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Reducing Hydrogen Sulfide (H₂S) Concentrations at Wastewater Collection Systems and Treatment Facilities Using Chemical Oxidation

Dornelle S. Thomas



THE FLORIDA STATE UNIVERSITY
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**REDUCING HYDROGEN SULFIDE (H₂S) CONCENTRATIONS AT WASTEWATER
COLLECTION SYSTEMS AND TREATMENT FACILITIES USING CHEMICAL
OXIDATION**

By
DORNELLE S. THOMAS

A Thesis submitted to the
Department of Civil and Environmental Engineering
in partial fulfillment of the
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Dedicated to my mother, Ms. Lelia Daniel

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ABSTRACT

Wastewater collection systems and treatment facilities are known for emitting offensive odors that cause neighboring residents to complain. One of the main odor compound contributors is hydrogen sulfide (H_2S). Presently, H_2S removal from wastewater facilities is mainly being accomplished by biological means relying heavily on the use of microorganisms. However, the use of microorganisms requires a more consistent and stable environment. In the absence of the previously stated conditions, the removal of H_2S has to be carried out by other means. Therefore, an alternative for wastewaters with unstable characteristics requiring minimal maintenance/human involvement is preferred to deal with H_2S emissions.

This study investigated the effectiveness of chemical oxidation by employing three oxidants, 50% hydrogen peroxide (H_2O_2), 12% sodium hypochlorite (NaOCl), and 5% potassium permanganate (KMnO_4) at mitigating H_2S aqueous and gas concentrations at wastewater collection systems and treatment facilities. The chemicals were supplied to the systems throughout four distinct testing phases using peristaltic pumps. $\text{H}_2\text{S}_{(\text{g})}$ levels were obtained using a Jerome Meter (860 model) while the dissolved sulfide concentrations were measured using a LaMotte Sulfide Test Kit.

This study found that of the three chemicals chosen, H_2O_2 is most effective and efficient at removing H_2S from wastewater collection and treatment facilities. However, throughout this study, $\text{H}_2\text{S}_{(\text{g})}$ removal efficiencies were affected by the physical conditions at the testing facilities. Therefore, after taking the corrective action needed to improve facility conditions, further investigation is required to appropriately evaluate the use of H_2O_2 at odor mitigation.

1 INTRODUCTION

Offensive odors emanating from wastewater collection and treatment systems have been a major concern for its neighboring environments and/or residents in contact with the system causing them to complain. Odors at wastewater treatment facilities and wastewater collection systems are generated when the wastewater turns septic due to the anaerobic decomposition of organic compounds. This may also occur through the decomposition of nitrogen compounds, such as proteins, releasing ammonia and other nitrogen-based odorants [10]. Although there are various contributors to the odor generated at collection systems and treatment facilities, this study focused on investigating and mitigating the odor produced by hydrogen sulfide (H_2S).

Hydrogen sulfide (H_2S) is produced during the reduction of sulfate by sulfate reducing bacteria under anaerobic conditions [4]. It has a foul, rotten egg odor [1] that can be detected by the human nose at concentrations as low as 4.7×10^{-4} ppm [7]. Exposure to low concentrations of H_2S for only a short period of time has the ability to dull an individual's sense of smell. Also, at very low concentrations, H_2S irritates the human eyes and respiratory tract. However, at very high concentrations (500-1000 ppm), H_2S can be fatal [8]. Due to its adverse health effects, it is very important to adequately control H_2S for public health and safety while protecting the environment.

This study compared the effectiveness of three selected chemicals in reducing H_2S concentrations at two wastewater collection systems and one wastewater treatment plant. These three chemicals were employed to specifically oxidize the H_2S within the water, thereby reducing emission levels at the facilities. The oxidants chosen were sodium hypochlorite ($NaOCl$), hydrogen peroxide (H_2O_2) and potassium permanganate ($KMnO_4$). Individually, each chemical was pumped directly into the systems and evaluated based on H_2S aqueous and gas concentrations and through the monitoring of other important parameters such as pH, temperature, and oxidation-reduction potential (ORP) readings thereafter. Each oxidant reacted differently with the constituents of the wastewater and created different end products and/or results.

This study was conducted in St. Thomas, United States Virgin Islands at the following facilities: Long Bay Lift Station; Cancryn Lift Station; and Airport Lagoon Treatment Plant. Testing for this study was performed in four phases beginning in July 2004 until March of 2007. Phases I, II and IV were conducted in the field and Phase III was conducted in the laboratory.

This thesis is a synopsis of the significance of treatment on the air and wastewater quality at the previously stated facilities in an effort to mitigate odor emissions. First, a brief introduction to wastewater collection and treatment systems is presented (Chapter 2). This chapter also includes a description of H_2S and previous research technologies employed for its removal. Thereafter, the testing procedures used throughout the scope of this study are described (Chapter 3). In Chapter 4, the data retrieved following testing was presented and discussed. Also included are the conclusions that were made based on the investigative results, limitations encountered during the study, and a few recommendations for future improvements (Chapter 5).

2 BACKGROUND AND MOTIVATION

2.1 Wastewater Collection Systems

Wastewater collection systems transport water from domestic, industrial and commercial facilities to wastewater treatment plants where it is treated. Collection systems include but are not limited to force mains, gravity sewers, manholes, pumping equipment and other facilities that collect and transport the water to wastewater treatment plants. Force mains rely on pressure to transport the wastewater from the discharge side of a pump to a point of gravity flow downstream until it reaches the treatment plant. In contrast, gravity sewers neglect the use of pumps and the wastewater relies on gravity utilizing the slope between the system and the plant. In addition to transporting the wastewater to a treatment plant, these facilities give access to the wastewater if the need arise. Consequently, collection systems also have the ability to affect the efficiency of a wastewater treatment plant. Factors that may contribute to such inefficiency include, extended wastewater transport time, extensive stagnant periods in the collection system and/or pipes and increasing wastewater temperatures. Therefore, it is imperative that these facilities be properly maintained and managed to sustain the quality of the wastewater as it is being transported to the treatment plant.

2.2 Wastewater Treatment Plants

Wastewater treatment plants are engineered facilities designed to incorporate a series of operations and/or processes to effectively handle and treat wastewater (domestic, commercial, and/or industrial). The desired treatment operations and/or processes included in a wastewater treatment plant are highly dependent on the quality of the raw wastewater and the quality of treatment needed for the desired effluent. The goal of the wastewater treatment plant is to remove the waste from the wastewater while protecting the neighboring environment, public health and receiving water bodies. In order to achieve this goal, wastewater treatment plants are generally designed to include physical, biological and/or chemical treatment methods to remove the waste. These methods are all integrated to satisfy primary, secondary and/or tertiary (advanced) treatment of the wastewater. In doing so, first the solids and debris that will float, settle, or are too large to pass through the screening operation are removed from the wastewater.

Then, the dissolved biodegradable organic matter is to be converted by bacteria and then stabilized where it can then be reused or disposed of. The latter aspect of the treatment facility is to disinfect the treated water prior to disposal. In a typical wastewater treatment plant, the primary stage of treatment removes about 60 percent of the suspended solids and 35 percent of the biochemical oxygen demand (BOD) [16], the oxygen needed by the microorganisms for the decomposition of organic matter. However, due to the high organic loading at wastewater treatment plants greater emphasis is placed on the removal of its organic wastes.

The Clean Water Act (CWA) requires at the very least, secondary treatment for all treatment facilities by insisting that they provide at least 85 percent BOD removal. Generally, either physical-chemical treatment or biological treatment is employed to remove the dissolved organic matter. The significant difference between the two techniques is in the quantity of sludge produced. Throughout physical-chemical treatment, a larger volume of sludge is generated due to the addition of coagulation agents. This increase in sludge in the absence of the oxidation of organics provided by biological treatment decreases the treatment quality. Secondary treatment, in addition to the physical treatment processes of primary treatment, involves the microbial oxidation of wastes. Therefore, biological treatment is most often used at wastewater treatment plants to biodegrade the organic wastes by accelerating the natural decaying process and neutralizing the wastes prior to disposal.

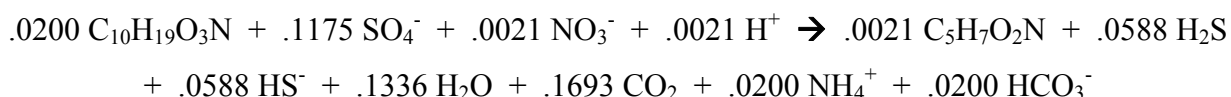
2.3 Biodegradation

Biodegradation is the microbial mediated process of breaking down the organic matter into simple or sometimes more toxic compounds by microorganisms. This procedure is accomplished by a process known as metabolism. First, a portion of the wastes is oxidized to end products which are used to provide the energy needed for cell maintenance and the synthesis of a new cell [7]. At the same time, some of the waste is converted into new cell as a result of the exchange of energy during oxidation. When all the organic matter is exhausted the new cell begins to consume its own tissue to obtain the energy needed for cell maintenance [7]. Typically, this decomposition can be performed under two distinct phases.

If oxygen is available to the system, this phase is referred to as aerobic decomposition. Oxygen supply is vital to biological treatment processes and the energy requirements of the organisms. The presence of oxygen produces stable end products such as carbon dioxide (CO₂), sulfate (SO₄), nitrate (NO₃) orthophosphate (PO₄) [16] and new biomass. However, when there is an insufficient amount of oxygen available or all has been exhausted, this results in another phase known as anaerobic decomposition.

2.4 Anaerobic Decomposition

Anaerobic decomposition (in the absence of oxygen) occurs at a much slower rate than aerobic decomposition and is carried out by anaerobic microbes. The anaerobic decomposition of solids, or the decomposition of nitrogen compounds, such as proteins [10], produces unstable noxious and toxic byproducts. Another contributor to such end products is the decomposition of sulfates to sulfides by sulfate reducing bacteria. During such decomposition, odorous end products including compounds such as ammonia (NH₃), methane (CH₄), and hydrogen sulfide (H₂S) are produced. Of the three, the most predominant odor compound at wastewater collection systems is hydrogen sulfide (H₂S) which can be transferred to and released at the headworks of wastewater treatment plants. An overall reaction for net synthesis of bacteria using sulfate as an electron acceptor and nitrate as a nitrogen source in domestic wastewater is represented by:



This conversion utilizes 6% of the electron equivalents in domestic wastewater for synthesis while the other 94% is used for energy. Thus, sulfate reduction of one equivalent of organic matter produces .0588 moles of H₂S.

2.5 Hydrogen Sulfide (H₂S)

H₂S is an extremely toxic and irritating gas. This inorganic sulfide is colorless, flammable, corrosive and soluble. Its high solubility is due to its ability to readily react with water and form

sulfide ions, (HS^- and S^{2-}). The odor characteristics associated with H_2S is that of a “rotten egg”. This scent can be detected at concentrations as low as 4.7×10^{-4} ppm [7]. H_2S is presented rather quickly at very low concentrations. However, it has the ability to dull the sense of smell. The inability to no longer present itself may cause one to become overexposed to the gas. Exposure to H_2S for long periods of time at low concentrations can cause eye and respiratory irritation, in addition to also having the ability to be lethal at high concentrations. H_2S is regulated by the Occupational Safety and Health Administration (OSHA) and has a permissible exposure limit of 20ppm ceiling limit concentration for no longer than 10 minutes. Hazardous H_2S concentration levels are detailed in Table 2.1.

Table 2.1 Hazardous Concentration Levels for Sulfides [8]

Concentration (ppm)	Effect
Nil	Normal Concentration of H_2S in air
5	Moderate odor, readily detectable
10	Eye irritation begins
30	Strong, unpleasant odor of rotten eggs
100	Coughing, loss of smell in 2 -16 minutes
200 – 300	Red eyes, rapid loss of smell, breathing irritation
300 – 700	Unconsciousness and possibly death in 30 – 60 minutes
700 – 1000	Rapid unconsciousness, death in a few minutes
1000 – 2000	Instant unconsciousness, death in a few minutes
4300	Lower explosive limit

With the adverse health effects associated with H_2S , along with its ability to damage facility equipment, its removal is of high priority. Therefore, it was necessary to investigate appropriate techniques and/or technologies for removing H_2S at given wastewater facilities previously studied.

2.6 Literature Review

For many years, various studies have been conducted at wastewater treatment systems on H₂S oxidation processes. However, majority of the research projects reviewed utilized biological treatment processes in order to deplete H₂S at wastewater facilities. Biological treatment has gained support as an effective and economical option for H₂S removal. In recent years, the mitigation of H₂S emissions by the use of bioreactors, biofilters or bioscrubbers have shown proven ability on sulfide oxidation. Some of the studies have been conducted by Ma et al. [14]; Barbosa et al. [2]; Easter et al [10]; Potivichayanon et al. [20]; Morgan-Sagastume and Noyola [18]; Duan et al. [9]; and Nishimura and Yoda [19]. Researchers have reported H₂S removal rates to be typically high, exceeding 98% [10].

In biological treatment, sulfide oxidation involves the use of chemolithotrophic organisms that obtain energy from the oxidation of sulfides into elemental sulfur or sulfate. The performance of chemolithotrophic bacteria and its ability to oxidize H₂S is affected by certain conditions within the systems. Such conditions include the availability of oxygen and sulfides, temperature and the chemolithotrophic bacteria chosen.

When optimal conditions are available, the use of biological treatment has been successful and economical at oxidizing H₂S. However, its use requires high maintenance and control environments. In the event that a controlled environment cannot be obtained, other emergent techniques for sulfide oxidation should be considered and researched. One such technique utilized for the oxidation of sulfides is chemical oxidation. Although some researchers have neglected the use of chemical treatment processes in H₂S oxidation due to high operating costs, others have found its use beneficial. The following studies investigated the use of chemical treatment with other technologies at sulfide oxidation.

Ksibi [12] found that chemical oxidation using H₂O₂ as an oxidant integrated with aerobic biological treatment effectively controls the organic matter, offensive odor and foaming in domestic wastewater. The research used iron (Fe²⁺) in the form of iron sulfate (FeSO₄), 7H₂O, and 30% H₂O₂ pure stabilized solution in Fenton's reaction. Based on the results, Fe²⁺ had no affect on treatment efficiency (odor control, oxidizing or degrading the organic matter). In

contrast, H_2O_2 gave an 85% chemical oxygen demand (COD) reduction and a BOD_5/COD ratio increase when H_2O_2 concentrations are adjusted relative to COD loads. In addition, H_2O_2 provided an efficient treatment process for disinfection of the domestic wastewater.

Couvert et al. [6] examined the efficiency of chemical scrubbing using H_2O_2 in the presence of poly- α -hydroxyacrylic acid (stabilizer used to slow down the decomposition of H_2O_2) in a small laboratory plant. This research studied the removal of H_2S and methylmercaptan (CH_3SH), two of the main odor sources surrounding wastewater treatment plants. The researchers designed a pilot unit consisting of a scrubbing column, a liquid circulation loop and an automatic regulation system of pH and H_2O_2 concentration. This methodology maintained a pH of 9.5 – 12 by the addition of 33% sodium hydroxide (NaOH) and utilized 35% H_2O_2 in an effort to oxidize the pollutants. This study finds that implementing H_2O_2 displayed great results for the removal of H_2S and encouraging ones for CH_3SH . In addition, the use of poly- α -hydroxyacrylic acid has contributed significantly to the reduction of H_2O_2 decomposition.

Charron et al. [5] investigated the use of H_2O_2 as a replacement for sodium hypochlorite (NaOCl) in a chemical scrubbing tower for the purpose of removing H_2S and CH_3SH and to avoid the formation of harmful chlorinated end-products. Due to the high decomposition of H_2O_2 in basic aqueous solutions, during basic oxidant scrubbing, the study first aimed at stabilizing the H_2O_2 scrubbing solution. Sodium silicate (Na_2SiO_3) was chosen for its tested ability at reducing H_2O_2 decomposition without inhibiting its reactivity. This study was conducted on a pilot unit ($3000 \text{ m}^3/\text{h}$) in a wastewater treatment plant and utilized a scrubbing column, a liquid circulation loop and an automatic regulation system of pH and H_2O_2 concentration. In order to maintain pH and H_2O_2 concentrations, 35% H_2O_2 and 33% NaOH were added to the scrubbing solution. Additional experiments were conducted in order to compare the performance of H_2O_2 and NaOCl . Those experiments revealed that NaOCl was more efficient at removing CH_3SH than H_2O_2 . This can be explained by the mass transfer acceleration provided by NaOCl oxidation. On the other hand, there was no mass transfer acceleration due to oxidation with the use of H_2O_2 because it only reacts with the dissociated form of the pollutants. This study concludes that regardless of the packing and the scrubbing pH used throughout the experiments, H_2O_2 is efficient at removing H_2S (>90% removal). However,

in order to achieve such results for the removal of CH_3SH , it was necessary to work with a pH greater than 10. In addition the reduction of H_2O_2 decomposition was successful with the addition of Na_2SiO_3 .

2.7 Research Motivation

Wastewater collection and treatment systems are a major source of odor emissions. The anaerobic decomposition of the wastewater generates sulfur compounds and nitrogen compounds, amongst others, creating the offensive odor surrounding these facilities. Of the odor emissions, H_2S is the most dominating and readily detected. As previously mentioned, H_2S is a toxic, irritable, and flammable gas that causes health effects at exposure to low concentrations while also having the ability to be fatal at higher concentrations. In an effort to remove H_2S from wastewater collection and treatment systems, researchers have examined the use of biological and chemical treatment methods. Although biological treatment processes are inexpensive and creates no environmental pollution, they are very sensitive to temperature and pH ranges and is therefore unreliable. The slightest change within the composition would affect the effectiveness of the treatment. Whereas, chemical treatment processes have higher operating costs, they are more stable making them more consistent. As a result, chemical treatment was considered for investigation while also being the desired treatment method for the operators. This method employs various chemicals as oxidizing agents. Nonetheless, in order to adequately choose an oxidant that is most efficient and cost effective of those readily available, for the given conditions, further research is needed.

