/L. Stated differently, water containing 3.85 mg/L of H_2S can produce a concentration of 0.1 %, or 1000 ppm, in air brought into contact with it. One mg/L in solution can produce a concentration of about 260 ppm by volume in the air if the temperature is $20^\circ C$, or 330 ppm by volume if the temperature is $30^\circ C$.

When dissolved in water, hydrogen sulfide is partially ionized, so that it exists as a mixture of H_2S and HS^- . The proportions depend principally upon the pH of the solution.

In typical natural water at a temperature of $20^\circ C$, and at pH 7.0, it is just 50 % ionized; that is, half of it is present as HS^- and half as un-ionized H_2S . Temperature and mineral content of the water affect the degree of ionization, but only by a small amount. The sulfide ion, S^{2-} also exists in water, but not in appreciable amounts except in solutions in which the pH is above 12.0. The solubility data given in the previous paragraph applies only to the equilibrium between the gas and the slightly acidic (low-pH) solution produced when it dissolves in pure water or between the gas and the unionized H_2S in waters where the pH is not low.

Toxicity of H₂S

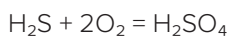
Everyone is familiar with the odor of H₂S in its natural occurrences. Because of this familiarity there has been a lack of appreciation of its toxic character, and many deaths have resulted from carelessness in dealing with it. The threshold odor concentration of H₂S is very low - between 1 and 10 mg/L. It is potentially very dangerous because its smell is quickly lost as the concentration increases. In oil refineries, tanneries, viscose plants, and many other chemical industries, men have occasionally been exposed to H₂S in concentrations that have resulted in death, and there have been many deaths in sewers on this account. Even the H₂S from swamps and from natural hot springs can be deadly. Several lives have been lost as a result of bathing in hot sulfurous spring waters in closed rooms. There is evidence that a concentration of 0.03 % (300 ppm) of H₂S in the air has caused death. It should be noted that this is the concentration that could arise from water containing 1 mg/L of unionized H₂S. Fortunately these hazards are now more widely recognized, and the frequency of fatal accidents has been greatly reduced.

Other forms of sulfide in waste waters

Up to this point the discussion has been about hydrogen sulfide and its ionized form, HS⁻. Sulfur combines with metals, too, producing compounds which are generally insoluble, such as zinc sulfide (ZnS), two copper sulfides (CuS and Cu₂S), several iron sulfides, etc. In all such combinations, as well as in H₂S and HS⁻, sulfur is in an electronegative state.

In this state it is simply called sulfide. In wastewaters of normal pH values (6.5 to 8.0), sulfide may be present partly in solution as a mixture of H₂S and HS⁻, and partly as insoluble metallic sulfides carried along as part of the suspended solids. In analyses of wastewaters, a distinction is made between dissolved sulfide and insoluble sulfide. The sum of these forms is called total sulfide. The concentrations are normally expressed in terms of the sulfur content. The amount of insoluble metallic sulfide does not ordinarily exceed 0.2 to 0.3 mg/L if the sewage is of residential origin, but the amount may be larger in sewers containing trade wastes. Sulfide in wastewaters reacts with dissolved oxygen, mostly by biological processes. Under the conditions prevailing in sewers, the principal biological oxidation product is thiosulfate. If oxidizing bacteria are abundant in the wastewater, and dissolved oxygen is also present, sulfide may be oxidized at a rate of 1 mg/L in five minutes, but in less active sewage, as for example fresh domestic sewage, the same reaction may take an hour. Sulfide can also react chemically with dissolved oxygen, that is, without the intervention of bacteria. This reaction is slow, producing a variety of products, including sulfur, thiosulfate, sulfite, sulfate, and others. The rate of reaction depends greatly on the presence of catalysts such as iron ions and the products produced are influenced by the pH value.

H₂S that escapes as a gas from solution in a sewer may be oxidized on exposed surfaces. If the surfaces are quite dry, free sulfur may be formed, but under moist conditions a species of bacteria named *Thiobacillus concretivorus* oxidizes it to sulfuric acid by the reaction:



The acid causes corrosive damage to vulnerable materials.

The process of oxidation of hydrogen sulfide is a complex series of reactions involving many members of the species *Thiobacilli*, each with its own optimum growth rate at a given pH value. Some of the *Thiobacilli* can remain active in solutions containing up to 7% of H₂SO₄ (pH about 0.2). The whole process of oxidation of hydrogen sulfide by bacteria and the factors which influence the bacterial corrosion of concrete in water are complex.

The occurrence of sulfide in sewage

Sewage contains bacteria, sulfate, and organic matter, so it has the elements required for sulfide generation. One further condition is necessary. The reduction of sulfate to sulfide can occur only under anaerobic conditions. In the absence of dissolved oxygen, nitrate can provide oxygen for bacteria and can thus prevent septic conditions developing. When all the "oxygen" provided by the nitrate anions has been consumed by the facultative anaerobic bacteria, the conditions will be strictly anaerobic. This is a state that can develop in sewage, because many kinds of bacteria are present that rapidly consume dissolved oxygen and "oxygen" from nitrate. However, if the sewer is partly filled, the water surface exposed to the air absorbs oxygen. The rate of absorption is slow, and the bacterial action may deplete it to concentrations of a few tenths of a mg/L, or sometimes only a few hundredths. Still, where any dissolved oxygen or nitrate at all is present there can be no reduction of sulfate.