2.8 Research Objectives

The objectives of this research on H_2S wastewater and air concentrations at collection systems and treatment plants were to:

1. Determine the characteristics of the existing wastewater and air quality at two wastewater collection systems and one wastewater treatment plant known to generate and release offensive odors;
2. Identify the correlation between pH, temperature and H_2S concentrations; and

3. Investigate the performance of sodium hypochlorite (NaOCl), hydrogen peroxide (H_2O_2), and potassium permanganate (KMnO_4) for oxidizing hydrogen sulfide (H_2S) in wastewater collection and treatment systems with the purpose of mitigating odor emissions.

3 MATERIALS AND METHODOLOGY

This research was conducted in St. Thomas, United States Virgin Islands at two wastewater collection systems and one wastewater treatment plant in four phases. Phase I of this study was performed to investigate the effectiveness between hydrogen peroxide (H_2O_2) and sodium hypochlorite (NaOCl) in hydrogen sulfide (H_2S) oxidation. Two years later, Phase II was conducted to observe the changes on the wastewater quality after continuously adding the preferred oxidizing agent (chemical) chosen in Phase I. However, between the completion of Phase I and the start of Phase II another oxidizing agent was considered for application. Therefore, Phase III was implemented to evaluate the performance between hydrogen peroxide (H_2O_2) and potassium permanganate (KMnO_4) at oxidizing hydrogen sulfide (H_2S). The need for additional data resulted in Phase IV of this study.

3.1 Facility Description

St. Thomas, United States Virgin Islands is located 75 miles east of Puerto Rico and is positioned such that the Caribbean Sea is on its northern side and the Atlantic Ocean on the southern side. The island, measuring 13 miles in length, sits at approximately 32 mi^2 (82.9 km^2) with its widest point less than 3 miles. On an average day in St. Thomas, ambient temperatures range between $78\text{-}88^\circ\text{F}$ ($26\text{-}31^\circ\text{C}$). As of 2000 (last year published), the Virgin Islands Census Bureau listed that the island had a population of 51,181 residents. Although the current population has not been calculated by the Census Bureau, it is constantly increasing. Amid its beautiful beaches, cool emerald hills, winding roads, and luscious ocean views, St. Thomas struggles to control the liquid wastes generated by its occupants.

As one may be aware, with increasing population rates there would also be larger volumes of waste produced. To appropriately handle and treat the island's liquid wastes generated, there are five wastewater treatment plants and four major lift (pump) stations in operation (shown in Fig 3.1). The pump stations are used to pump the wastewater uphill to a point where gravity can continue to transport the liquid waste (wastewater) from residential housing, and commercial facilities to wastewater treatment plants where it is treated. At the wastewater treatment plant,

the wastewater is conveyed through biological, physical and/or chemical treatment processes to remove the existing pollutants. The primary goal of the wastewater facilities is to adequately collect, treat, dispose and/or reuse the wastewater while protecting its surrounding environment of its byproducts/constituents. However, they are known to generate harmful compounds, some creating offensive odors due to anaerobic biodegradation.

For some time, complaints have been made about objectionable odors from two wastewater collection systems (Long Bay and Cancryn Lift Station) and one wastewater treatment facility (Airport Lagoon Treatment Plant) on island. Although it is common to associate an odor with wastewater treatment facilities, the concentration levels surrounding the previously mentioned facilities are a concern. In an effort to ameliorate the conditions at those facilities, a study was performed. Prior to performing tests, the facilities and wastewater conditions were inspected.

The Long Bay Lift Station is a collection system located southwest of the Pearl M Pearson Housing Community and directly south of Lucinda Millin Home – a home for the elderly (shown in Fig 3.2). Also, about a mile or two away from the system is the Havensight dock. This port includes a large shopping center and houses headline cruise ships carrying a large number of tourists daily that may come in proximity to this system upon arrival. During the summer months, opposite the fence of the Long Bay Lift Station, is the home to the Virgin Islands Rising Stars Youth Steel Orchestra Summer Camp (a steel pan associated camp for young children to young adults). With sulfides being formed, the odor released raised an issue of discomfort in the nearby.

Downwind from the Long Bay Lift Station is the Cancryn Lift Station. The Cancryn Lift Station is a collection system located slightly northwest of the Addelita Cancryn Junior High School as shown in Fig 3.3. This institutional facility, opposite the system, houses an average of 860 students per school year (August thru June) from the hours of 7:30 am to 3:30 pm. Aware that an institutional facility and other commercial facilities are located in proximity with the Cancryn Lift Station, it became imperative to proceed with an alternative to eliminate the odors being emitted from the lift station. This facility also sits along one of the islands major roadways, Veteran's Drive (also shown in Fig 3.3). As a very active roadway, many residents



Figure 3.1 Aerial View of the Wastewater Collection and Treatment Facilities on St. Thomas, USVI



Figure 3.2 View of Lucinda Millin Home from the Entrance of the Long Bay Lift Station



Figure 3.3 View of the Addelita Cancryn Junior High School and Veteran's Drive from the Cancryn Lift Station

are faced with the aroma being emitted from the Cancryn Lift Station sometimes twice a day (to and from work) if not more. As a result, numerous complaints are made about an objectionable odor coming from this collection system.

The Long Bay Lift Station includes 3 6”X6” (6” intake and 6” discharge) pumps. During a pumping cycle there is only one pump in operation. With one pump operating, this lift station pumps approximately 415,000 gallons per day (GPD) with its minimum flow at 220 gallons per minute (GPM) at 1:00 am and its maximum flow at 500 GPM around 9:00 am. This flow is pumped via a gravity system to the Cancryn Lift Station. On the other hand, at the Cancryn Lift Station, there are 3 12”X12” (12” intake and 12” discharge) pumps also with only one pump operating per pumping cycle. At this facility, its maximum flow occurs at 9:00 am at a flow of 3000 GPM and its minimum flow at 1200 GPM at 1:00 am. However, this lift station utilizes a force main system to transport its flow directly to the Airport Lagoon Treatment Plant. **[Data provided by Steven Aubain, O&M Manager – St. Thomas/St. John Wastewater]**

At each lift station it is evident that very little is being done in regards to maintenance. At both facilities, there are huge grease blocks on the wastewater surface sometimes covering the entire surface. Also a representation of no upkeep is the grading at each station being partially covered with a variety of debris that was submerged and/or suspended in the wastewater. The debris on the grading may have been a result of the system overflowing at some point in time and has since been neglected. Because of low maintenance, the effectiveness of the collection systems ability to perform its daily tasks is hampered. Nevertheless, the wastewater is transported to a treatment facility.

There are several types of treatment facilities that may be employed to treat the wastewater conveyed through wastewater collection systems. The type and size of treatment systems chosen is dependent on the quantity of flow and type of treatment needed for the given location. Generally, lagoons, sequence batch reactors, trickling filters and oxidation ditches are used for treatment purposes for small areas. On St. Thomas, an aerated lagoon system (the Airport Lagoon Treatment Plant) was employed to provide proper treatment for the wastewater from the previously listed lift stations.

The Airport Lagoon Treatment Plant, located southwest of the Cyril E. King Airport (as shown in Figure 3.4), is a secondary treatment plant that processes the domestic and commercial sewage from the town area of St. Thomas including the two previously stated lift stations as well as a few additional lift stations within that vicinity. This plant was designed to treat a peak flow of 4.0 MGD but often times accept loads greater than that. This lagoon system includes three basins all equipped with submersible blower systems while half of the middle (settling) basin (located between the aeration and chlorine contact basins) is also equipped with 3" pipes at its bottom that was intended to capture the sludge produced for removal (shown in Figure 3.5). Unfortunately, the piping system is unsuccessful at capturing and removing the sludge leaving an excessive amount of sludge buildup at the bottom of that basin. In addition to the discharge from domestic and commercial facilities, this facility is also accepting stormwater runoff. The inability to handle and effectively treat the nutrient content in the wastewater results in algae buildup at the surface of the middle basin. (As can be seen in Figure 3.6)

The sludge that cannot be removed stays at the bottom of the basin, turns septic and creates then releases an objectionable odor. This odor greets the islands visitors upon departure from the aircraft and hampers neighboring workers (shown in Figure 3.7) throughout a given day.

Because of the ineffectiveness of the pipe system for sludge removal the wastewater is unable to get the aeration needed for biological growth that is necessary in carrying out the proper treatment. The lack of aeration within the system causes the microorganisms to die off in the basin that, if provided, would give them the opportunity to grow and multiply. Because of this, the biological treatment process of the plant used to control the decomposition and stabilization of organic matter is compromised. Another factor affecting the systems aeration is the direction of the wind.

If the wind is blowing in the direction of the airport's runway or terminal, the operators are instructed to turn the blowers off. Without the proper air, microorganisms, and sludge removal, this basin basically acts like a holding tank. In order to try and alleviate sludge buildup at the bottom of the basin, the sludge is pumped from the basins bottom using a 3000-gallon sludge pump truck. An estimated 9000 gallons is removed from this facility daily. The first load is

lifted from the effluent basin in the morning and the other two are taken from the middle basin later that day.

To adequately monitor changes in the effectiveness of the plant, daily influent and effluent tests are performed as well as weekly outfall tests for BOD, TSS, and fecal coliform. However, due to the previously stated problems associated with the Airport Lagoon Treatment Plant, it is unable to meet the recommended discharge limits and often times is found in violation of treatment codes. Reports have shown that during the months that this study was performed the Airport Lagoon Treatment Plant was insufficient in providing the proper treatment for its given influent. (See Appendix A for Discharge Monitoring Reports)



Figure 3.4 The Middle Basin of the Airport Lagoon Treatment Plant Located Southwest of the Cyril E. King Airport



Figure 3.5 Airport Lagoon Treatment Plant during Construction



Figure 3.6 Algae Growth in Middle Basin of Airport Lagoon Treatment Plant



Figure 3.7 Delta Airline Employee Covers Her Nose from the Odor Emanating from the Neighboring Airport Lagoon Treatment Plant [17]

3.2 Existing Conditions

The wastewater at the three previously stated facilities is domestic and contains no industrial inputs. Therefore, it is comprised mostly of human wastes and household detergents. However, it also includes stormwater run-offs. Consequently, like any other wastewater, there are various compounds that constitutes to the reactions within and conditions of the water. Generally, wastewater includes nitrogen compounds, phosphorus compounds, and organic compounds. In addition to these compounds, the two lift stations are encountering increasing grease volumes. Although fats, oil and grease are not unusual in domestic wastewater they are a concern in large quantities. The volumes of grease at these locations are attributable to the illegal discharge from restaurants, in addition to, the households discharging of its used oils down the drain. A request to enforce design/operation codes for all restaurants to use grease traps would aid in further problems at collection systems and/or treatment facilities. Another solution to the problem would be to have households bottle used oils/grease and dispose of it at the landfills where it will be appropriately handled and treated. If strongly enforced and abided by, grease volumes would hereby be reduced and the collection and treatment systems would be at ease.

The transport system between the two lift stations is also another issue affecting the condition of the wastewater after it leaves the Long Bay prior to its arrival at the downwind facility. Upon discharge from the Long Bay Lift Station, the wastewater is pumped uphill to the Beltjen's Place road and is then left to gravity feed to the Cancryn Lift Station. However, it appears that the current slope is not sufficient enough to provide the needed wastewater transport. Although no tests have been conducted to obtain the time between when the wastewater is discharged from the Long Bay Lift Station to its arrival at the Cancryn Lift Station, discussions have been held to conduct a dye test in an effort to obtain the data. Nonetheless, it is believed that due to the slope's inability to transport the wastewater, it stays within the pipes and turns septic. Therefore, when it arrives at the Cancryn Lift Station it is already in its septic/toxic form, giving reasoning behind more complaints being made about the Cancryn Lift Station compared to those made at the Long Bay Lift Station. Because of the quality of the wastewater leaving the Cancryn Lift Station, odor-producing compounds are generated and released at the headworks of the treatment plant. As a result, odor complaints are relatively as high as those from the Cancryn Lift Station and sometimes higher.

3.3 Odor Design Criteria

Special focus is needed on certain wastewater parameters for the deterrence of objectionable odors at wastewater collection and treatment facilities. This can be accomplished by supplying the most effective oxidizing agent to the systems, maintaining the aesthetics and equipments of the facilities and keeping measurements for the following parameters within the appropriate ranges.

3.3.1 pH

In order for the biological life within a wastewater system to exist, pH (hydrogen ion concentration) values are relatively narrow and are generally between 5 and 9. If the pH values of a given wastewater sample fall outside this range it makes treatment of the water by biological means difficult [7]. Although hydrogen sulfide degrading compounds can survive at pH values as low as 2, a more neutral pH is needed for the biological degradation of other compounds [10].

Therefore, to appropriately handle wastewater conditions, pH values should be within an optimum range of 6.5 – 7.5 that is sufficient for bacterial growth [7].

According to Charron et al. [5], the differences in reactivity between oxygen and different sulfide species is related to the effect of pH on the sulfide oxidation rate. For example, the sulfide oxidation rate for the dissociation of H_2S to HS^- and S^{2-} is dependent on the pH of the solution. The S^{2-} ion dissociation constant is low and forms at pH values lower than 14. Consequently, HS^- ion formation is the dominant available form for biodegradation at pH greater than 6 [2].

3.3.2 Temperature

Wastewater temperatures change rather often and influence the conditions of the water. Temperature in wastewater treatment impacts the chemical reactions and reaction times within the systems and upon treated effluent discharge, it impacts the aquatic life and the suitability for reuse purposes [7]. For example, the intake water temperatures are a concern for the applicability of water to be used for cooling purposes at industrial facilities. Likewise, high temperatures in the discharged treated effluent to an existing water body have the ability to affect a species life.

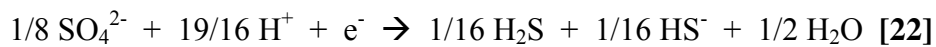
In most wastewater treatment systems it is rather important to measure temperature because of the biological treatment processes included that are temperature dependent. The bacterial activity that is needed and responsible for the removal of BOD depends on an optimum temperature for maximum performance. The optimum temperature range is $25^\circ\text{C} - 35^\circ\text{C}$ [7]. Increasing temperatures accompanied by an increase in the rate of biochemical reactions decreases the quantity of oxygen present. Haaning Nielsen et al. [11] found that in active wastewater, the rate of sulfide oxidation approximately doubles over a 15°C temperature increase.

As previously stated, H_2S is present in wastewater systems under anaerobic conditions. During anaerobic conditions, mesophilic bacteria dominate. Typically, mesophilic bacteria grow best in the temperature ranges of $15 - 45^\circ\text{C}$ [8]. Microorganisms are capable of operating efficiently

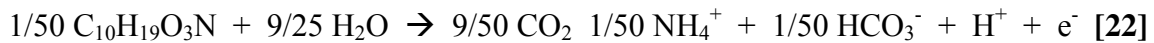
within the given temperature range. At temperatures below 15°C, treatment efficiencies are reduced as the biological systems slow down [10]. In addition, temperatures above 40°C utilizing thermophilic bacteria rapidly decline substrate removal.

3.3.3 Oxidation-Reduction Potential (ORP)

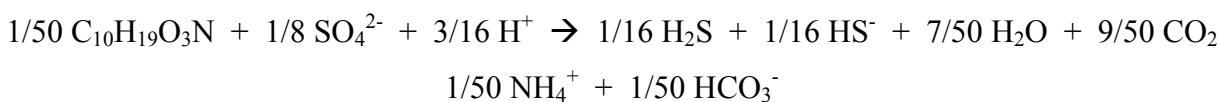
ORP is an effective way of measuring the oxygen source that is available to microorganisms. While a dissolved oxygen (DO) meter is a good way of measuring residual dissolved oxygen, it does not give an accurate representation of the oxygen source available, especially when DO gets to 0.2 mg/L and lower. However, an ORP reading gives description and understanding to a higher extent of the oxygen source within a given system. An ORP reading of +50 to about +225 mV indicates the presence of dissolved oxygen (O₂), while an ORP reading of +225 to +400 mV indicates the presence of oxygen and nitrate (NO₃). An ORP reading in the range of -50 to +50 mV indicates that no free available dissolved oxygen is present and that nitrate is present as an electron acceptor (oxygen source). This is the range needed for anoxic tanks and timed anoxic cycles. There should be no free DO present in this zone, and a DO meter would read zero mg/L. Typically, in wastewater collection systems ORP readings are around -300 mV or less. ORP readings less than -50 mV indicate there is no free oxygen or nitrate present, and that the microorganisms would be utilizing sulfate (SO₄) as an electron acceptor for their energy requirements. From the overall reaction provided in Section 1.4 the reduction half reaction for sulfate is as follows:



The oxidation half reaction for domestic wastewater, written on a one-equivalent basis, is



Adding the reduction and oxidation equations results in an overall balanced reaction in which no free electrons (free energy) are present:



This overall equation is a representation of the energy requirement for the oxidation of domestic wastewater and the reduction of sulfate. Figure 3.8 is a display of how ORP readings can be used to identify the oxygen source and chemical processes within a given wastewater sample.

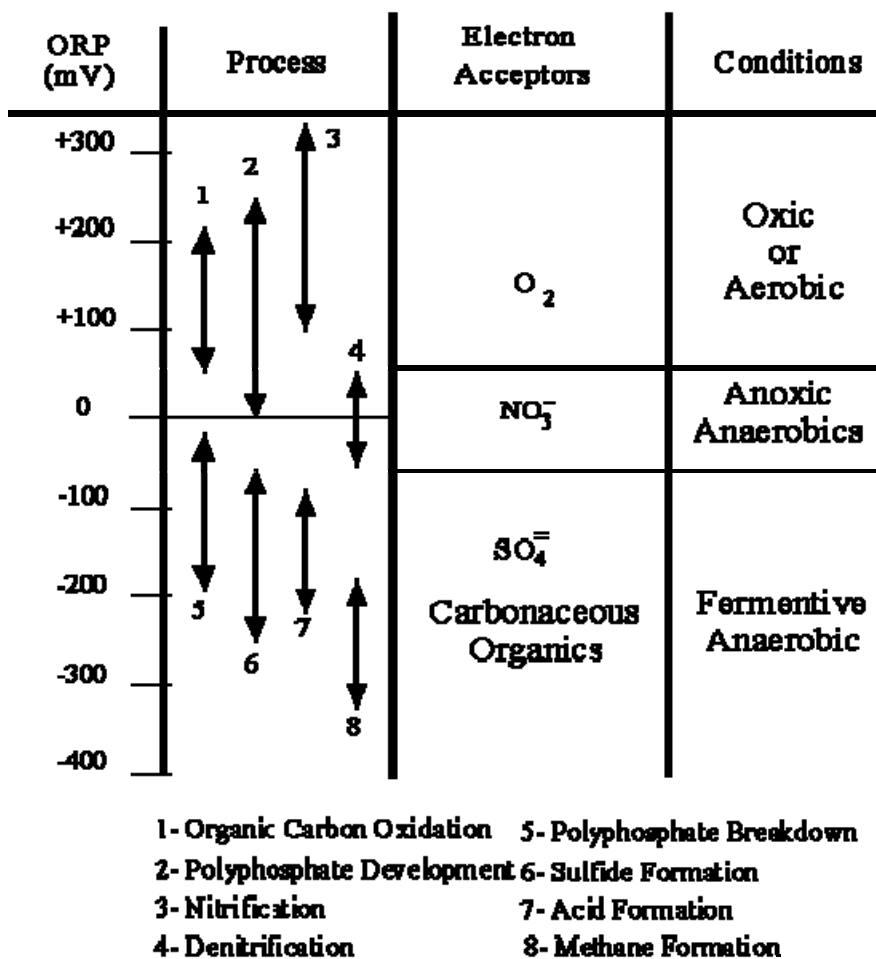


Figure 3.8 Processes, Electron Acceptors and Conditions for Specific ORP Ranges

3.3.4 Conductivity

Conductivity or specific conductance measures the ability for the water to produce electricity. The presence of inorganic dissolved solids generally affects the conductivity in the water.

Examples of such inorganic dissolved solids occupying the water include chloride, sulfate, nitrate, bicarbonate and phosphate anions, or sodium, magnesium, calcium, iron and aluminum cations. A conductivity measurement provides the amount of dissolved solids in the water, but neglects to detail what kind of dissolved solids are present. The conductivity at wastewater collection systems and treatment facilities are generally high since there is no treatment for dissolved solids and because of that the levels at the lift stations and aerated lagoon plant were expected to be very high. However, conductivity measurements are more of a concern when the wastewater's future use is for irrigation. Because the effluent would not be used for irrigation, conductivity measurements were not the main focus.

3.3.5 Salinity

Given that all three facilities are located on an island, there was a concern on the amount of saltwater infiltrating the systems. For observation purposes, salinity measurements were taken in the field. In measuring the salt concentration of the water an estimated amount of dissolved salts can be established and is expected. However, saltwater intrusion may be one good explanation for high values for salinity at any wastewater collection or treatment system. Saltwater intrusion is the movement of salt water into a non-salt water environment, such as a freshwater marsh. This intrusion may occur as the result of a natural process like a storm surge from a hurricane. However, more often saltwater intrusion results from human activities such as construction of navigation channels, for example. Nonetheless, on St. Thomas, one major result of saltwater intrusion may be due to deficiencies in the piping system to and from the facilities in addition to storm surges in the event of a hurricane. It is believed that the dominating contributing source of salinity in the systems would be the condition of the piping system simply because of age and lack of maintenance and/or repair.

3.3.6 Chemical Contact Time

Chemical contact time is another important design consideration throughout the oxidation process. It defines the time during which the organisms within the wastewater are exposed directly to the chemical agent. Chemicals are generally added to the systems as a liquid solution

and may require initial mixing in an effort to improve contact between chemicals and organisms. This can be achieved through the use of turbulent flow regimes or by mechanical means such as static mixers or pumps. Generally, the faster the rate of reaction between the organism and the chemical agent the more efficient they are at removing pollutants.

3.4 Chemical Costs

As previously stated, three chemicals were selected to oxidize H₂S throughout this study. When comparing NaOCl, H₂O₂ and KMnO₄ as alternatives for H₂S removal, chemical costs are obviously an important factor. Table 3.1 compares the relative chemical costs for each chemical in an effort to test for cost effectiveness. The unit costs for each chemical agent chosen were obtained from the chemical supplier, Mr. Eisenhauer of Terra Chem, Inc. Generally, KMnO₄ is supplied in a dry crystalline form and priced accordingly, however its unit cost provided in Table 3.1 is for its manufactured liquid solution. As can be seen, NaOCl is the cheapest while H₂O₂ is the most potent and expensive of them all. However, in order to appropriately select the chemical that is most effective, efficient, and economical at oxidizing H₂S, the chemical performances along with chemical costs would be equally weighed and evaluated.

Table 3.1 Cost Comparisons

Chemical	Concentration	Form	Unit Costs
NaOCl	12%	Liquid	\$3.65/gal
H ₂ O ₂	50%	Liquid	\$6.00/gal
KMnO ₄	5%	Liquid	\$5.45/gal

3.5 Treatment Phases

3.5.1 Phase I

Phase I was performed during the period of July 23rd – August 6th, 2004 at the two wastewater lift stations and at the lagoon treatment facility. The study consisted of:

- Installation of PVC pipes and peristaltic pumps at each site for chemical addition; and
- Measurements of pH, temperature, conductivity, salinity, dissolved sulfides and atmospheric hydrogen sulfide concentrations at the scene.

Above measurements were conducted using a YSI 63 pH, conductivity, salinity, and temperature meter, a Pinpoint ORP monitor, a LaMotte Sulfide Test Kit and a Jerome (860) H₂S gas monitor. The YSI 63 utilized a replaceable pH sensor for the determination of hydrogen ion concentration in the sample water. Prior to its use, the YSI 63 meter was calibrated using the 3-point calibration. The 3-point calibration utilized three standard buffer solutions that included pH 4, pH 7, and pH 10 solutions. When the pH of the media to be monitored cannot be anticipated, this method assures maximum accuracy. The handheld portable meter was dispersed into the collection systems and at the headworks of the treatment facility. The YSI meter was used in this study to perform pH, conductivity, salinity and temperature testing on the wastewater at the Long Bay Lift Station, the Cancryn Lift Station and the Airport Lagoon Treatment Plant. This instrument displayed readings for the previously stated parameters which indicated certain characteristics of the wastewater that aided in the treatment technique and analysis. Each parameter gives a story of its own as well as in conjunction with the other parameters on the condition of the wastewater.

Grab samples were also taken at each location to measure the total amount of sulfides (soluble and insoluble) contained in the wastewater. The LaMotte Sulfide Test Kit was utilized to perform sulfide tests. Measurements were taken in the absence of and in the presence of the chemicals individually. Tests were taken twice daily with one sample drawn and tested in the morning and the other in the afternoon in order to relate the effect of ambient temperature on the quality of the wastewater at the collection systems and at the treatment facility. It was also performed in order to evaluate the impact the time of day had on the systems in regards to flow volumes and/or activity entering the systems.

First, an approximate 5qt sample was collected (from the collection systems and from the headworks of the treatment facility). After the sample was collected, 100mL was used to fill the kit's flocculation bottle. Thereafter, the handheld portable ORP monitor was submerged in the remaining grab sample. Two reagents (sodium hydroxide with toluene and aluminum sulfate)

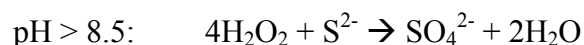
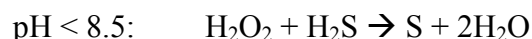
were then added to the flocculation bottle and reacted for fifteen minutes to allow the solids to settle. At this point, the ORP reading was retrieved. From the flocculation bottle, 7.5 ml of the clear liquid was then transferred into two test tubes (labeled test tube 1 and test tube 2). After adding sulfuric acid and N,N –dimethyl-p-phenylenediamine sulfate, ferric chloride hexahydrate and ammonium phosphate to test tube 1; sulfuric acid, ferric chloride hexahydrate and ammonium phosphate was added to test tube 2. Thereafter, in the event that test tube 1 turns blue, indicating the presence of sulfide, reagents were added to test tube 2 until its color reached that of test tube 1. Using methylene blue at 0.1% and <0.1% concentration levels, dissolved sulfide concentrations were calculated based on color test tube comparison of one test tube to the other. In order to achieve the H_2S concentration, the dissolved concentration was multiplied by a pH correction factor based on the pH obtained using the YSI 63 meter. Reference for determining the correction factor was based on testing kit manual. The list of correction factors for specified pH values can be found in Appendix B (Table B.1).

Atmospheric H_2S rates were taken using a portable gas monitor (Jerome 860). This meter was placed at the doorway of the lift stations and at the headworks of the lagoon treatment plant. The Jerome meter was set to take two minute interval readings at the Cancryn Lift Station and at the Airport Lagoon Treatment Plant (without chemicals and with H_2O_2 added) and one minute interval readings at Long Bay and at Airport (during the addition of $NaOCl$). Gas readings were recorded for one and a half days. They started the morning of July 26, 2004 and concluded on the afternoon of July 27, 2004. The meter provided H_2S emission data numerically along with a graphical representation, which made it easy to understand the effects the facilities would have on its neighbors based on the given $H_2S_{(g)}$ levels.

To help eliminate the odor problem at the three locations, two chemicals were chosen and tested in Phase I for sulfide control at the wastewater collection systems and treatment facility. Chemical addition can control sulfides by: 1) chemical oxidation (Cl_2 , H_2O_2); 2) sulfate reduction inhibition by providing an additional oxygen source (NO_3); 3) precipitation (metal salts); or 4) pH control (strong alkalis). The chemicals that were used to control sulfides throughout this phase were Hydrogen Peroxide (H_2O_2), and Sodium Hypochlorite ($NaOCl$); each with its own advantages and disadvantages.

3.5.1.1 Hydrogen Peroxide (H₂O₂)

H₂O₂ is used to chemically oxidize H₂S based on the following reactions:



Generally, 90% of the peroxide is reacted within 10 to 15 minutes, with the reaction completed in 20 to 30 minutes. Peroxide also reacts with other components of wastewater that exhibit an oxygen demand such as BOD and ammonia nitrogen. For this purpose an additional amount of H₂O₂ must be added to the required amount needed for H₂S so that the demand of the other oxygen-requiring substances may be satisfied.

H₂O₂ is commercially available as solutions of 35-, 50- and 70-percent H₂O₂ by weight. Throughout this study a solution of 50-percent H₂O₂ by weight was used. For handling purposes, it is not recommended that solutions stronger than 50-percent be used.

H₂O₂ has certain advantages over other sulfide control alternatives. Such advantages include:

- Usable in gravity sewers or force mains applications
- Relatively simple and inexpensive
- Produces harmless by-products
- Results in additional Dissolved Oxygen (DO) to the stream
- Suppresses H₂S generation for 3 to 4 hours after H₂O₂ addition [26]

However, at 50% H₂O₂ by weight safety issues for the handler as well as for other onsite operators became a major concern. At this concentration, H₂O₂ is extremely toxic and hazardous. Also, in the absence of catalysis, reactions may take several minutes. Therefore, H₂O₂ is often used in conjunction with a catalyst for greater efficiency. In addition, higher dosages are required for H₂S control in excess of 2 hours. However any residual left behind after oxidation would decompose to oxygen and water. Therefore, an increase in dosages would not pose a problem but would preserve aerobic conditions within the systems.

3.5.1.2. Sodium Hypochlorite (NaOCl)

Sodium hypochlorite (NaOCl) may be considered a liquid form of chlorine, kept in solution by the incorporation of caustic Sodium Hydroxide (NaOH). Throughout this study a 12% concentration of NaOCl was utilized. It is used to oxidize H₂S and organic odors based on the following equation leaving a byproduct of Hydrogen Sulfate (H₂SO₄) and Sodium Chloride (NaCl).



Some advantages associated with the use of Sodium Hypochlorite as an oxidizing agent are:

- Fast reaction
- Provides residual H₂S control after reacting with ammonia
- Extensive history regarding its use in collection and treatment systems for odor control
- Inhibits the growth of biofilm [26]

However, there are some disadvantages associated with the use of NaOCl for H₂S control at wastewater collection systems and treatment facilities. One major downfall associated with the use of NaOCl in wastewater treatment is its tendency to react with organics as well as H₂S. Due to the high organic loads at collection systems or at the headworks of treatment facilities, higher dosages would be required and would create higher chlorinated by-products within the systems. This increases the volatile organic compounds (VOCs) emission rates hampering the quality of the air. NaOCl also have a short shelf life due to its ability to lose strength rather quickly during normal storage conditions.

It was the ability for each chemical to control sulfide formation and emission that they were evaluated, in conjunction with its health and hazard data. From the results of the performance of each chemical, the decision was made for the continued use of H₂O₂ at each facility. From September 2004 to June 2006, H₂O₂ was being added to the Cancryn Lift Station, the Long Bay Lift Station and the Airport Lagoon Treatment Facility. However, due to the lack of change at the Airport Lagoon Treatment Facility the addition of H₂O₂ was amended in March 2006.

3.5.2 Phase II

Phase II testing was conducted during June 26, 2006 – June 29, 2006. This phase was done to evaluate the successfulness of H_2O_2 after being applied to each system for approximately two years. Three months prior to this study because of the conditions at the Airport Lagoon Treatment Plant, the lack of change, and improper handling of chemicals, the addition of H_2O_2 at this facility was terminated. Therefore, H_2O_2 would only be added to the Long Bay and Cancryn Lift Stations. Throughout the course of this experiment period, slight change was observed at the Cancryn Lift Station. As a result, the feeding rate at the uphill facility (Long Bay Lift Station) was doubled in order to monitor the impact caused on the Cancryn Lift Station emission rates. After increasing the feeding rate at the Long Bay Lift Station, the odor at the Cancryn Lift Station was observed to reduce tremendously. However, a few days prior to performing tests at the facilities, the supply of H_2O_2 at the Cancryn Lift Station was depleted, leaving H_2O_2 being added only to the Long Bay Lift Station.

Initially, a Jerome 860 H_2S gas meter was placed at each facility. The gas meters were placed at the door frames of the lift stations and at the headworks of the treatment plant. However, the meter readings differed throughout this phase of testing. Unlike Phase I where it was set to take one and two minute interval readings, this time it was set to take five minute interval readings. Gas readings were taken for four days starting the morning of June 26, 2006 to mid-day June 30, 2006. This was done to give a wider range of testing throughout this study for a better understanding and visual of changes, if generated.

Using the same methodology from Phase I, the same form of testing was performed. The YSI 63 pH, temperature, salinity and conductivity meter was dispersed in the wastewater at the lift stations and at the headworks of the treatment plant. The instant temperature was stabilized on the instrument, pH, temperature, salinity and conductivity readings were taken. Thereafter, a grab sample of 1L was obtained from the previously stated locations and was used to conduct wet tests. From the grab sample, 100mL was used to determine the total sulfide content at the facilities using the LaMotte Sulfide Test Kit. The ORP monitor was dispensed in the remainder of the grab sample and used to obtain ORP readings. Wet tests were conducted twice daily (one in the morning and the other in the afternoon) for the allotted four days of testing. However, one

wet test was done on Thursday, June 29, 2006 with no wet tests conducted on Friday, June 30, 2006. Due to the similarity and a consistent range of data results during those four days of testing the decision was made to cease testing scheduled for the duration of the week.

3.5.3 Phase III

As previously stated, there are many benefits associated with the use of H_2O_2 as an oxidizing agent for H_2S . However, its performance against KMnO_4 (another widely used oxidant in wastewater treatment) is unknown and can only be detected through further evaluation.

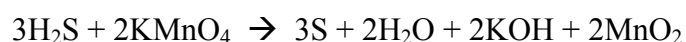
Therefore, another phase of testing had to be performed. Phase III was conducted on July 21, 2006 and then on July 24, 2006 using bench tests. A sample was drawn in the morning from the Long Bay Lift Station and the Cancryn Lift Station and was taken to the laboratory for further evaluation. Prior to grabbing the sample, tests were performed on the existing conditions of the wastewater at the system. From those tests the temperature, pH, salinity, conductivity, dissolved sulfide and liquid H_2S values were obtained. Thereafter, the sample was drawn and taken to the Mangrove Lagoon Laboratory for testing and evaluation.