A layer of slime builds up on the submerged pipe wall in a sewer, very thin where the stream is swift, but a millimeter or more in thickness where it is slow. The slime layer is the site of intense micro-biological action, and it is here that



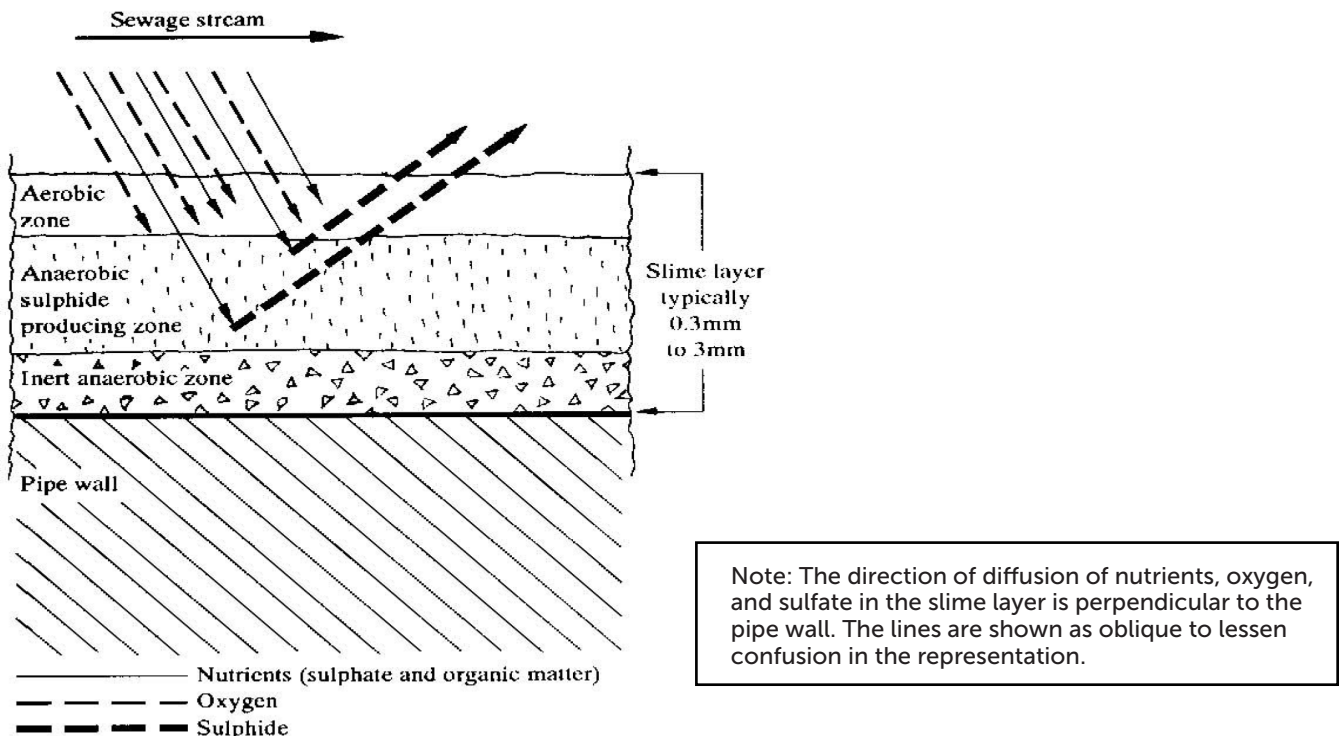
anaerobic conditions develop, and that sulfate reduction and sulfide generation can take place.

There is frequently an aerobic (oxygen containing) zone in the slime layer where it is in contact with the flowing stream. In a typical case the aerobic zone may extend into the slime layer to a depth of only 0.1 mm, but it may be deeper if the stream carries several mg/L of dissolved oxygen. Sulfate and part of the organic nutrients diffuse through the aerobic zone and into deeper layers, thus supplying the requirements of bacteria that produce sulfide, and so it comes about that sulfide generation can occur even when the stream contains dissolved oxygen, but is unlikely to occur if nitrate were present as it will diffuse into the lower layers of the slime and provide a source of oxygen to prevent septicity. The zone where sulfide is produced is generally only a few tenths of a millimeter in thickness. The sulfate or the organic nutrients are used up in that distance and unless the slime layer is quite thin, there is a deeper layer that is relatively inactive. Sulfide diffusing out of the zone where it is produced is at least in part oxidized to thiosulfate in the aerobic zone. If much oxygen is present, the sulfide will all be oxidized there, but if the oxygen condition is low, then part of the sulfide will escape from the slime layer into the stream. When this condition prevails, the sewer may show "sulfide build-up", meaning that the concentration in the stream will progressively increase as the sewage moves down the pipeline. However, oxidation occurs to some extent in the stream, and some H₂S escapes to the atmosphere, so the concentration tends to approach a steady state condition where the losses are equal to the rate that sulfide is produced.

Figure 6 shows a cross section view of the slime layer of a sewer, pictured on a magnified scale. Oxygen, organic nutrients and sulfate are seen to be diffusing into the slime layer. Oxygen and part of the organic nutrients are used up in the aerobic zone. Sulfate and the remainder of the organic nutrients are diffusing farther, reaching the anaerobic zone. The dense population of anaerobic bacteria found there, especially the species *Desulfovibrio desulfuricans*, is bringing about the reaction that produces sulfide, at a rate determined by the rate that the nutrients can diffuse into that zone. Sulfide is diffusing outward from the slime layer, part of it being oxidized in the aerobic zone and part escaping into the stream.

The concentration of oxygen necessary to prevent any sulfide build-up may vary widely, depending upon a number of conditions. The velocity of the stream is one factor. At low velocity the motion of the water is not very efficient in carrying oxygen to the slime layer, and under these conditions a higher oxygen concentration is necessary if sulfide is to be barred from the stream than when the stream is swift. In a typical case it may require 0.5 mg/L of dissolved oxygen to prevent sulfide build-up, but under some conditions as much as 1.0 mg/L, or even more, may be required.

Figure 6. Cross Section Of Slime Layer Forecasting Sulfide Build-Up



A characteristic of the generation of sulfide in sewers is its sporadic occurrence. In the early decades of this century, this seemingly random appearance of sulfide in sewers was the subject of much speculation. Now that the mechanism of sulfide build-up is better understood, the reasons are clearer. It is evident that a major determining factor is the amount of oxygen (both dissolved and available from nitrate) in the sewage stream. If the oxygen concentration is high, there will be no sulfide build-up; if it is low, then sulfide build-up is expected.

The rate of sulfide production is influenced not only by oxygen concentration, but by other factors as well. The rate increases with increase of temperature, and it depends in a complex way on the concentrations of organic nutrients and of sulfate. The rate of sulfide production can be limited by a scarcity of either sulfate or organic matter. Since both are consumed in the biological reactions that produce sulfide, they are required in a certain ratio. If there is an excess of organic nutrients, then the rate is limited by the amount of sulfate and if there is an excess of sulfate it is limited by the amount of organic nutrients.