At the laboratory, tests were conducted to evaluate the effectiveness of H_2O_2 and KMnO_4 was compared. Ten beakers were filled with 250mL of the raw sample. Each beaker was given an ID number (1-5H/P) per chemical used matching the total number of drops of the chemical added to the sample. For example, beaker 1H contained one drop of H_2O_2 whereas, beaker 1P contained one drop KMnO_4 . Both samples containing one drop (0.03mL) of each chemical were tested simultaneously which allowed for better comparison and data analysis of results. Before evaluating each sample with the addition of the chemicals, each beaker was stirred at a rotational speed of 60 – 100 rpm for a few seconds on a Fisher Scientific – Fisher Isotemp stirring hotplate (magnetic stirrer). Then, 100mL was placed in a flocculation bottle from the LaMotte Sulfide Test Kit for dissolved sulfide calculation (as previously mentioned). To obtain pH, temperature, salinity, and conductivity readings, approximately 100mL of the remaining sample was placed in a graduated cylinder in which the YSI 63 was submerged.

General characteristics of KMnO_4 in addition to its advantages and disadvantages when applying it to a wastewater collection or treatment system will be briefly described below.

3.5.3.1. Potassium Permanganate (KMnO_4)

5% KMnO_4 was employed to oxidize H_2S as well as other organic odors in a wastewater sample. It is available in crystalline form and can be added to the system in its dry form or in a concentrated solution prepared onsite. There is a fast reaction between H_2S and KMnO_4 based on the following chemical reaction:



Benefits related to the use of KMnO_4 in wastewater treatment include:

- Oxidizes Iron (Fe) and Manganese (Mn),
- No halogenated disinfection by-product production [11], and
- Effective for organic odors.

On the contrary, KMnO_4 provided in its dry or liquid form creates a messy handling situation or requires a labor intensive-feeding system. In addition, KMnO_4 is unable to control residual H_2S [26].

3.5.4 Phase IV

Due to the limited data collected on a day-to-day basis, Phase IV was implemented in an effort to provide additional data points for evaluation. Phase IV was conducted during the period of March 6-7, 2007 at the Cancryn Lift Station. Special focus was placed on the Cancryn Lift Station because when compared to the other facilities it proved to have a greater range of H_2S aqueous and gaseous concentrations with the ability to display change. Prior to testing at the facility, H_2O_2 was being added to the lift stations. In order for the systems to return to its raw conditions, the chemical pumps were turned off on March 5, 2007 at 1300 at the Long Bay Lift Station and at 1315 at the Cancryn Lift Station. Beginning at around 1015 on March 6, 2007, testing began on the raw (wastewater and air) conditions at the facility. Between 1300 and 1330

that day, the chemical pumps were turned back on. At 940 on March 7, 2007, testing resumed at the lift station in the presence of H₂O₂. The methodology used in this phase of treatment was the same as that used in Phases I and II of this study

4 RESULTS AND DISCUSSION

At the start of this study, the raw wastewater conditions at the facilities were investigated. After chemical addition, an analysis of each chemical's performance was evaluated throughout the specified time period of June 2004-March 2007. This chapter therefore discusses results of the tests used to select the most effective chemical to be added to the wastewater for odor mitigation.

4.1 Phase I

4.1.1 Testing on Raw Wastewater Conditions

As previously stated, in order to fully understand that which is needed, tests were conducted on the raw wastewater conditions at the Long Bay Lift Station, Cancryn Lift Station and the Airport Lagoon Treatment Plant. Table 4.1 shows the data collected from the tests performed at each facility. From the data, H₂S concentrations averaged 0.35ppm at the Long Bay Lift Station and 2.12ppm at the Cancryn Lift Station. These measured concentrations proved the Cancryn Lift Station to be more problematic due to its average concentrations being six times greater than that of the Long Bay Lift Station. Based on the complaints made by residents prior to this study, such measurements were understood. Although the vast majority of the complaints made between the three facilities were on the Airport Lagoon Treatment Plant, only one test was performed during this testing period. From that test, a measured H₂S concentration of 2.71ppm was obtained. As can be seen, the H₂S concentrations are higher at the Airport Lagoon Treatment Plant.

As discussed in Section 3.3, the potential for odor problems due to high H₂S concentrations at wastewater facilities can be observed based on the measurements of certain wastewater parameters. Placing special focus on three of the six parameters discussed in Section 3.3 can give a better understanding to the current levels of H₂S concentrations at the systems. Those parameters are pH, temperature and ORP. Due to prior knowledge of these parameters, certain trends are expected throughout the study. Those trends include: (1) a decrease in pH values would create an increase in H₂S concentrations (as can be seen from the reaction provided in

Section 2.4); (2) an increase in temperature would result in an increase in H_2S concentrations; and (3) it is expected that the lower the ORP readings the higher the H_2S concentrations.

Analysis on the data provided in Table 4.1 displayed some of the expected trends. However, not all the expected trends were met. At the Long Bay Lift Station, there was an expected negative correlation between ORP and H_2S . In contrast to that which was expected, there was a positive correlation between pH and H_2S and a negative correlation between temperature and H_2S . This however was not the case at the Cancryn Lift Station. The correlation between the parameters at the Cancryn Lift Station was the complete opposite to the findings at the Long Bay Lift Station. The expected trends between temperature and H_2S and between ORP and H_2S were observed. However, due to the limited data collected at the Airport Lagoon Treatment Facility no further analysis was conducted.

Figures 4.1 – 4.3 are graphical representations of the $\text{H}_2\text{S}_{(\text{g})}$ concentrations and ambient temperatures at each wastewater facility under raw conditions from July 23, 2004 to July 27, 2004. As shown in the figures, again there is evidence that there is a trend between temperature and $\text{H}_2\text{S}_{(\text{g})}$ concentrations. It can be seen that with an increase in temperatures there is an increase in $\text{H}_2\text{S}_{(\text{g})}$ concentrations. With the given trends, initial raw emission conditions revealed averages of 1.57ppm at Long Bay and 3.10ppm at Cancryn.

However, the data collected from the Airport Lagoon Treatment Plant on $\text{H}_2\text{S}_{(\text{g})}$ concentrations readings included its raw conditions in addition to concentration readings in the presence of H_2O_2 . The addition of H_2O_2 to the plant began at around 1000 on July 24, 2004. The average H_2S concentration during the testing period at the plant was found to be an astonishing 0.30ppm. Based on the large amounts of odor complaints made by the residents within the environment surrounding the Airport Lagoon Treatment Plant such a low reading came as a surprise. However, a reading of the sort may have resulted from the structure of the facility. With the Airport Lagoon being a completely open facility, the placement of gas meters was greatly affected by the wind. Although the gas meters were placed at the same location (at the headworks) during testing periods, readings were influenced by the direction of the wind. Readings were observed to be higher when the wind blew in an easterly direction.

Table 4.1 Typical Raw Wastewater Characteristics for the Long Bay and Cancryn Lift Stations and Airport Lagoon Treatment Plant

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (µS)	Specific Conductance (µS)
LONG BAY RAW	7/26/2004	1245	0.6	0.37	32.5	6.49	-222	0.9	2031.0	1254
LONG BAY RAW	7/26/2004	1548	0.7	0.27	32.8	6.89	-192	0.9	1965.0	1208
LONG BAY RAW	7/27/2004	712	2.2	0.37	32.2	7.42	-297	1.0	2273.0	1420
LONG BAY RAW	7/27/2004	1420	1.0	0.39	32.9	6.89	-234	1.0	2361.0	1458
Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
CANCRYN RAW	7/26/2004	1155	5.0	1.95	31.8	6.86	-310	5.1	10.37	6.45
CANCRYN RAW	7/26/2004	1502	5.0	2.20	31.8	6.76	-252	4.7	9.62	5.99
CANCRYN RAW	7/27/2004	925	6.0	1.98	31.5	7.03	-290	5.0	10.23	6.38
CANCRYN RAW	7/27/2004	1505	6.0	2.34	31.8	6.93	-289	4.3	8.82	5.48
AIRPORT RAW	7/23/2004	932	8.2	2.71	31.7	6.96	-326	9.1	17.78	11.07

4.1.2 Testing on Raw $\text{H}_2\text{S}_{(\text{g})}$ Levels

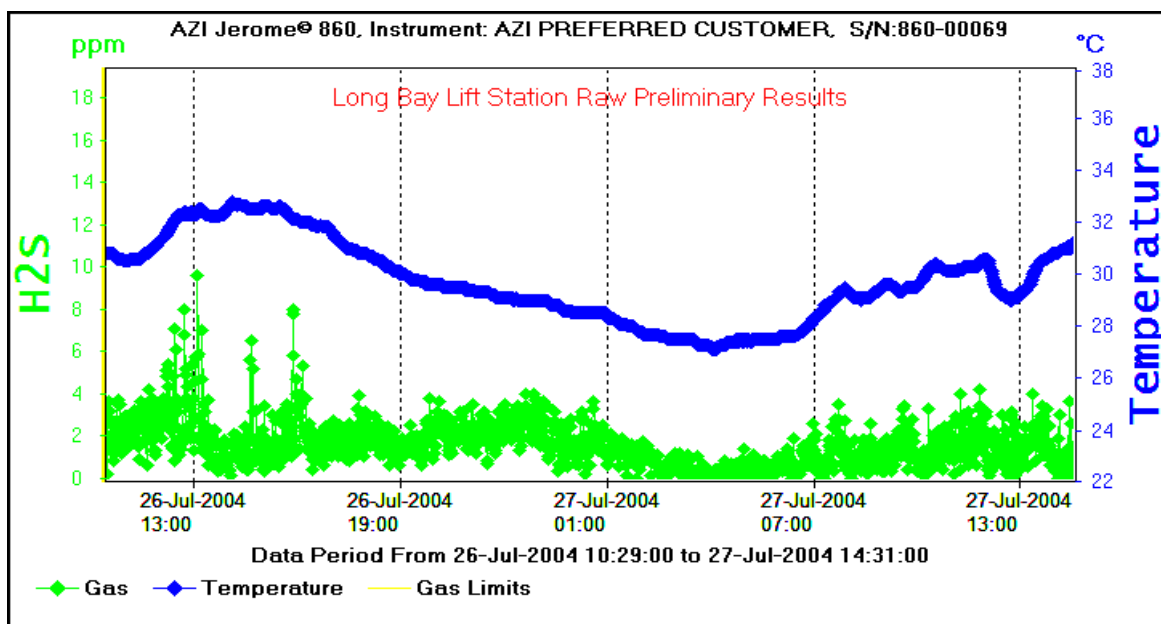


Figure 4.1 $\text{H}_2\text{S}_{(\text{g})}$ Raw Concentration Levels at the Long Bay Lift Station

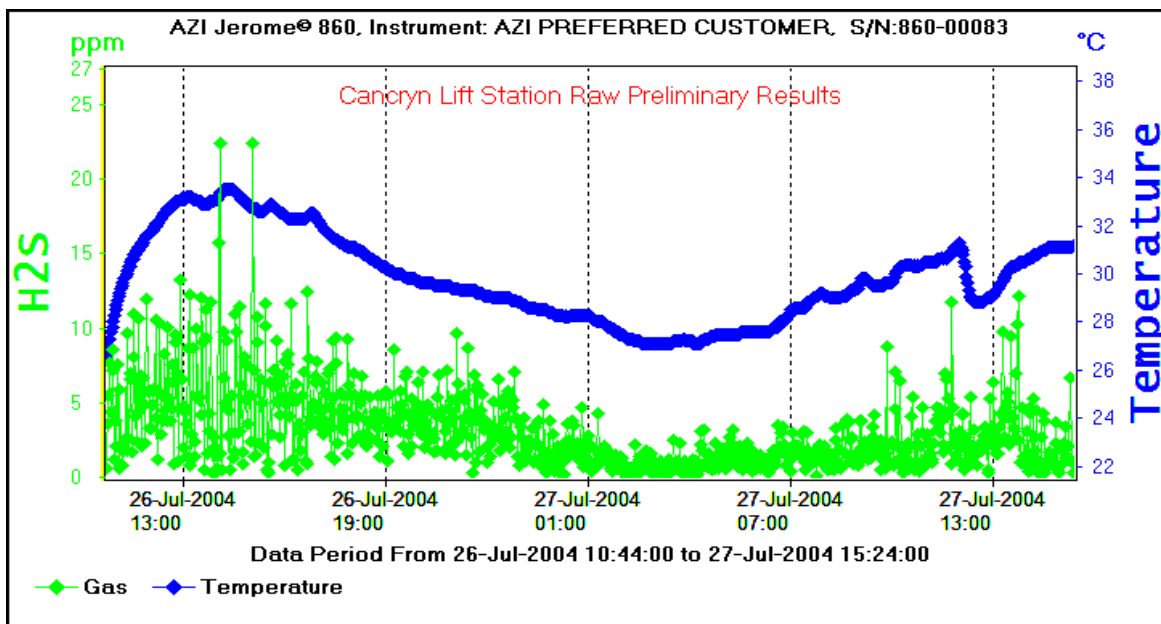


Figure 4.2 Raw $\text{H}_2\text{S}_{(\text{g})}$ Concentration Levels at the Cancryn Lift Station

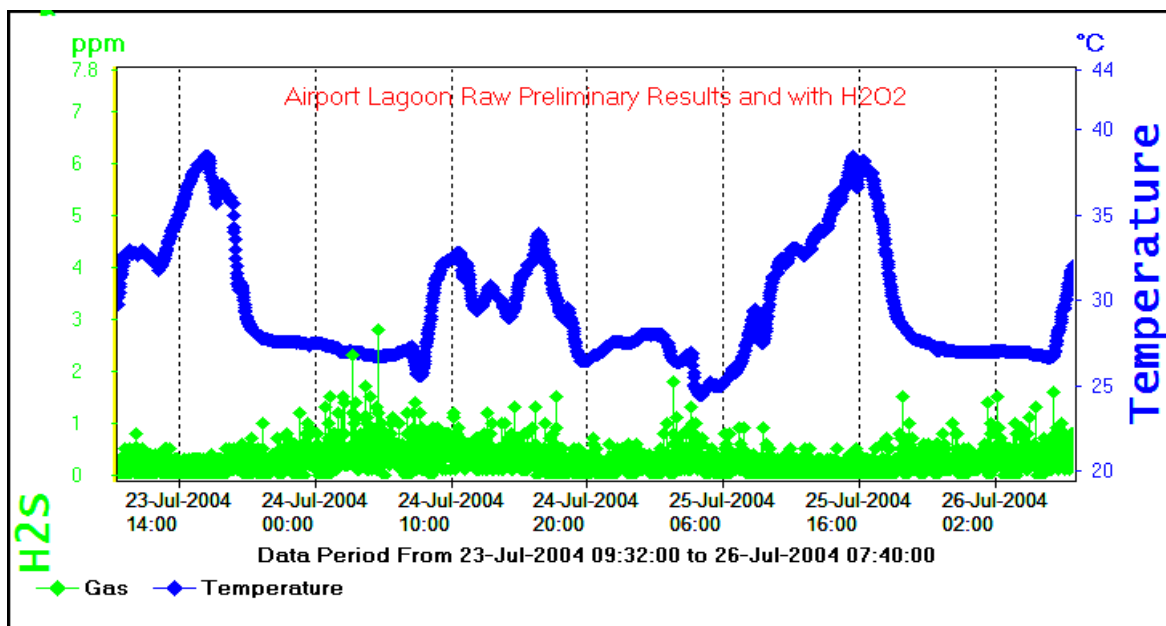


Figure 4.3 The Airport Lagoon Treatment Plant Raw $\text{H}_2\text{S}_{(\text{g})}$ Concentration Levels and the Influence of H_2O_2 on Air Quality after its Application

4.1.3 H_2O_2 Addition

Data evaluation, after the addition of H_2O_2 , was accomplished by comparing the test results of the raw data collected to the test results of the data collected after supplying H_2O_2 to the systems. Although tests were conducted on different days, the condition of the wastewater entering the systems was characteristically similar. Data collected during the addition of H_2O_2 can be found in Table 4.2. Hence, after reviewing the data within Table 4.2, the conductivity values collected on 7/24/04 at the Long Bay Lift Station may have been due to human/equipment error.

H_2O_2 definitely influenced the two lift stations. Wastewater measurements taken during the addition of H_2O_2 resulted in calculated mean and standard deviation (s.d.) values of 87.3% (s.d. = 12.6) H_2S removal at the Long Bay Lift Station and 90.2 % (s.d. = 11.6) H_2S removal at the Cancryn Lift Station. (Shown in Table 4.3) However, there was no evidence of a change in the conditions at the Airport Lagoon Treatment Plant. During initial testing at the facility only one sample of data was collected whereas, two samples were taken during the addition of each chemical. This created inconsistency between the lift stations and the treatment plant methods of evaluation. In order to obtain somewhat of an understanding to the chemical effect at the Airport Lagoon Treatment Plant, H_2S concentration averages were utilized. In doing so, the addition of

Table 4.2 Influence of H₂O₂ on the Wastewater Quality at the Lift Stations and the Lagoon Treatment Plant

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (µS)	Specific Conductance (µS)
LONG BAY w/ H ₂ O ₂	7/28/2004	925	0.2	0.05	32.4	7.15	-110	1.0	2170	1340
LONG BAY w/ H ₂ O ₂	7/28/2004	1520	0.1	0.08	32.7	6.24	-60	0.9	1995	1230
LONG BAY w/ H ₂ O ₂	7/29/2004	1043	0.0	0.00	30.9	7.22	-49	0.0	23.30	13.70
LONG BAY w/ H ₂ O ₂	7/29/2004	1554	0.1	0.03	32.3	6.98	-30	0.9	2032	1258
Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
CANCRYN w/ H ₂ O ₂	7/28/2004	1010	1.3	0.51	31.6	6.90	-162	5.0	10.31	6.40
CANCRYN w/ H ₂ O ₂	7/28/2004	1435	0.2	0.08	32.0	6.87	-38	4.6	9.43	5.84
CANCRYN w/ H ₂ O ₂	7/29/2004	1005	0.0	0.00	31.3	7.28	-109	4.4	8.94	5.60
CANCRYN w/ H ₂ O ₂	7/29/2004	1625	0.8	0.22	31.6	7.10	-81	3.9	8.13	5.06
AIRPORT w/ H ₂ O ₂	7/26/2004	1104	6.2	2.42	31.6	6.94	-336	7.3	14.41	8.97
AIRPORT w/ H ₂ O ₂	7/27/2004	823	13.0	5.72	31.6	6.84	-284	7.7	15.19	9.47

Table 4.3 Influence of the H₂O₂ on the H₂S Removal after Testing at the Long Bay and Cancryn Lift Stations

Long Bay Lift Station				Cancryn Lift Station			
Test	H ₂ S concentration (ppm)		Percent Removed	Test	H ₂ S concentration (ppm)		Percent Removed
	Raw	w/ H ₂ O ₂			Raw	w/ H ₂ O ₂	
1	0.37	0.05	86.5	1	1.95	0.51	73.8
2	0.27	0.08	70.4	2	2.2	0.08	96.4
3	0.37	0	100.0	3	1.98	0	100.0
4	0.39	0.03	92.3	4	2.34	0.22	90.6
Average	0.35	0.04	87.3	Average	2.12	0.20	90.2
Std. deviation	0.05	0.03	12.6	Std. deviation	0.19	0.22	11.6

Table 4.4 Correlation matrices for the Lift Stations of H₂S with Temperature, pH, and ORP in the presence of H₂O₂

Long Bay with H2O2						Cancryn with H2O2					
Dis. Sulfide	H2S	Temp.	pH	ORP		Dis. Sulfide	H2S	Temp.	pH	ORP	
Dis. Sulfide	1					Dis. Sulfide	1				
H2S	0.6189814	1				H2S	0.9816821	1			
Temp.	0.7639749	0.926397	1			Temp.	0.0441894	0.057019	1		
pH	-0.063538	-0.82234	-0.63728	1		pH	-0.4786895	-0.53678	-0.84822	1	
ORP	-0.7290113	-0.32572	-0.273	-0.14324	1	ORP	-0.6376089	-0.6995	0.608418	-0.09576	1

H₂O₂ proved to have no significant effect on the H₂S concentrations and provided no H₂S removal.

As shown in Table 4.4 (in the presence of H₂O₂), there was evidence that dissolved sulfides were positively correlated to H₂S. However, this correlation was stronger at the Cancryn Lift Station compared to the Long Bay Lift Station. Nevertheless, both facilities prove that sulfides are attributes of the odor source. In addition, all expected trends were met. Consequently, the increase in the acidic conditions (low pH values) at the systems produced greater H₂S concentrations. Likewise, increasing temperatures under such conditions yield increasing H₂S concentrations. Hence, low ORP readings would correspond with those increasing H₂S concentrations.

4.1.4 H₂S_(g) Emission Levels after the Addition of H₂O₂

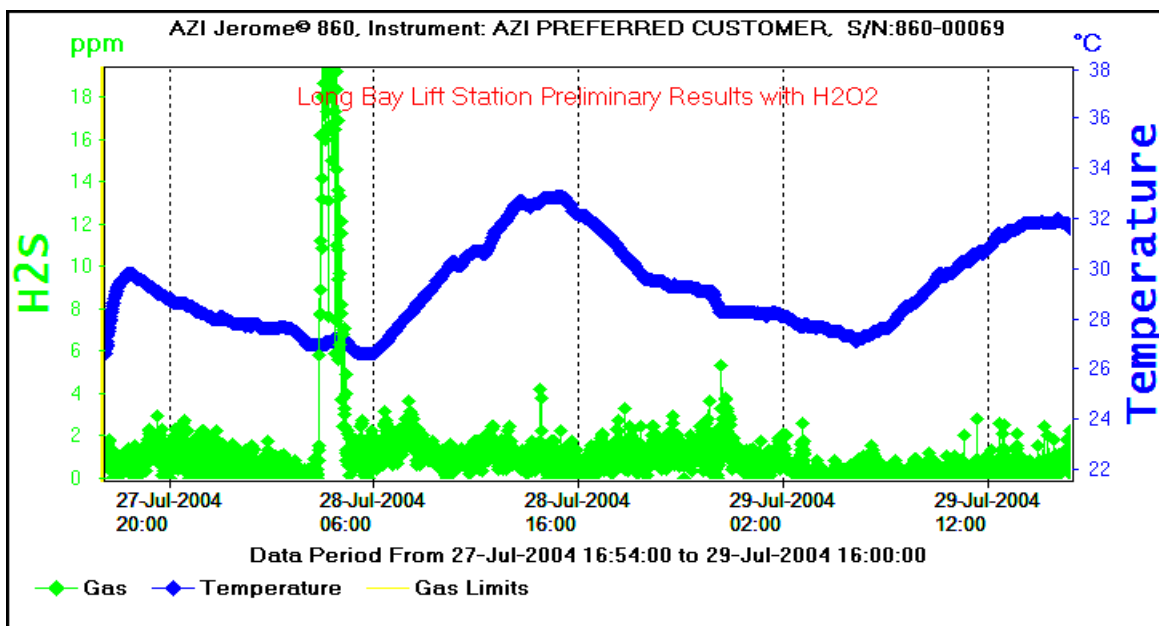


Figure 4.4 Influence of H₂O₂ on the Air Quality at the Long Bay Lift Station

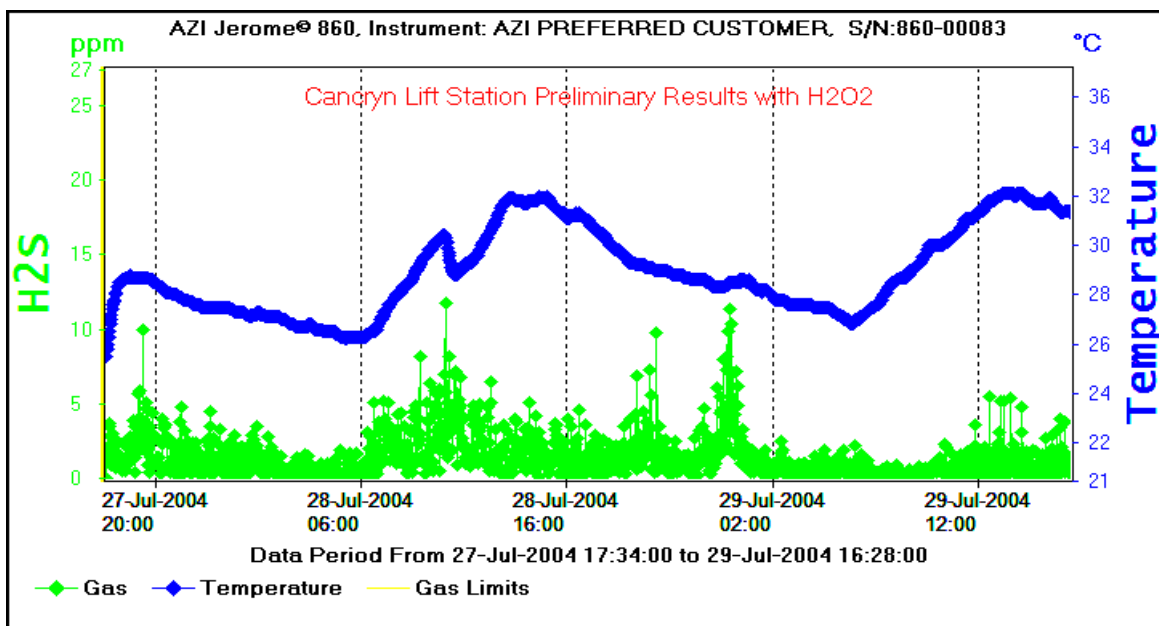


Figure 4.5 Influence of H_2O_2 on the Air Quality at the Cancryn Lift Station

The addition of H_2O_2 has improved $\text{H}_2\text{S}_{(\text{g})}$ conditions at the Long Bay Lift Station as well as at the Cancryn Lift Station. This can be seen through the comparison of Figures 4.1-4.2 and Figures 4.4-4.5. Also shown in Figures 4.4-4.5 is another positive correlation between temperature and $\text{H}_2\text{S}_{(\text{g})}$ concentrations. In addition, it can be seen in Figure 4.4 that the $\text{H}_2\text{S}_{(\text{g})}$ concentrations at the Long Bay Lift Station displayed a spike of about 33.3ppm. This large spike measured during the testing period demonstrates the ability of the contamination levels at the facilities to vary. One explanation for the given observation would be an extended period of time in which the wastewater at the system remained stagnant generating higher $\text{H}_2\text{S}_{(\text{g})}$ concentrations at the facility. When a flow entered the system, $\text{H}_2\text{S}_{(\text{g})}$ concentrations dropped due to mixing. Besides that, $\text{H}_2\text{S}_{(\text{g})}$ concentrations at the Long Bay Lift Station averaged 1.22ppm, whereas, at the Cancryn Lift Station $\text{H}_2\text{S}_{(\text{g})}$ concentrations averaged 1.44ppm. Although the conditions at the Lagoon Treatment Plant also decreased (as can be seen in Figure 4.3), this may have nothing to do with the $\text{H}_2\text{S}_{(\text{g})}$ emitted but more so with the direction of the wind. The wind may have been in a direction opposite the meter and therefore the readings were not that high. The observed emission concentrations by the researcher were far greater than that indicated on the meter.

4.1.5 NaOCl Addition

One week after testing in the presence H_2O_2 , testing began with the addition of NaOCl. The systems were allotted a week to return to its raw conditions in order to adequately evaluate the effectiveness of the chemical. Table 4.5 provides the data obtained during that testing period. Although the H_2S concentrations reduced with the addition of NaOCl, results were not as low compared to the removal efficiencies obtained during the addition of H_2O_2 . The addition of NaOCl resulted in an averaged 70.6% (s.d. = 26.8) H_2S removal at the Cancryn Lift Station and 64.7% (s.d. = 9.9) H_2S removal at the Long Bay Lift Station. (Shown in Table 4.6) The H_2S removal obtained at the Long Bay Lift Station was after the removal of test #2. Originally, test #2 resulted in a -11.1% and was therefore removed. Unfortunately, NaOCl was unable to remove the H_2S from the Airport Lagoon Treatment Plant. Again, the overall conditions at the Airport Lagoon Treatment Plant did not improve.

In Table 4.7, notice that the wastewater conditions in the presence of NaOCl are not consistent with the expectations of the chosen parameters and H_2S concentrations. Once again it was proven that special focus was needed to address H_2S relative to odor emissions based on the strong correlation between dissolved sulfides and H_2S . The correlation between H_2S concentrations and pH and the correlation between temperature and ORP at the Long Bay Lift Station is the complete opposite to that at the Cancryn Lift Station. Although two of the three expected trends were met at the Long Bay Lift Station shown in Table 4.7, neither were strong. In contrast, there was a strong negative correlation between ORP and H_2S concentrations providing further evidence behind the strong sulfide content of the wastewater.

The addition of NaOCl did have an effect on the emission rates at the facilities; however it was not as impressive as that of H_2O_2 . Shown in Figures 4.6-4.8 are the $\text{H}_2\text{S}_{(\text{g})}$ concentrations at the facilities during the addition of NaOCl. At the Long Bay lift station, $\text{H}_2\text{S}_{(\text{g})}$ ranges were higher in comparison to the addition of H_2O_2 with an average concentration of 2.04ppm. $\text{H}_2\text{S}_{(\text{g})}$ levels at the Cancryn Lift Station were rather high at the early stages of the addition of NaOCl. Thereafter, they began to decrease. Nevertheless, the concentrations averaged at 3.14ppm. Again emission concentrations at the lagoon treatment plant were not clearly identified by the meter displaying relatively low concentrations.

Table 4.5 Influence of NaOCl on the Wastewater Quality at the Lift Stations and Lagoon Treatment Plant

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (μS)	Specific Conductance (μS)
LONG BAY w/ NaOCl	8/4/2004	1105	0.2	0.09	32.7	6.80	-204	0.9	2178	1337
LONG BAY w/ NaOCl	8/4/2004	1657	0.6	0.30	32.8	6.72	-184	0.9	2165	1329
LONG BAY w/ NaOCl	8/5/2004	1112	0.5	0.14	32.9	7.05	-182	1.0	2199	1340
LONG BAY w/ NaOCl	8/5/2004	1412	0.5	0.17	33.1	6.96	-189	0.9	2112	1296
Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
CANCRYN w/ NaOCl	8/4/2004	1200	0.0	0.00	31.8	6.87	-225	5.8	11.72	7.33
CANCRYN w/ NaOCl	8/4/2004	1611	0.8	0.35	32.1	6.82	-207	5.9	11.93	7.40
CANCRYN w/ NaOCl	8/5/2004	1017	5.0	1.20	31.7	7.23	-274	6.4	12.74	7.93
CANCRYN w/ NaOCl	8/5/2004	1321	4.0	0.96	31.9	7.16	-253	6.1	12.23	7.59
AIRPORT w/ NaOCl	8/6/2004	900	11.0	4.84	31.8	6.80	-351	8.0	15.65	9.73
AIRPORT w/ NaOCl	8/6/2004	1415	10.0	3.30	32.2	6.95	-362	5.2	10.76	6.66

Table 4.6 Influence of NaOCl on the H₂S Removal after Testing at the Long Bay and Cancryn Lift Stations

Long Bay Lift Station				Cancryn Lift Station			
Test	H ₂ S concentration (ppm)		Percent Removed	Test	H ₂ S concentration (ppm)		Percent Removed
	Raw	w/ NaOCl			Raw	w/ NaOCl	
1	0.37	0.09	75.7	1	1.95	0	100
3	0.37	0.14	62.2	2	2.2	0.35	84.1
4	0.39	0.17	56.4	3	1.98	1.2	39.4
				4	2.34	0.96	59.0
Average	0.38	0.13	64.7	Average	2.12	0.63	70.6
Std. deviation	0.01	0.04	9.9	Std. deviation	0.19	0.55	26.8

Table 4.7 Correlation matrices for the Lift Stations of H₂S with Temperature, pH, and ORP in the presence of NaOCl

Long Bay with NaOCl						Cancryn with NaOCl					
	Dis. Sulfide	H2S	Temp.	pH	ORP		<i>Dis. Sulfide</i>	<i>H2S</i>	<i>Temp.</i>	<i>pH</i>	<i>ORP</i>
Dis. Sulfide	1					Dis. Sulfide	1				
H2S	0.81593173	1				H2S	0.9917888	1			
Temp.	0.50709255	0.076218	1			Temp.	-0.4790566	-0.38027	1		
pH	0.10923726	-0.48552	0.628878	1		pH	0.9721027	0.934129	-0.63759	1	
ORP	0.93848021	0.618862	0.475896	0.357535	1	ORP	-0.918226	-0.86483	0.784793	-0.97597	1