The organic nutrients available for sulfide production in sewers have not been identified, but they must be in solution, since they must diffuse to the sulfide producing zone. It has been assumed that in typical municipal sewage the organic nutrients for sulfide generation are proportional to the biochemical oxygen demand or BOD (Davy, 1950; Pomeroy & Bowlus, 1946) or to the chemical oxygen demand or COD (Boon & Lister, 1975).

The effects of velocity on sulfide build-up are complex. At low velocity, solids may settle and move slowly and intermittently along the bottom. The loosely deposited solids quickly become depleted of oxygen, and sulfide generation proceeds until the depletion of sulfate or organic nutrients. If the solids are then disturbed by the motion of the water, sulfide is released into the stream in greater amount than would result from the process depicted in Figure 6. Higher velocities prevent this from happening, and also increase oxygen absorption into the stream, increase the rate of oxygen transfer to the slime layer, and shorten the time that the sewage spends in transit, all of which lead to lower sulfide concentrations. On the other hand, at low velocities, and especially if the sewage is intermittently stationary, as is usually the case in pressure mains from pumping stations, nutrients may become depleted in the water adjacent to the slime layer, thus retarding sulfide generation. An increase of velocity in a completely filled pipe will, up to a point, increase sulfide generation.

In the light of present knowledge, an equation could be written that would express the rate of sulfide build-up as a function of the various factors that influence generation by the slime layer and the losses by oxidation and escape to the air. Such an equation would not be very useful, because of the difficulty of securing the input information that would be required. Most important would be the dissolved oxygen concentration. An accurate prediction of dissolved oxygen would require a detailed history of the sewage for an hour or so upstream from a point where a prediction of sulfide build-up would be attempted. Absorption of oxygen at the surface of the stream can be predicted if slope, pipe size and flow quantity are known, but extra oxygen will be added at junctions, drops, and other points of turbulence, and it is difficult to predict the rate at which oxygen will be consumed.

The only practical approach to the problem of predictions is to limit such attempts to the restricted case that the unpredictable factors are favorable for build-up. That is to say, it will be assumed that sufficient sulfate is present so that it is not limiting, that oxygen concentration is low, that no nitrate is present either derived from the water supply or from industrial discharges, and that there is no toxic condition or other factor that inhibits the action of the slime layer.

The earliest attempts to predict sulfide build-up were limited to yes-or-no answers; there would or would not be build-up (Davy, 1950; Pomeroy & Bowlus, 1946). It was recognized, however, that quantitative forecasts might be possible for the restricted case of sewage in pressure mains and other completely filled pipes, where it is denied any contact with air. Sewage pumped into a pressure main often contains dissolved oxygen which may result from its fall into the wet well or from other causes, and on this account there may be no sulfide build-up initially, but after a time the dissolved oxygen and nitrate "oxygen" will be completely depleted and then the maximum sulfide producing capability of the slime layer will be displayed.

When the sewage becomes completely anaerobic, generation occurs not only at the pipe wall but also in the stream. The amount produced in the stream, however, is small in comparison with the output by the slime layer except in very large pipes.

In a small pipe of, say, 100 mm diameter, troublesome sulfide concentrations may arise even where the retention time of the sewage in the main is as little as ten minutes. In larger mains the build-up rate is slower, but significant amounts are likely to be produced within 20 to 30 minutes in a pipe of one meter diameter.

Description of Melbourne, Florida Sewerage Collection System at Test Site

The control point selected for the study was Lift Station 23 (LS 23). This particular station is responsible for moving approximately 50% of the wastewater entering the receiving wastewater plant from the north side of Melbourne. Two other major lift stations (LS 6 and 15) are responsible for moving the remaining 50% directly to the receiving plant.

Three major lines feed LS 23. The most flow comes from the line from LS 55 and 65. Flow from these two stations combine at LS 55 and proceed under pressure for 2 miles to LS 23. The combined flow from these two stations accounts for approximately 75 to 80% of the total flow to LS 23. Two smaller stations directly feed LS 23 that account for the balance of flow to the station. LS 4 accounts for approximately 14% of the remaining flow and LS 7 for the remaining approximately 9%. LS 4 and 7 combine just prior to entering LS 23. Both of these lift stations are under pressure for about half of the distance from the stations on the way to LS 23 before finishing the trip under gravity flow.

Retention times within the collection systems from LS 4, 7 and 55 were tested using fluoracene dye. During peak flow conditions retention times were between 2 and 3 hours for LS 4 and 7. Travel time for flow from LS 55 was just under one hour during peak flows.

Flow through LS 23 will typically vary between 1.5 and 2.0 MGD. In general, the flow patterns can be broken down into three patterns as measured by lift station pump cycle frequency. Peak flows occur between the hours of 7 and 11 AM and again from 6 to 10 PM. Moderate flows occur between 10 AM and 6 PM and again between 10 PM and 12 AM. Low flows, as would be expected, occur between the hours of 12 AM and 7 AM.

Baseline Sulfide Data Prior to Start of Treatments

Base line Odallogger data was collected for LS 23 over several days. The following Odallogger data typifies hydrogen sulfide levels within LS 23 prior to treatment.