4.1.6 H₂S Emission Levels after NaOCl Addition

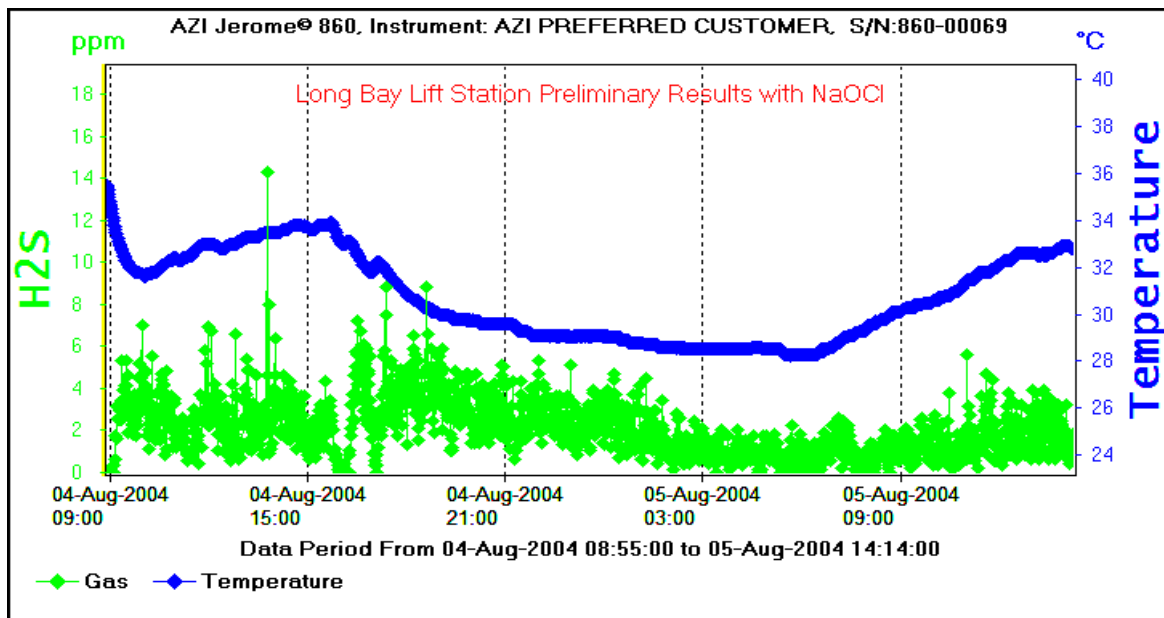


Figure 4.6 Influence of NaOCl on the Air Quality at the Long Bay Lift Station

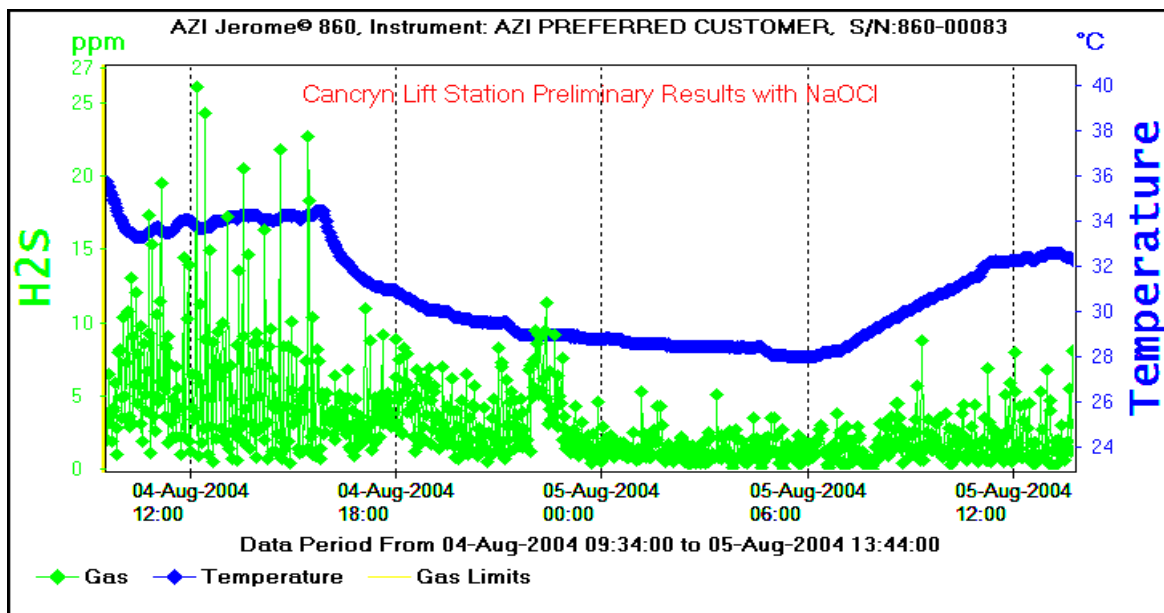


Figure 4.7 Influence of NaOCl on the Air Quality at the Cancryn Lift Station

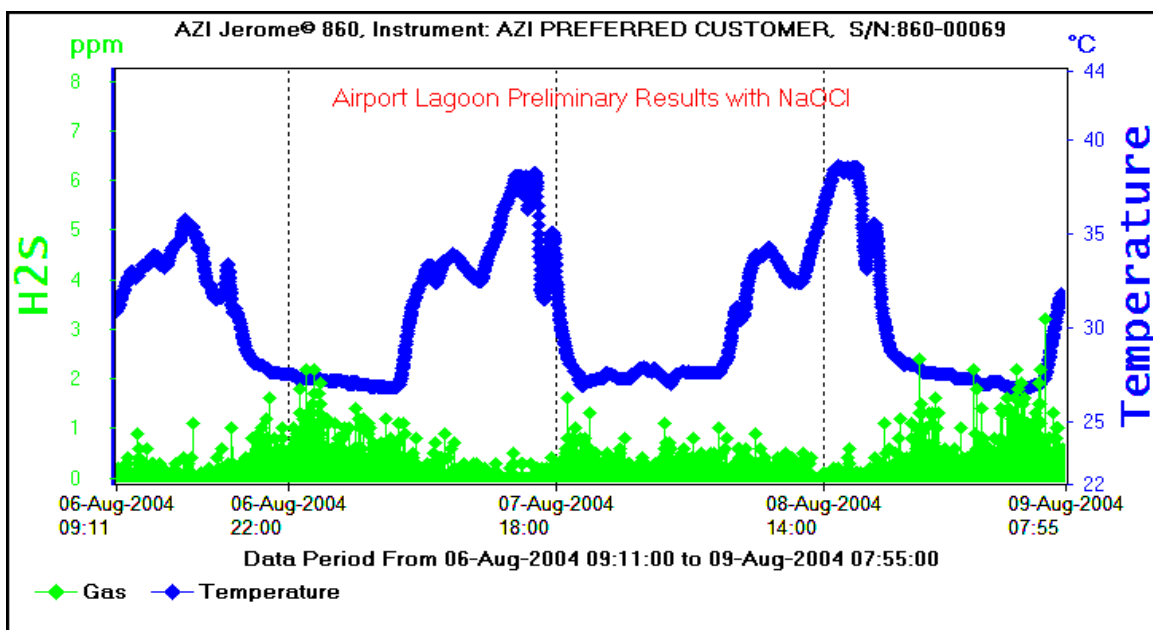


Figure 4.8 Influence of NaOCl on the Air Quality at the Airport Lagoon Treatment Plant

4.1.7 Chemical Comparisons in Relation to H₂S Removal

Similar tests were conducted throughout Phase I in order to compare both oxidants at removing H₂S. Pairwise comparisons were accomplished using the R statistical program in an effort to retrieve the significant differences between the raw data and the data with each chemical. As can be seen from the data collected, the use of both chemicals was significant at removing H₂S. However, further analysis proved that the differences between the raw data and H₂O₂ data at both the Long Bay and Cancryn Lift Stations are of greater significance than the comparisons between the raw wastewater and the wastewater with NaOCl. (Shown in Table 4.8) On the other hand, it was proven that the differences between the raw conditions and conditions after the addition of each chemical at the Airport Lagoon Treatment Plant were not significant (also shown in Table 4.8). These results were consistent with previous field observations which revealed that the wastewater at the lift stations obtained greater H₂S removal efficiencies with the addition of H₂O₂ during the specified testing periods.

Table 4.8 Phase I Pairwise Comparison Results

	P-Values		
	Long Bay	Cancryn	Airport
Raw - H₂O₂	0.000186	0.0000946	0.830023
Raw - NaOCl	0.0091609	0.0006292	0.830023

4.2 Phase II

4.2.1 Influence of H₂O₂ after a 2-year Addition Period to the Systems

After the completion of Phase I, H₂O₂ was added consecutively to the systems for two years before the start of Phase II. Since the addition of H₂O₂, conditions at the facilities may have changed and may have been affected by the chemical performance. If this was the case, those changes would be revealed in the following tables and figures and would be further discussed.

As seen in Tables 4.9 – 4.11, after the 2-year addition of H₂O₂, H₂S levels were reduced at the lift stations. The H₂S concentrations at the Long Bay Lift Station still proved tolerable.

Accordingly, there were no high concentrations of H₂S in the wastewater (average value of .09ppm). However, at the Cancryn Lift Station, there were not as many wastewater data results for H₂S concentrations because of the inability to obtain grab samples. From the data obtained, H₂S concentrations were not as low compared to when H₂O₂ was previously added to the system. This result may have been due to the depletion of H₂O₂ prior to testing. However, H₂O₂ was still being added to the Long Bay Lift Station. As expected, the conditions at the Airport Lagoon Treatment Plant were in no way affected.

H₂S_(g) concentrations averaged 1.16ppm with a maximum of 17.8ppm at the Long Bay Lift Station. The maximum concentration resulted in a spike similar to the measurement obtained during the previous phase of testing while in the presence of H₂O₂. H₂S_(g) levels at the Cancryn Lift Station were considerably higher (average value of 6.94ppm). H₂S_(g) concentration averages were calculated after reviewing measurements for the data points in Figures 4.9 – 4.10. After obtaining H₂S(g) readings at the Airport Lagoon treatment plant (shown in Figure 4.11), it was proven that the addition of H₂O₂ did nothing to improve its conditions. Greater H₂S_(g) concentration measurements were obtained during this testing period.

Table 4.10 Effectiveness of H₂O₂ on H₂S Removal after being Consecutively Added to the Long Bay Lift Station for 2-years

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (µS)	Specific Conductance (µS)
LONG BAY	6/26/2006	810	0.0	0.00	32.8	6.98	-58	0.5	1191	1046
LONG BAY	6/26/2006	1242	0.2	0.11	34.5	6.60	-10	0.5	1104	932
LONG BAY	6/27/2006	815	0.1	0.06	32.3	6.55	-14	0.4	929	817
LONG BAY	6/27/2006	1119	0.3	0.13	33.2	6.77	-18	0.5	1145	988
LONG BAY	6/28/2006	907	0.1	0.02	32.6	7.39	-45	0.5	1225	1068
LONG BAY	6/28/2006	1235	0.3	0.22	32.9	6.30	-53	0.5	1075	932
LONG BAY	6/29/2006	908	0.4	0.10	32.5	7.24	-91	0.5	1235	1082

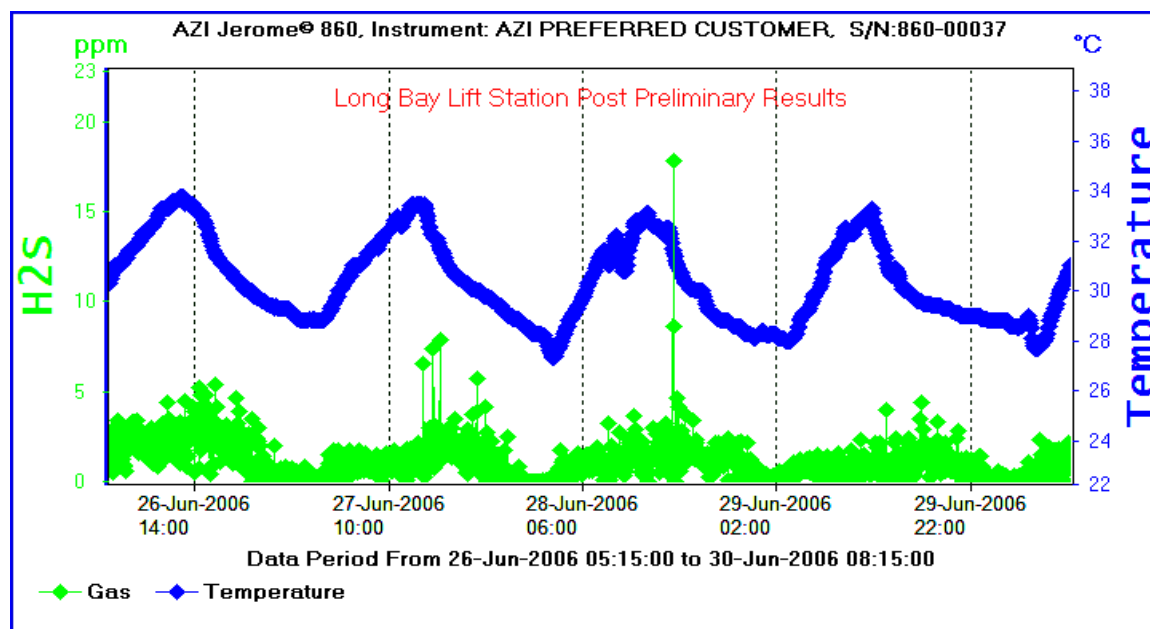


Figure 4.9 Influence of H₂O₂ on the Air Quality at the Long Bay Lift Station after 2-years addition

Table 4.11 The Effect of H₂O₂ on H₂S Removal after being added to the Cancryn Lift Station for Approximately 2-years

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
CANCRYN	6/26/2006	900	*	*	31.9	7.16	*	5.7	11.64	10.27
CANCRYN	6/26/2006	1312	*	*	32.3	7.09	*	4.4	9.07	7.97
CANCRYN	6/27/2006	905	*	*	31.9	7.21	*	5.5	11.16	9.84
CANCRYN	6/27/2006	1205	2.2	0.62	32.1	7.09	-187	5.0	10.27	9.09
CANCRYN	6/28/2006	955	4.0	0.96	31.9	7.16	-213	5.6	11.29	9.98
CANCRYN	6/28/2006	1308	5.0	1.65	32.0	7.01	-193	4.6	9.54	8.43
CANCRYN	6/29/2006	1002	3.8	0.91	31.9	7.24	-210	5.1	10.35	9.15

* Grab samples were unable to be taken.

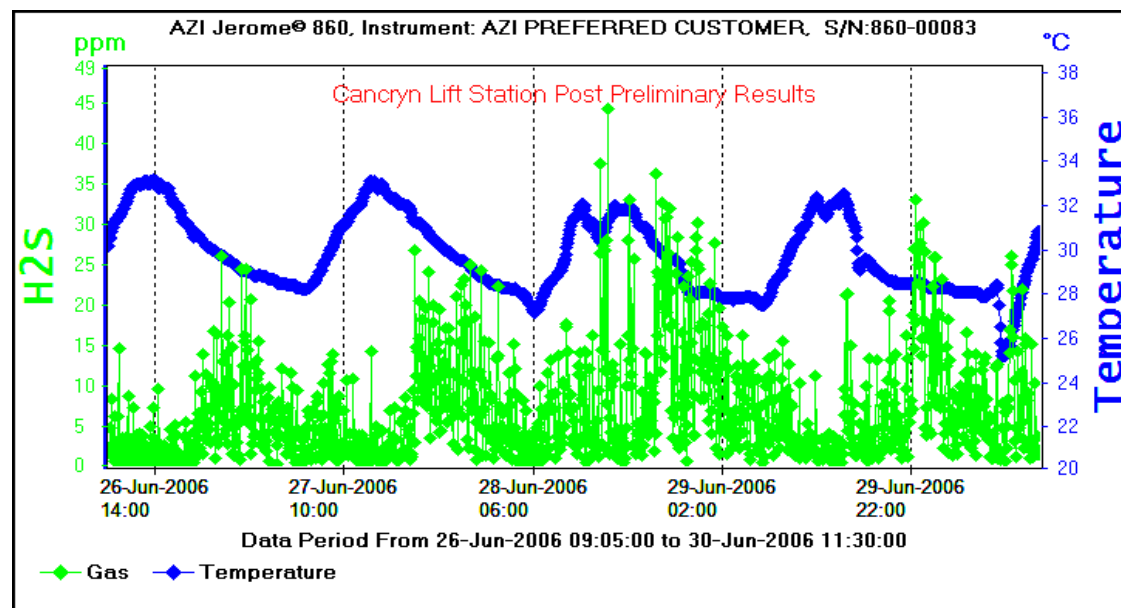


Figure 4.10 Influence of H₂O₂ on the Air Quality at the Cancryn Lift Station after an Approximate 2-year Addition Period

Table 4.12 Effectiveness of H₂O₂ on H₂S Removal at the Lagoon Treatment Plant after Being Added to the Facility for 21-months

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
AIRPORT	6/26/2006	930	9.0	2.52	31.9	7.08	-263	7.8	15.30	13.82
AIRPORT	6/26/2006	1523	11.0	3.63	32.3	7.01	-270	4.6	9.61	8.44
AIRPORT	6/27/2006	935	15.0	3.60	32.0	7.19	-266	7.9	15.75	13.83
AIRPORT	6/27/2006	1305	14.0	3.36	32.4	7.15	-290	4.9	10.05	8.80
AIRPORT	6/28/2006	1050	11.0	2.20	32.0	7.25	-283	7.1	14.08	12.47
AIRPORT	6/28/2006	1403	11.0	2.64	32.2	7.18	-312	5.3	10.90	9.59
AIRPORT	6/29/2006	1102	12.0	2.40	32.1	7.32	-306	6.6	13.32	11.78

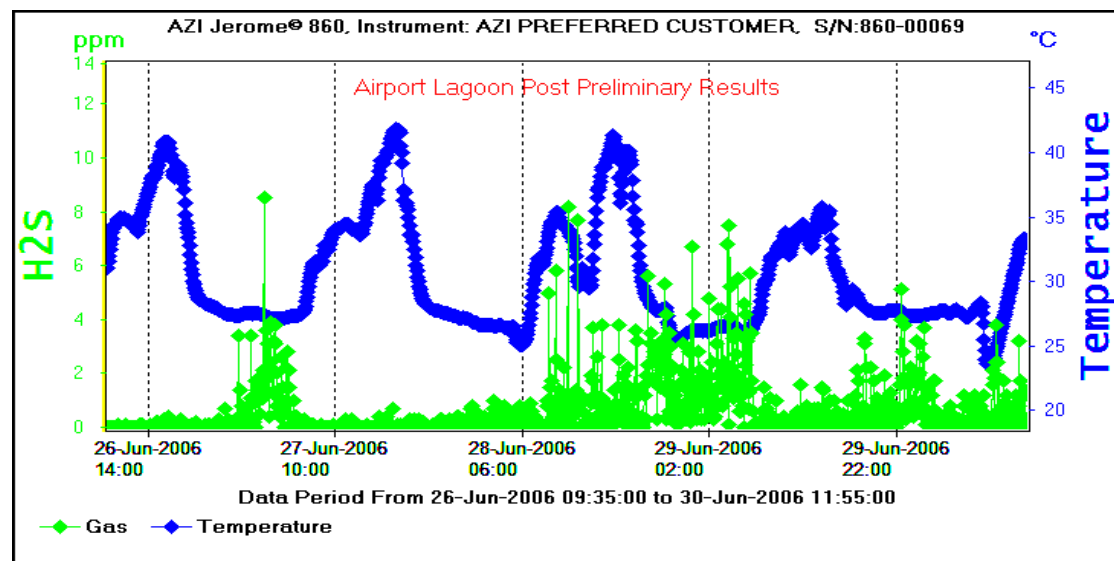


Figure 4.11 Influence of H₂O₂ on the Air Quality at the Airport Lagoon Treatment Plant after Being Added for 21-months

4.2.2 Effect of H₂O₂ Addition compared to Phase I Raw Conditions

The data presented in Table 4.13 indicated that supplying H₂O₂ consecutively for two years to the wastewater systems were significant but only to the lift stations. It can be seen by comparing Tables 4.9 and 4.13, because of the lack of chemical supply to the system there was a drop in significance at the Cancryn Lift Station.