Figure 7: Sulfide Concentration at LS 23 Prior To Treatment (1st Sample)

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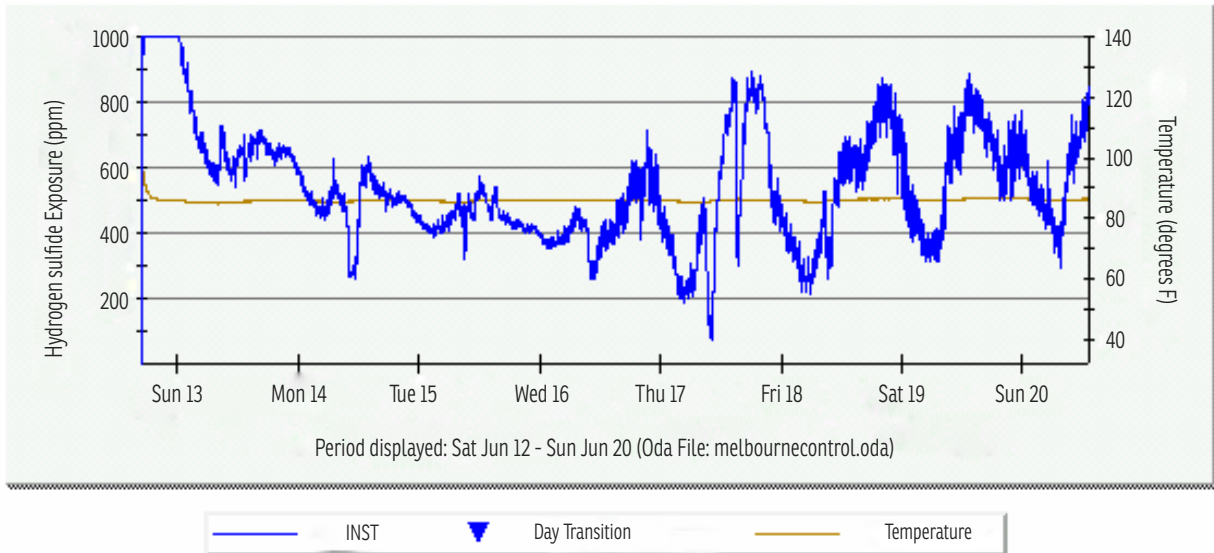
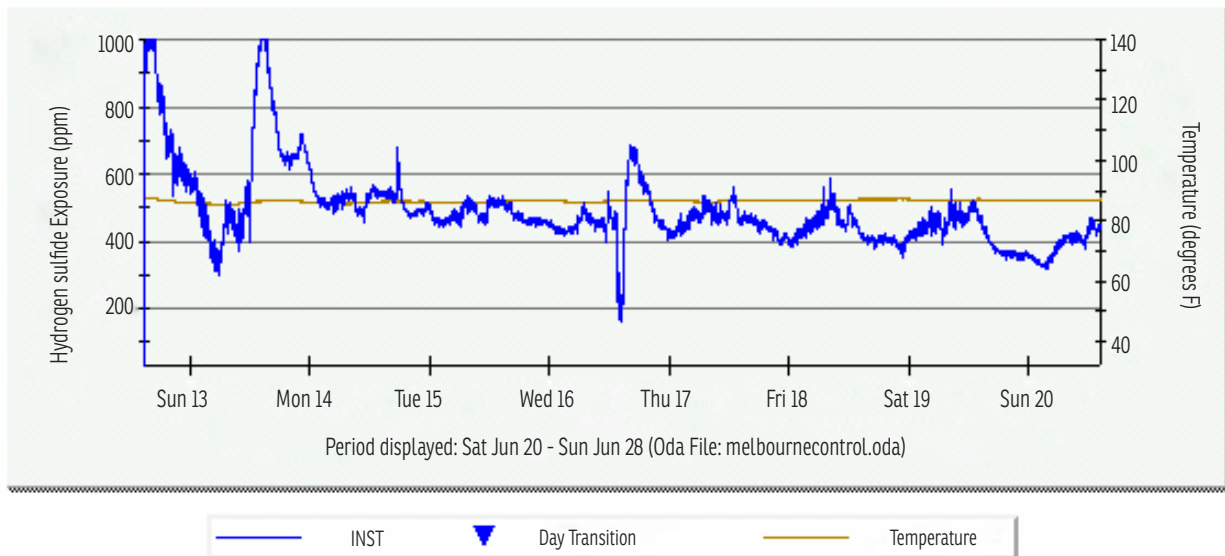


Figure 8: Sulfide Concentration at LS 23 Prior To Treatment (2nd Sample)

Session: 1 (OdaLog: OL45054054)



It is apparent from these data that hydrogen sulfide levels in that air vary regularly between 500 ppm and 1000 ppm. Melbourne officials stated that the system suffers from some inflow infiltration throughout the collection system. Heavy rains were prevalent in the area during periods of lower sulfide values. It would seem logical to correlate the rain events with lower sulfides but more extensive study would need to be done.

While odor issues are a major concern, levels of hydrogen sulfide within the air at the levels indicated above will result in substantial loss of infrastructure over time. Loss of concrete and metal parts coming into contact with these levels of hydrogen sulfide will be significant. Additionally, electrical contacts in the vicinity of hydrogen sulfide at these levels will suffer severe corrosion.

In addition to the efforts to establish baseline information for hydrogen sulfide within the air at LS 23, a substantial effort was given to understanding the variance of total sulfide within the wastewater column. Regular samples were taken over 24 hour periods for sulfides. The following table and figures display the results of this effort with the tabulized data noting results of discrete sampling events and the graph depicting the results of 24 hour sampling events.

Figure 9. LF 23 Water-borne Total Untreated 24-Hour Sulfides For 6/27/04

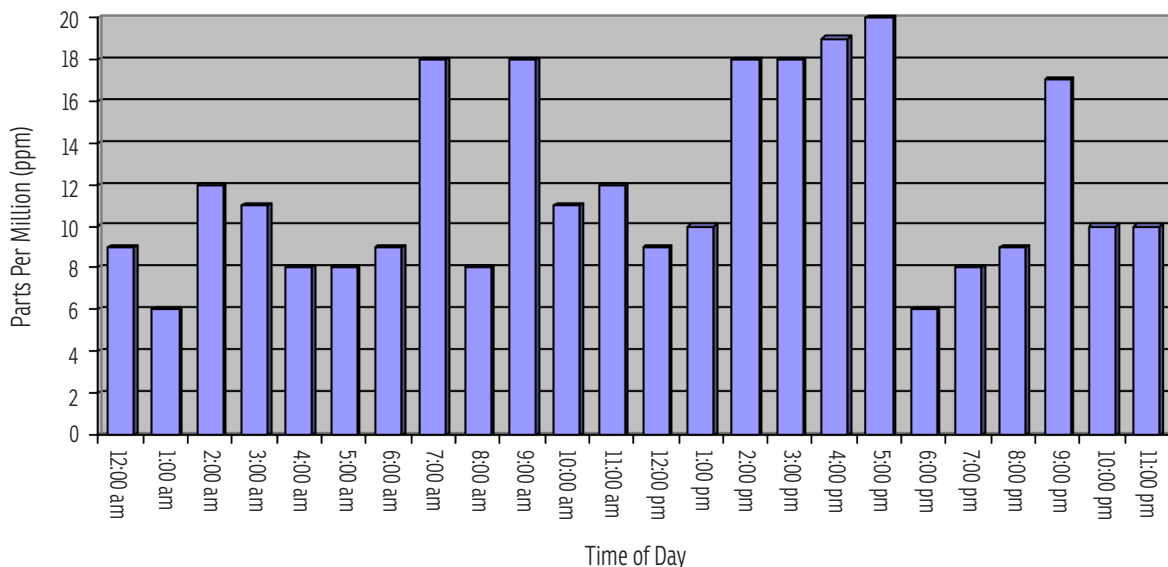
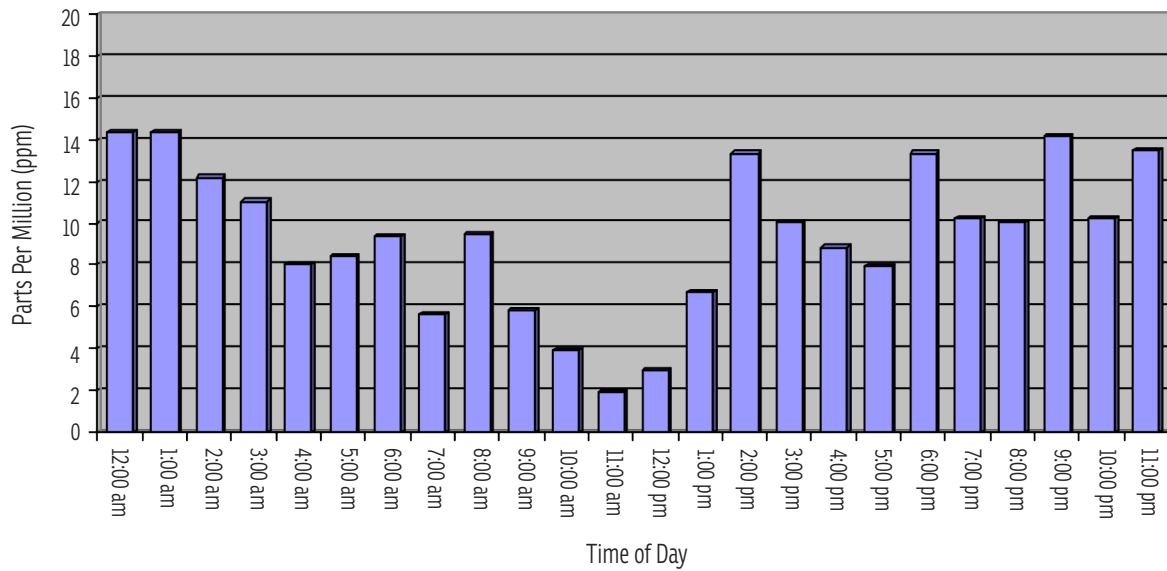


Figure 10. LF 23 Water-borne Total Untreated 24-Hour Sulfides For 6/29/04



Ultra-S3 Dosage Assessment

Initial trials using Ultra-S3 were conducted to establish the upper level of treatment necessary to treat sulfides entering LS 23 to an acceptable level. The target for “acceptable” was assumed to be 1 ppm total sulfide within the water column. After the upper level of treatment was established, work was done to determine treatment dosages for treating sulfides during periods of lower flow. The long term approach for treatment of the system would include a computer controlled system capable of adjusting injection rates from higher levels to lower levels over the course of the day as required to get the job done. This strategy will result in significant savings in chemical costs over time.

Three injection points were established within the collection system at LS 4 and LS 7 and LS 55, respectively. Since it was reported that LS 55 would be an eventual control point for sulfides it was determined that treatment be conducted from this location. Treatment was conducted from LS 4 and LS 7 instead of from LS 23 in order to save cost for the trial. Treatment of the line entering LS 23 from these two locations would have required running injection lines from LS 23 upstream to a point that assured enough contact time for treatment. It was much cheaper to simply treat the two stations. Long-term treatment of these two stations effluent would be done from LS 23.

Several studies were conducted to determine a range of acceptable dosages for treatment of total sulfides at variable times of the day. Again, the objective was to determine a dosage schedule that would allow a system to ramp up or down during a day’s treatment to adequately treat the sulfides without overdosing and wasting chemical. Calculations for anticipated dosage through the day were made from baseline sulfide information and flow through the system. Tests were conducted based on this information at 1.8, 2.2, 2.5 and 2.8 gallons of treatment chemistry per hour. Results were monitored with a combination of hourly grab samples using an ISCO sampler for water-borne sulfides and an Odallogger for hydrogen sulfide within the air.

The following figures depict the findings of the dosage assessment.

Figure 11. LS 23 Water-borne Total Sulfide For Ultra-S3 Treatment at 2.5 Gallons Per Hour
Date: 7/1/2004