Table 4.13 Phase II Pairwise Comparison Results

	P-Values		
	Long Bay	Cancryn	Airport
Raw - H ₂ O ₂	0.0001878	0.0038334	0.7703015

4.3 Phase III

4.3.1 Laboratory Test Results

The laboratory performance of H₂O₂ and KMnO₄ in regard to H₂S removal is documented by the data in Tables 4.14 - 4.15. Initial tests (on raw conditions) were completed in the field and then grab samples were transported to the Mangrove Lagoon Laboratory for testing. During transport, the grab samples were not preserved. As a result, during laboratory testing it was observed that temperature values decreased and pH values increased. However, throughout testing the values for the measured parameters remained consistent. Based on the Long Bay Lift Station sample data, 100% H₂S removal was achieved after two drops of H₂O₂ whereas three drops of KMnO₄ was used for the removal efficiency for the grab sample. From the Cancryn Lift Station sample data, one drop of H₂O₂ resulted in 100% H₂S removal with KMnO₄ still utilizing three drops for the removal efficiency. The results of the chemical performances at oxidizing H₂S are a representation of the potency of the chemical. The 50% H₂O₂ by weight uses far more oxygen by weight than 5% KMnO₄: one drop of KMnO₄ used 6.08mg of O compared to the 141.18mg used by H₂O₂. In this regard, note that H₂O₂ is again successful at removing H₂S from the wastewater sample.

Table 4.14 Laboratory Results on the Chemical Performance of H₂O₂ and KMnO₄ on H₂S Removal for the Long Bay Lift Station's Wastewater Sample

Sample Location	Date	Chemical Used	# Drops	LIQUID SAMPLE RESULTS						
				Dissolved Sulfide (ppm)	Liquid H ₂ S (ppm)	Temp. (°C)	pH	Salinity (ppt)	Conductance (µS)	Specific Conductance (µS)
LONG BAY	7/21/2006	None	None	1.00	0.50	32.0	6.67	0.6	1429	1260
LONG BAY	7/21/2006	H ₂ O ₂	1	0.10	0.02	24.2	7.38	0.3	599	608
LONG BAY	7/21/2006	KMnO ₄	1	0.40	0.07	24.9	7.40	0.6	1266	1270
LONG BAY	7/21/2006	H ₂ O ₂	2	0.00	0.00	23.8	7.40	0.6	1153	1182
LONG BAY	7/21/2006	KMnO ₄	2	0.10	0.01	23.6	7.49	0.6	1241	1283
LONG BAY	7/21/2006	H ₂ O ₂	3	0.00	0.00	22.8	7.43	0.6	1208	1266
LONG BAY	7/21/2006	KMnO ₄	3	0.00	0.00	23.2	7.61	0.6	1172	1214
LONG BAY	7/21/2006	H ₂ O ₂	4	0.00	0.00	22.8	7.37	0.6	1209	1260
LONG BAY	7/21/2006	KMnO ₄	4	0.00	0.00	23.1	7.60	0.6	1185	1229
LONG BAY	7/21/2006	H ₂ O ₂	5	0.00	0.00	23.3	7.43	0.6	1175	1214
LONG BAY	7/21/2006	KMnO ₄	5	0.00	0.00	23.0	7.56	0.6	1146	1191

Table 4.15 Laboratory Results on the Chemical Performance of H₂O₂ and KMnO₄ on H₂S Removal for the Cancryn Lift Station's Wastewater Sample

Sample Location	Date	Chemical Used	# Drops	LIQUID SAMPLE RESULTS						
				Dissolved Sulfide (ppm)	Liquid H ₂ S (ppm)	Temp. (°C)	pH	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
CANCRYN	7/24/2006	None	None	4.00	0.80	31.8	7.25	7.5	14.80	13.10
CANCRYN	7/24/2006	H ₂ O ₂	1	0.00	0.00	25.6	7.39	7.1	12.55	12.42
CANCRYN	7/24/2006	KMnO ₄	1	0.80	0.09	25.3	7.60	7.0	12.28	12.25
CANCRYN	7/24/2006	H ₂ O ₂	2	0.00	0.00	23.6	7.38	7.3	12.33	12.72
CANCRYN	7/24/2006	KMnO ₄	2	0.50	0.06	25.4	7.59	6.9	12.12	12.08
CANCRYN	7/24/2006	H ₂ O ₂	3	0.00	0.00	23.7	7.44	7.3	12.32	12.66
CANCRYN	7/24/2006	KMnO ₄	3	0.00	0.00	27.9	7.72	7.0	12.92	12.24
CANCRYN	7/24/2006	H ₂ O ₂	4	0.00	0.00	25.6	7.50	7.3	12.98	12.79
CANCRYN	7/24/2006	KMnO ₄	4	0.00	0.00	26.2	7.76	7.3	13.07	12.72
CANCRYN	7/24/2006	H ₂ O ₂	5	0.00	0.00	25.2	7.43	7.2	12.74	12.66
CANCRYN	7/24/2006	KMnO ₄	5	0.00	0.00	26.4	7.71	7.2	12.95	12.54

4.4 Phase IV

4.4.1 Effect of H₂O₂ at the Cancryn Lift Station

Throughout Phase IV, special focus was given to the Cancryn Lift Station for being the most problematic facility with the ability to be transformed. This phase of testing also provided additional data points for analyzing chemical effect and condition changes. The data collected during this testing period (March 6-7, 2007) can be found in Tables 4.16 and 4.17, including data on the raw wastewater and data in the presence of H₂O₂. After comparing both tables (4.16 and 4.17), the addition of H₂O₂ to the Cancryn Lift Station was significant (p-value = .0000973) and resulted in H₂S removals in the range of 41.1 – 100%. However, when comparing data points for test #2 it resulted in a 41.1% H₂S removal. This percent removal was not consistent with the data set and was therefore removed. By removing this data point, the addition of H₂O₂ resulted in an average 93.5% removal.

Data provided in Table 4.18 display the correlations between specific wastewater parameters and H₂S. Review of the data indicated that there were strong correlations between the dissolved sulfides and H₂S. From the given data, the odor emanating from the lift station is evidently sulfide-based. As can be seen, under raw conditions, increasing H₂S concentrations are generated with the decrease in pH. After the application of H₂O₂, ORP levels became strongly correlated to H₂S.

Comparing emission concentrations (Figures 4.12 and 4.13) under both conditions (raw and in the presence of H₂O₂) did not show any significant effect. Prior to chemical addition, H₂S_(g) concentrations averaged 4.23ppm. In the presence of H₂O₂, it averaged 3.72ppm resulting in a mere 12.1% removal. However, the existing facility conditions may have compromised this result. Such conditions may include but are not limited to pipes not being completely filled during transport, change in the inflow, extended sitting times in the pipes, and/or longer stagnant periods at the systems.

Table 4.16 Raw Wastewater Results for the Cancryn Lift Station

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved Sulfide (ppm)	Liquid H ₂ S (ppm)	Temp. (°C)	pH	ORP (mV)	Salinity (ppt)	Conductance (mS)	Specific Conductance (mS)
CANCRYN	3/6/2007	1018	7.3	2.40	30.9	7.02	-314	8.1	15.63	14.05
CANCRYN	3/6/2007	1030	3.4	0.95	30.9	7.11	-336	7.6	14.83	13.36
CANCRYN	3/6/2007	1100	6.2	1.74	32.3	7.07	-310	8.0	15.84	13.87
CANCRYN	3/6/2007	1107	5.2	1.72	30.9	7.02	-319	8.5	16.19	14.63
CANCRYN	3/6/2007	1122	6.3	3.84	30.6	6.51	-284	10.3	19.11	17.48
CANCRYN	3/6/2007	1231	5.1	2.24	31.5	6.83	-258	3.7	7.70	6.85
CANCRYN	3/6/2007	1241	5.2	2.29	31.6	6.84	-288	3.7	7.70	6.84

Table 4.17 Influence of H₂O₂ on the Wastewater Quality at the Cancryn Lift Station

Sample Location	Date	Time	LIQUID SAMPLE RESULTS							
			Dissolved	Liquid H ₂ S	Temp.	pH	ORP	Salinity	Conductance	Specific Conductance
			Sulfide (ppm)	(ppm)	(°C)		(mV)	(ppt)	(mS)	(mS)
CANCRYN w/ H ₂ O ₂	3/7/2007	943	1.0	0.24	31.0	7.19	-116	7.7	14.86	13.37
CANCRYN w/ H ₂ O ₂	3/7/2007	1008	3.3	0.56	30.9	7.36	-273	8.1	15.71	14.12
CANCRYN w/ H ₂ O ₂	3/7/2007	1016	0.0	0.00	30.9	7.20	-11	8.3	16.03	14.45
CANCRYN w/ H ₂ O ₂	3/7/2007	1041	0.4	0.11	31.0	7.12	-52	8.2	15.84	14.22
CANCRYN w/ H ₂ O ₂	3/7/2007	1138	0.2	0.07	31.1	7.02	-40	8.6	16.66	14.92
CANCRYN w/ H ₂ O ₂	3/7/2007	1208	0.5	0.17	30.8	6.98	-86	9.1	17.51	15.77
CANCRYN w/ H ₂ O ₂	3/7/2007	1243	0.7	0.31	31.0	6.84	-67	9.3	17.41	15.90

Table 4.18 Phase IV Correlation Matrices

Cancryn Raw					
	Dis. Sulfide	H ₂ S	Temp.	pH	ORP
Dis. Sulfide	1				
H ₂ S	0.6198209	1			
Temp.	0.0508908	-0.31162	1		
pH	-0.2663993	-0.91712	0.32151	1	
ORP	0.215869	0.607818	0.193684	-0.70241	1

Cancryn with H ₂ O ₂					
	Dis. Sulfide	H ₂ S	Temp.	pH	ORP
Dis. Sulfide	1				
H ₂ S	0.9407356	1			
Temp.	-0.2267308	-0.185	1		
pH	0.6019709	0.32623	-0.196	1	
ORP	-0.9877971	-0.93202	0.275659	-0.58433	1

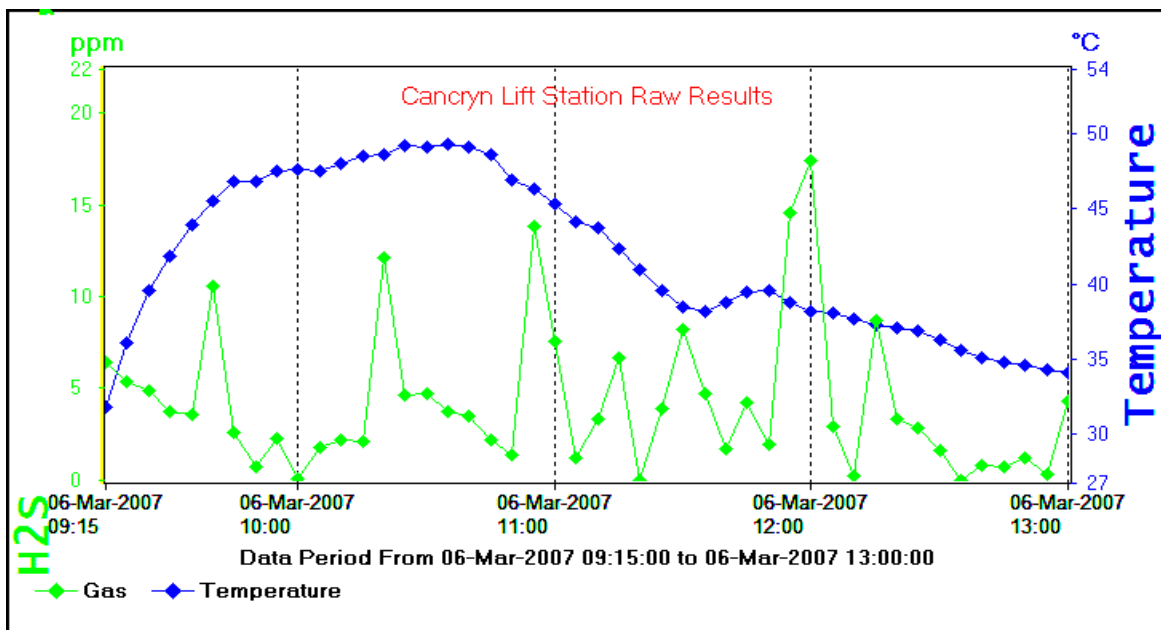


Figure 4.12 Raw H₂S_(g) Concentration Levels at the Cancryn Lift Station

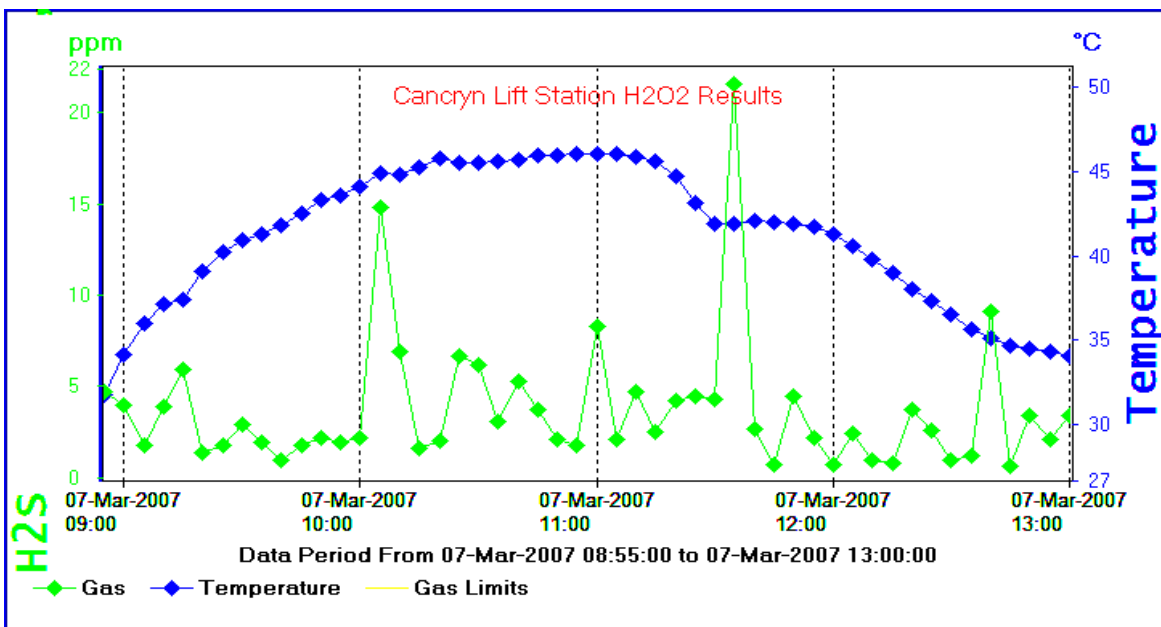


Figure 4.13 Influence of H₂O₂ on the Air Quality at the Cancryn Lift Station

4.5 Overall Correlation and Chemical Trends

Review of the data obtained after field results indicated certain correlation trends. However, by investigating only the field results, Phase III and KMnO_4 were eliminated from the discussion. Comparison across phases revealed strong correlation trends between dissolved sulfides and H_2S and ORP and H_2S , positive and negative respectively. These trends were observed for every facility tested except for the Airport Lagoon Treatment Plant. Therefore, it was proven that the odor problem at the lift stations were highly due to the release of dissolved sulfides. Field tests were conducted at the Cancryn Lift Station throughout each phase reviewed. As a result, along with the previously stated trends, the expected correlation trends between temperature and H_2S and pH and H_2S were obtained with the exception of temperature and H_2S during Phase II. However, the correlations were not strong.

Correlation trends were also investigated across chemical addition. The data provided indicated that at the lift stations all expected correlation trends were met during H_2O_2 addition. During that time, the Long Bay Lift Station showed strong correlations between temperature and H_2S and pH and H_2S . However, the Cancryn Lift Station only displayed a strong positive correlation between dissolved sulfides and H_2S . On the other hand, the use of NaOCl at the systems showed strong positive correlations between dissolved sulfides and H_2S at both lift stations with the addition of a strong negative correlation between ORP and H_2S at the Cancryn Lift Station. Based on the data obtained, the use of H_2O_2 provided stronger correlations.

In addition to correlation trends, chemical performance across phases and facilities were also examined. From the data provided it was proven that H_2O_2 showed greater H_2S removal efficiencies throughout each phase for each lift station. Although H_2O_2 may not be the most cost effective chemical choice, its performance greatly outweighed its cost. On the other hand, the Airport Lagoon Treatment Plant displayed no change in its conditions under any circumstance.

5 CONCLUSIONS

The aim of this study was to investigate the characteristics of the wastewater at the following wastewater facilities; Long Bay Lift Station, Cancryn Lift Station and the Airport Lagoon Treatment Plant. This research focused on choosing the most effective chemical of the three selected (H_2O_2 , NaOCl , and KMnO_4) at removing H_2S from the wastewater facilities in an effort to mitigate odor emissions. Throughout each phase, H_2O_2 have shown proven ability at H_2S removal at the lift stations. During Phase I, H_2O_2 was significantly greater (p-value $<.0002$) at reducing H_2S concentrations in comparison to NaOCl . H_2O_2 application during Phase II was also significant (p-value $<.004$) when compared to the raw conditions obtained during Phase I. Although there was a noticeable change in the wastewater characteristics throughout this phase of testing, H_2O_2 was still capable of impacting the facilities significantly. Laboratory tests also revealed impressive results when compared to KMnO_4 . In addition, the use of H_2O_2 at the Cancryn Lift Station was significant, p-value $=.0001$.