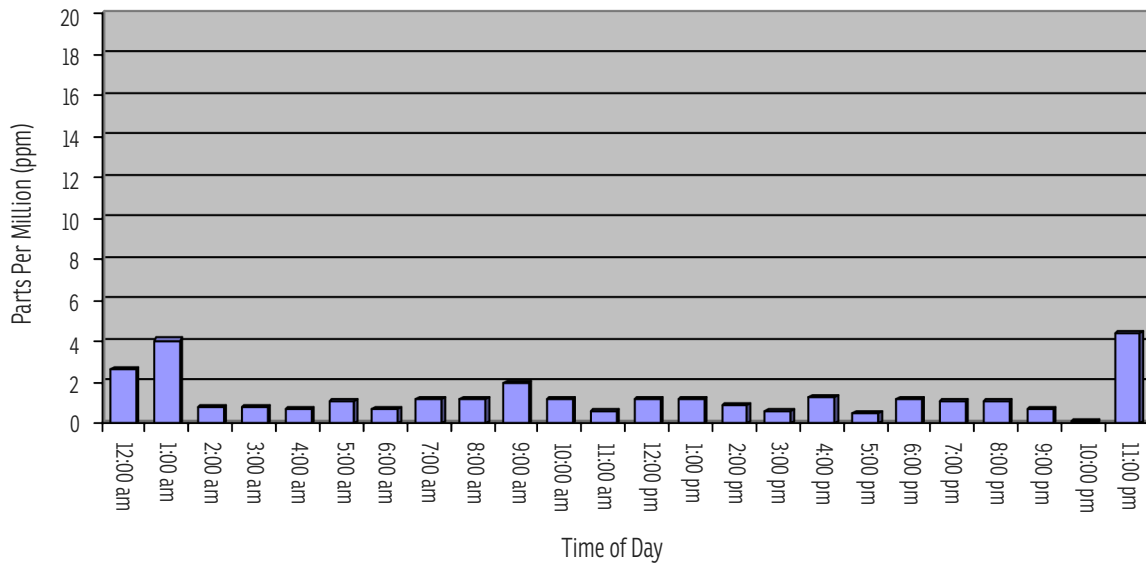


Figure 12. LS 23 Water-borne Total Sulfide For Ultra-S3 Treatment at 2.1 Gallons Per Hour
Date: 7/4/2004

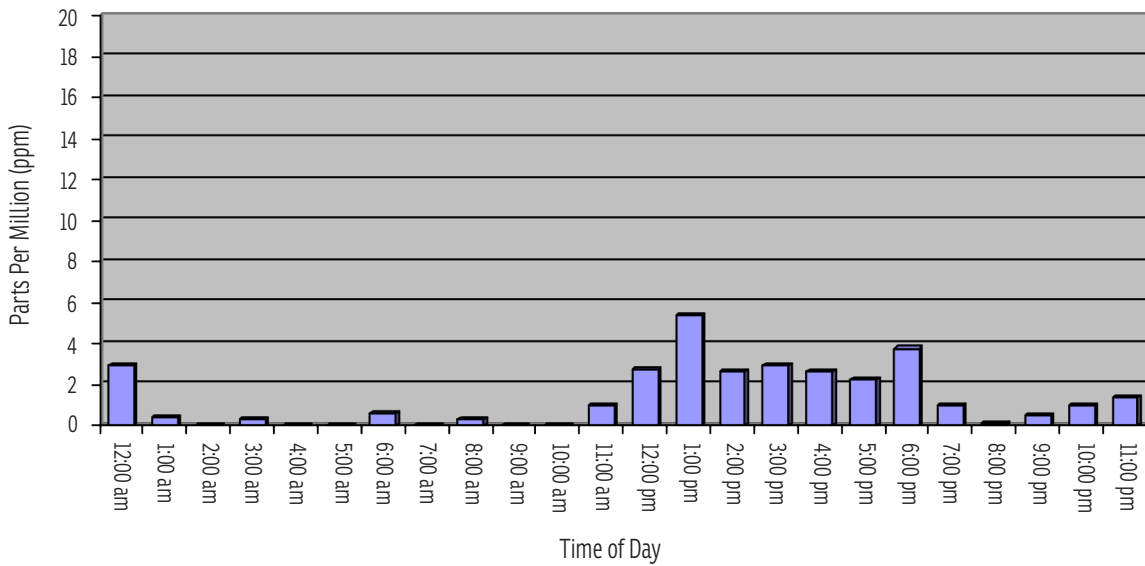


Figure 13. LS 23 Water-borne Total Sulfide For Ultra-S3 Treatment at 2.8 Gallons Per Hour
Date: 7/7/2004

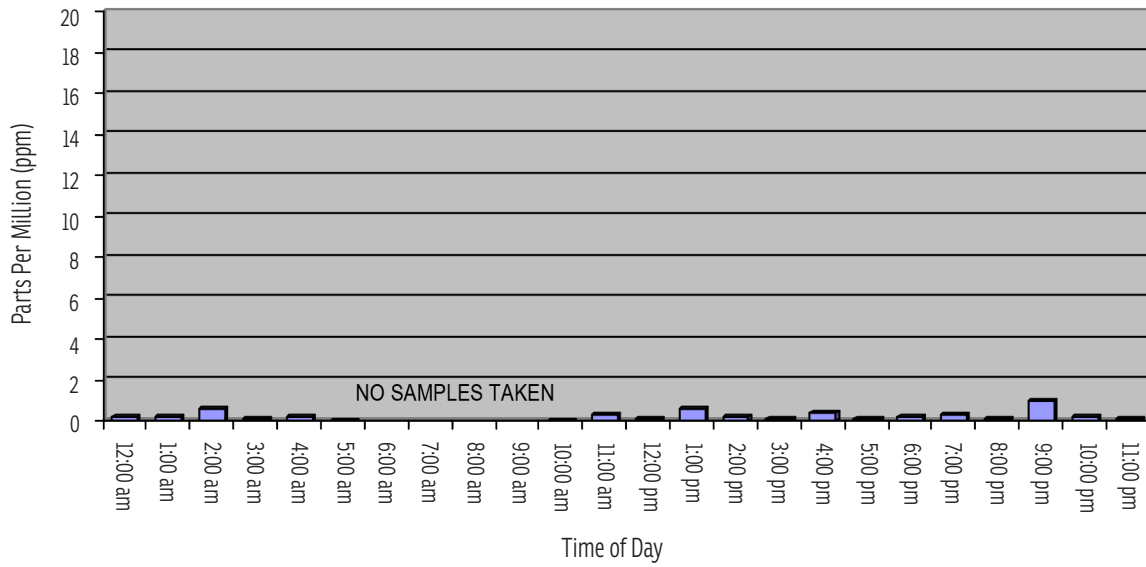
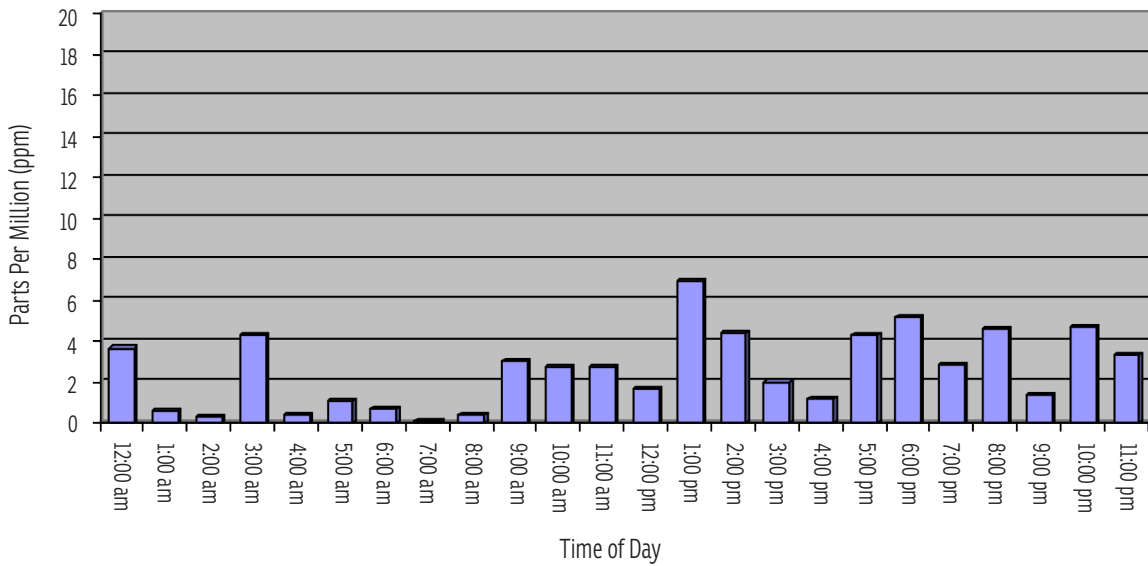


Figure 14. LS 23 Water-borne Total Sulfide For Ultra-S3 Treatment at 1.8 Gallons Per Hour
Date: 7/8/2004



Assessment of the treated data indicated that a reasonable test dosing schedule for the LS 23 system would be as follows:

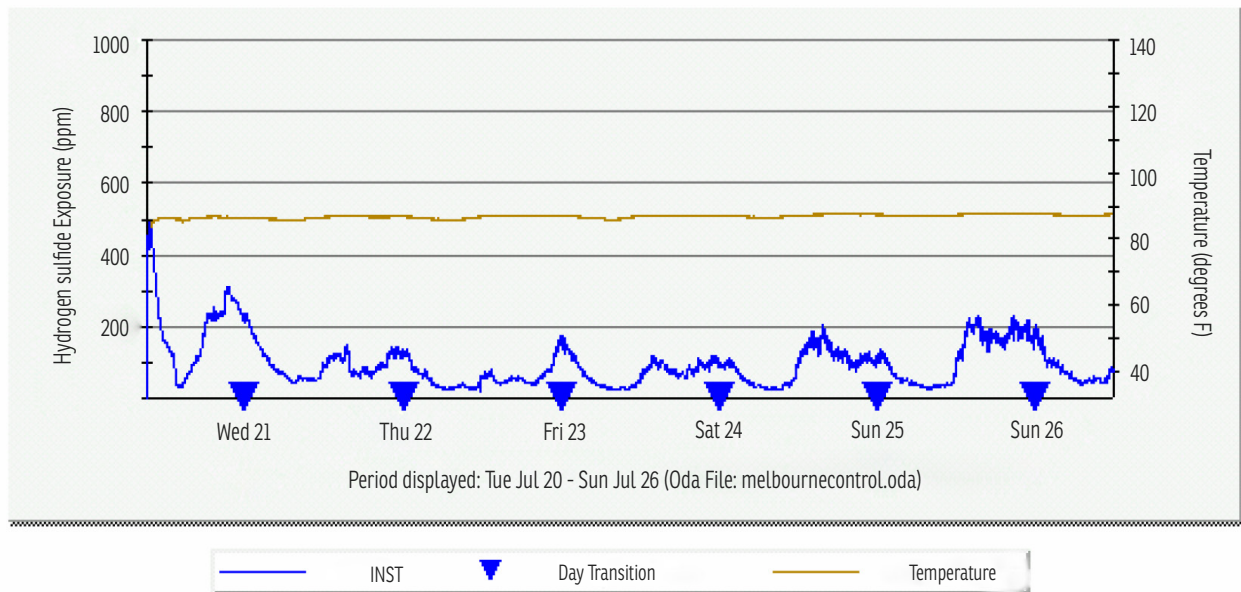
Table 4: Test Dosing Schedule For LS 23 Trial

Time Range	Gallons/Hour	Total Gallons
12 AM - 6 AM	1.8	10.8
6 AM - 10 AM	2.5	10.0
11 AM - 7 PM	2.8	22.4
7 PM - 12 AM	2.5	12.5
		Estimated Daily Total: 55.7

Confirmation Test

The final days of the pilot testing were dedicated to confirmation of the above assessments. Daily observations were made as to the efficiency of the system at the prescribed dosages. Manual adjustments were made to the system as necessary. The following OdaLogger graph depicts the hydrogen sulfide within the air during the adjustment period. The results of field adjustments during this period forced the amount of Ultra-S3/peroxide used upwards slightly from estimates.

Figure 15: Sulfide Concentration At LS 23 With Ultra-S3 Treatment
Session: 1 (OdaLog: OL45054054)



Final dosage ranges resulted in the following Odalogger graph. Hourly water samples were taken during this period over 24 hours for total sulfides within the water. These data are presented in Figure 17 below.

Figure 16: Sulfide Concentration At LS 23 With Ultra-S3 Treatment

Session: 1 (OdaLog: OL45054054)

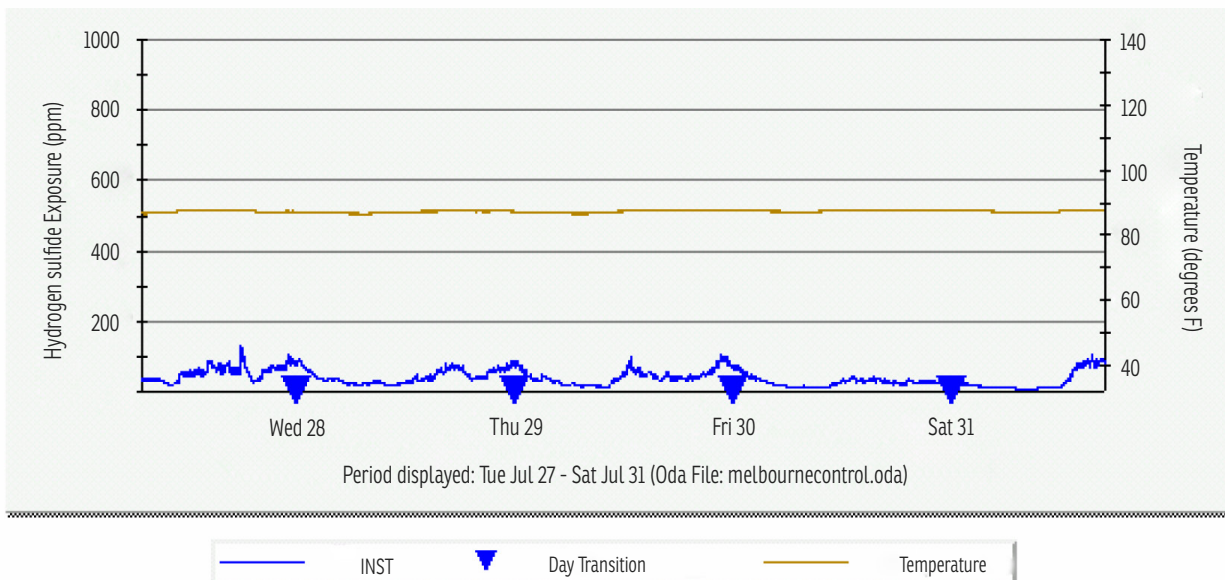
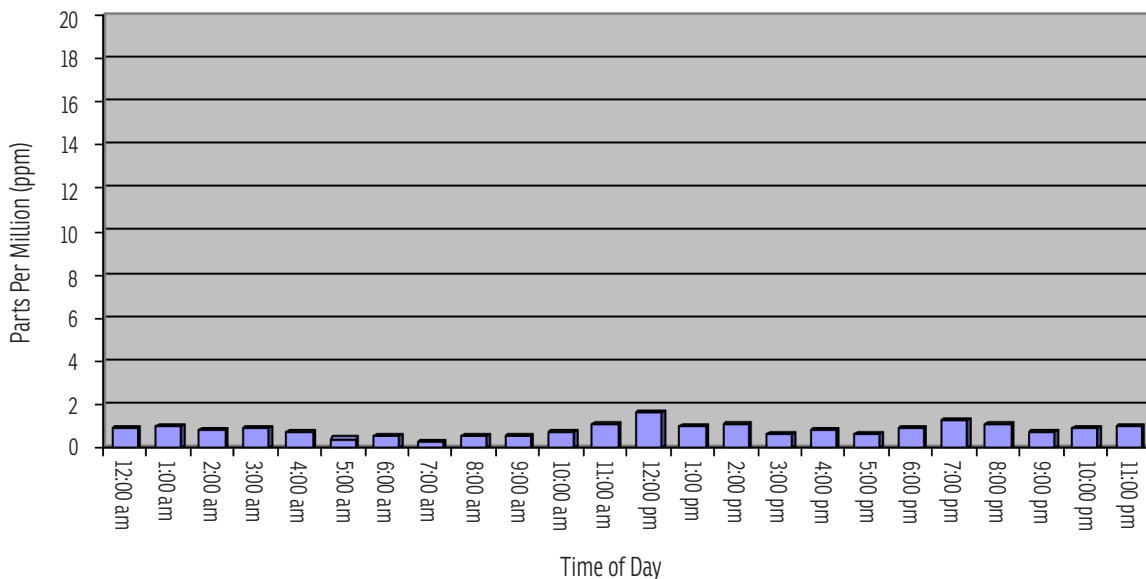


Figure 17. LS 23 Water-borne Total Sulfide For Ultra-S3 Treatment at Variable Rates

Date: 7/28/2004 - 7/29/2004



The total dosage of Ultra-S3/peroxide over a 24-hour period will approximate 60 to 65 gallons per day (GPD) at LS 23 based on the findings of this study.

Since LS 23 represents slightly over 50% of the total flow into the receiving wastewater plant in north Melbourne, it may be logical to assume that a similar total dosage (i.e. 60 GPD) will suffice for daily treatment of flow into the other two major lift stations (i.e. LS 6 and LS 15) targeted for treatment. This, of course, assumes that the total sulfide generation within the other two locations are similar to LS 23. Therefore, a reasonable estimate of total Ultra-S3/peroxide to treat all three lift stations would be about 120 GPD.

Treatment using the Ultra-S3 process would be conducted from each of the current lift station locations by running conduit protected injection lines upstream of each line entering the target lift station. An objective of at least three minutes of in-line contact time would be targeted for each stream prior to entering the lift station.

Conclusions

The following conclusions are noted for the study:

1. LS 23 can be treated using approximately 60 GPD of Ultra-S3 treatment chemicals.
2. Ultra-S3 treatment at LS 23 can meet goals set by Melbourne for treatment efficiency.
3. No grease build-up was noted during the treatment.
4. Given similar sulfide levels at LS 6 and LS 15, approximately 120 GPD will be needed to treat all three stations.
5. Treatment of sulfides entering each station can be accomplished from the lift station grounds.
6. It is probable that lower dosages can be used during colder months.

Recommendations

While the objective of the treatments into the various lift stations within the Melbourne system is to reduce odor, it should be pointed out that Melbourne is undoubtedly experiencing significant infrastructure decay due to sulfide related corrosion. The corrosion brought on by sulfides is destroying concrete and metal throughout the system, including the wastewater treatment plant. A professional analysis of the costs associated with sulfide related corrosion at Melbourne will result in an understanding that significant amounts of money is being lost yearly to infrastructure decay, especially at the receiving wastewater plant. Such a study would justify a more aggressive approach for treating sulfides than plans call for at present.

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