$\text{H}_2\text{S}_{(\text{g})}$ concentrations also reduced significantly throughout the presence of H_2O_2 at the lift stations. Although H_2O_2 generated change throughout Phase II, the 2-year span between Phase I and II caused results to vary. $\text{H}_2\text{S}_{(\text{g})}$ levels at the Long Bay Lift Station continued to improve. However, the lack of chemical supply greatly affected the Cancryn Lift Station resulting in higher emission averages. Likewise, during Phase IV $\text{H}_2\text{S}_{(\text{g})}$ concentrations produced greater averages. Other factors may have impacted these results and will be later discussed.

The Airport Lagoon Treatment Plant displayed no significant change in conditions with the addition of either chemical. Chemical addition at the treatment plant was useless due to the facility's inability to adequately treat the influent. The extreme conditions at the lagoon treatment plant can only be improved after corrective actions have been implemented to upgrade the facility.

As evidenced by data presented herein, chemical oxidation by use of H_2O_2 is capable of H_2S reduction at wastewater collection systems. Literature review has shown its proven ability at wastewater treatment plants; however, the inability of the lagoon treatment plant in this study to

operate efficiently could not prove this. On the other hand, chemical performance on odor emission removal efficiencies changed significantly throughout this study. Based on observation, $\text{H}_2\text{S}_{(\text{g})}$ levels fluctuated overtime. Overall, evaluation of $\text{H}_2\text{S}_{(\text{g})}$ levels proved significant. However, throughout the latter part of this study, H_2O_2 was unable to achieve high $\text{H}_2\text{S}_{(\text{g})}$ removal rates. It is believed that removal efficiencies were greatly affected by the physical system conditions. Therefore, further investigation is required to accurately evaluate chemical performance on $\text{H}_2\text{S}_{(\text{g})}$ removal in an effort to improve odor emissions.

5.1 Research Limitations

Throughout the scope of this study, certain problems were encountered that may have affected the results of testing. Those shortcomings however, are greatly related to the existing site conditions. The wastewater discharged from the Long Bay Lift Station is pumped uphill to a point where gravity will continue its transport in an effort to reach the Cancryn Lift Station. Based on site observation, the gradient is unable to properly handle the transport. Therefore, transport times are increased creating additional problems to the sewer, collection and treatment systems. However, no additional tests were conducted to support this theory. Nevertheless, there is a possibility that the wastewater stays in the pipes and turns septic. A large flow would be required for the wastewater to continue its journey to the Cancryn Lift Station. However, due to the emission levels obtained prior to and after treatment at the Cancryn Lift Station it appears as though the pipes are barely filled to capacity throughout this process. These conditions may have reduced the effectiveness of each chemical's performance.

Throughout this study, there were also some equipment shortcomings that hampered testing. During Phase II, grab samples was unable to be retrieved from the Cancryn Lift Station. Also, a few days prior to Phase II testing the supply of H_2O_2 depleted and was unable to be replenished. Thus, testing had to be conducted in the absence of H_2O_2 at the facility. In addition, throughout Phase III, the ORP monitor broke. The lack of equipment to provide testing on certain occasions resulted in limited data points.

As stated in Section 3.1, the Airport Lagoon Treatment Plant has been unsuccessful at treating its daily wastewater loads. It was designed to treat a peak flow of 4.0 MGD and sometimes receive larger volumes in the absence of a sufficient sludge handling and disposal system. The facility was constructed with pipes located to the bottom of basin #2 to adequately collect the sludge but have been unable to do so. As an aid, sludge pump trucks remove approximately 9000gal/d. Yet, no improvements are made. In addition, accurate emission rates were unable to be obtained based on wind direction. Often times, $H_2S_{(g)}$ levels appeared lower than the actual odor observed as a result of the wind directing odor emissions away from the gas monitor.

5.2 Recommendations

In an effort to improve the conditions at the previously stated facilities the following recommendations should be considered. During this study, the existing conditions at the wastewater lift stations were unpleasant. The composition of the discharge water from wastewater collection facilities is pertinent to the conditions at the facility. Therefore the lift stations should be properly maintained.

In addition, the sewer pipes needs to be investigated due to the increasing possibilities of deterioration. Further research is needed to explore the effect of the sewer pipes on the air and wastewater quality at the facilities; paying special attention to the pipes between the Long Bay and Cancryn Lift Station. Investigating the current sewer pipe conditions would reveal the potential problems for which upgrades are needed. Following this research, in the event upgrades are made, additional tests should be conducted similar to those in this study for comparison.

Finally, the design and construction of a wastewater treatment plant to replace the Airport Lagoon Treatment Plant is highly recommended. The treatment plant should integrate unit processes and/or operations to effectively and efficiently handle and treat the wastewater currently directed to the Lagoon Treatment Plant.

APPENDIX A

Performance data for the Airport Lagoon Treatment Plant during the testing period for this study are provided in the following tables. The first table for each month of testing is an operations log. This table provides wastewater characteristics for the influent and effluent of the treatment plant. Measurements were taken at the headworks and prior to discharge. Also included was the discharge monitoring reports (DMRs) that were obtained one mile offshore from the treatment plant. As can be seen from the DMRs, effluent BOD₅ and suspended solid measurements did not meet the required National Pollutant Discharge Elimination System (NPDES) limits.

Table A.1 Daily Operations Log for the Airport Lagoon Treatment Plant for July 2004

DAILY OPERATIONS LOG
CHARLOTTE AMALIE WWTP
(AIRPORT LAGOON)
July 2004

Date	TIME		Operator Signature	Influent					Aeration Units No. 1			Aeration Units No. 2			Effluent					
	IN	OUT		Totalizer	Flow	D.O.	pH	Temp.	D.O.	pH	Temp.	D.O.	pH	Temp.	695783	Flow	D.O.	pH	Temp.	TRC
1	7:00	3:30	SA	331.9	0.750	0.07	7.0		0.0	7.0	27.6	0.0	7.0	27.6	699432	3.4	0.0	7.0	28.2	0.1
2	7:00	3:30	SA	332.64	0.740	0.08	7.0		0.02	7.0	27.9	0.02	7.1	27.9	738395	3.649	0.02	7.0	28.3	0.04
3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5	8:00	11:00	SA	334.55	0.191	0.06	7.0	27.8	0.02	7.0	27.8	0.02	7.0	27.8	709674	10.242	0.02	7.0	28.4	0.03
6	7:00	3:30	SA	334.85	0.300	0.08	7.0	27.7	0.02	7.0	27.7	0.02	7.0	27.7	710849	1.175	0.02	7.0	27.9	0.00
7	7:00	3:30	SA	335.66	0.810	0.08	7.0	27.6	0.02	7.0	27.6	0.02	7.0	27.6	714821	3.972	0.02	7.0	27.6	0.00
8	7:00	3:30	SA	336.44	0.780	0.06	7.0	27.3	0.02	7.0	27.3	0.02	7.0	27.3	718166	3.345	0.02	7.0	27.6	0.00
9	7:00	3:30	SA	337.15	0.710	0.07	7.1	27.8	0.02	7.0	27.8	0.02	7.0	27.8	721555	3.389	0.02	7.0	27.6	0.00
10	7:00	8:30	CF	337.80	0.650	0.03	7.1	28.3	0.02	7.0	28.3	0.02	7.0	28.3	724866	3.311	0.02	7.0	28.4	0.00
11	10:30	11:30	CF	338.58	0.780	0.04	7.1	29.4	0.02	7.0	29.4	0.02	7.0	29.4	728659	3.993	0.02	7.0	29.4	0.00
12	7:00	3:30	SA	336.16	0.580	0.06	7.0	25.5	0.02	7.0	25.5	0.02	7.0	25.5	731553	2.894	0.02	7.0	29.8	0.00
13	7:00	3:30	SA	339.90	0.740	0.07	7.0	29.4	0.02	7.0	29.4	0.02	7.0	29.4	735117	3.564	0.02	7.0	29.6	0.00
14	7:00	3:30	SA	340.60	0.700	0.06	7.0	29.4	0.03	7.0	29.4	0.03	7.0	29.4	738395	3.278	0.02	7.0	29.5	0.00
15	11:15	-	RD	340.73	1.130	0.12	7.0								741709	3.314	0.92	7.0	29.9	0.00
16	7:00	3:30	SA	342.08	0.350	0.08	7.1	28.9	0.02	7.0	28.9	0.02	7.0	28.9	745143	3.434	0.02	7.0	29.7	0.00
17	8:00	9:00	CF	342.81	0.730	0.07	7.1	28.8	0.02	7.1	28.8	0.02	7.0	28.8	748525	3.382	0.02	7.0	29.8	0.00
18	6:30	7:30	CF	343.50	0.710	0.07	7.0	29.6	0.02	7.0	29.6	0.02	7.1	29.6	752194	3.669	0.02	7.1	29.8	0.00
19	7:00	3:30	CF	343.85	0.350	0.08	7.0	29.5	0.02	7.1	29.5	0.02	7.0	29.5	754693	2.499	0.02	7.0	29.8	0.00
20	7:00	3:30	SA	344.50	0.650	0.06	7.0	28.9	0.02	7.0	28.9	0.02	7.0	28.9	758087	3.394	0.02	7.0	29.6	0.00
21	7:00	3:30	SA	345.63	1.130	0.07	7.2	28.8	0.02	7.0	28.8	0.02	7.0	28.8	762280	4.193	0.02	7.0	29.6	0.00
22	7:00	3:30	SA	346.40	0.770	0.02	7.1	29.3	0.06	7.0	29.3	0.06	7.1	29.3	765482	3.202	0.02	7.0	29.3	0.00
23	7:00	3:30	SA	347.18	0.780	0.03	7.0	29.6	0.04	7.0	29.6	0.04	7.0	29.6	768715	3.233	0.03	7.0	29.7	0.00
24	8:30	9:30	SA	347.69	0.510	0.03	7.1	29.5	0.03	7.1	29.5	0.03	7.0	29.5	771052	2.370	0.02	7.1	29.5	0.00
25	7:30	8:30	SA	348.88	0.190	0.02	7.1	29.5	0.03	7.0	29.5	0.03	7.0	29.5	774962	3.910	0.02	7.0	29.4	0.00
26	7:00	3:30	SA	345.84	0.960	0.06	7.0	29.4	0.03	7.0	29.4	0.03	7.0	29.4	778173	3.211	0.02	7.0	29.6	0.00
27	7:00	3:30	SA	350.86	1.020	0.04	7.0	29.6	0.03	7.0	29.6	0.03	6.9	29.6	781684	3.511	0.03	7.0	29.8	0.00
28	7:00	3:30	SA	351.77	0.910	0.06	7.0	29.5	0.03	7.0	29.5	0.03	7.0	29.5	784742	3.058	0.03	7.0	29.7	0.00
29	7:00	3:30	SA		1.180	0.07	6.9	30.9	0.06	7.1	30.9	0.06	6.8	30.9	788476	3.734	0.03	7.0	30.5	0.00
30	7:00	3:30	SA		1.140	0.06	7.0	30.8	0.05	7.1	30.8	0.05		30.1	792242	3.766	0.03	7.0	30.5	0.00
31	8:00	9:00	CF		1.040	0.07	6.8	29.8	0.05	7.1	29.8	0.06		29.8	795715	3.414	0.03	7.0	29.9	0.00
Total					19.791											96.457				
Avg.					0.733	0.060	7.026	29.0	0.03	7.0	28.9	0.03	7.0	28.9		3.572	0.06	7.0	29.3	0.0
Min.					0.190	0.020	6.800	25.5	0.02	7.0	25.5	0.02	6.8	25.5		1.175	0.02	7.0	27.6	0.0
Max					1.180	0.120	7.200	30.9	0.06	7.1	30.9	0.06	7.1	30.9		10.242	0.92	7.1	30.5	0.0

Influent flow meter inoperable

Table A.2 Discharge Monitoring Report for the Airport Lagoon Treatment Plant for July 2004 (p1)

DISCHARGE MONITORING REPORT																														
PERMITTEE NAME/ADDRESS: Department of Public Works Charlotte Amalie WWTP 8244 Subbase St. Thomas					VI0020044 PERMIT NUMBER		001 A DISCHARGE NUMBER		MAJOR F - FINAL																					
FACILITY: Charlotte Amalie WWTP LOCATION: Charlotte Amalie					VI00802 VI 00801		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="6">MONITORING PERIOD</th> </tr> <tr> <th>YEAR</th> <th>MO</th> <th>DAY</th> <th>YEAR</th> <th>MO</th> <th>DAY</th> </tr> <tr> <td>2004</td> <td>07</td> <td>01</td> <td>2004</td> <td>07</td> <td>31</td> </tr> </table>			MONITORING PERIOD						YEAR	MO	DAY	YEAR	MO	DAY	2004	07	01	2004	07	31	FROM TO *** NO DISCHARGE ☐ ***		
MONITORING PERIOD																														
YEAR	MO	DAY	YEAR	MO	DAY																									
2004	07	01	2004	07	31																									
ATTN: Director																														
PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX.	FREQUENCY OF ANALYSIS	SAMPLE TYPE																			
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS																						
Temperature, Water Deg. Centigrade 00010 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	29.3	30.5	(04)	0	1/1	Grab																			
	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Average	32.2 Daily Maximum	Deg. C		Daily	GRAB																			
BOD, 5-DAY (20 DEG. C) 00310 G 0 0 Raw Sewage Influent	SAMPLE MEASUREMENT	*****	*****	*****	*****	154	180.5	(19)	0	1/7	24 Hr Composite																			
	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Monthly Avg.	Report Weekly Max.	mg/l		Weekly	COMPOSITE																			
BOD, 5-DAY (20 DEG. C) 00310 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	108	*****	(19)	3	1/7	24 Hr Composite																			
	PERMIT REQUIREMENT	*****	*****	*****	*****	100 Monthly Avg.	*****	mg/l		Weekly	COMPOSITE																			
pH 00400 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	7.0	*****	7.1	(12)	0	1/1	Grab																		
	PERMIT REQUIREMENT	*****	*****	*****	*****	6.0 Minimum	*****	9.0 Maximum	SU		Daily	GRAB																		
Solids, Total Suspended 00530 G 0 0 Raw Sewage Influent	SAMPLE MEASUREMENT	*****	*****	*****	*****	170	196.3	(19)	0	1/7	24 Hr Composite																			
	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Monthly Avg.	Report Weekly Max.	mg/l		Weekly	COMPOSITE																			
Solids, Total Suspended 00530 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	26.3	*****	(19)	0	1/7	24 Hr Composite																			
	PERMIT REQUIREMENT	*****	*****	*****	*****	40 Monthly Avg.	*****	mg/l		Weekly	COMPOSITE																			
Toxicity 03598 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	*****	*****	CODE 9	(2F)																					
	PERMIT REQUIREMENT	*****	*****	*****	*****	*****	*****	Report Daily Mx	Acute Toxicity	Quarterly	GRAB																			
NAME/TITLE		I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.						Telephone		Date																				
PRINCIPAL EXECUTIVE OFFICER								(340) 714-5171		04/08/17																				
Ronald DeRossett Operations Manager								SIGNATURE OR PRINCIPLE EXECUTIVE OFFICER OR AUTHORIZED AGENT		Area Code / No. Yr / Mo / Day																				
TYPED OR PRINTED																														
COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here): THERE SHALL BE NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS. FECAL COLIFORM SHALL ALSO BE MONITORED AT THE END OF THE 400 METER MIXING ZONE. SEE PERMIT FOR ADDITIONAL REQUIREMENTS.																														

Table A.3 Discharge Monitoring Report for the Airport Lagoon Treatment Plant for July 2004 (p2)

Page 1 of 2

DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS: Department of Public Works

Charlotte Amalie WWTP

8244 Subbase

St. Thomas

VI 00802

FACILITY: Charlotte Amalie

LOCATION: Charlotte Amalie

VI00801

VI0020044

PERMIT NUMBER

001 A

DISCHARGE NUMBER

Major

F - FINAL

MONITORING PERIOD

YEAR	MO	DAY
2004	07	01

YEAR	MO	DAY
2004	07	31

FROM

TO

*** NO DISCHARGE

ATTN: Director

PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX.	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
Flow, In conduit or thru treatment plan 50050 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	3.572	*****	(03)	*****	*****	*****		0	99/99	Continuous
	PERMIT REQUIREMENT	4.0 Mo Avg	*****	MGD	*****	Report Average	Report Daily Max.	*****		Continuous	CALCULATED
Chlorine, Total Residual 50060 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****		*****	*****	0.0	(20)	0	1/1	Grab
	PERMIT REQUIREMENT	*****	*****	*****	*****	*****	2.0 Daily Max.	PPM		Daily	GRAB
Coliform, Fecal General 74055 1 0 0 Effluent Gross Value	MEASUREMENT	*****	*****	*****	*****	*****	89	(13)	0	1/7	Grab
	REQUIREMENT	*****	*****	*****	*****	*****	10000 Daily Mx	#/100ml		Weekly	GRAB
BOD, 5-day Percent Removal 81010 K 0 0 Percent Removal	MEASUREMENT	*****	*****	*****	*****	29.8	*****	(23)	2	01 / 30	Calculated
	REQUIREMENT	*****	*****	*****	*****	30 Mo Avg	*****	Per-Cent		Once/Month	CALCULATED
Solids, Suspended Percent Removal 81011 K 0 0 Effluent Gross Value	MEASUREMENT	*****	*****	*****	*****	84.6	*****	(23)	0	1/30	Calculated
	REQUIREMENT	*****	*****	*****	*****	60 Mo Avg	*****	Per-cent		Once/Month	CALCULATED

NAME/TITLE
PRINCIPAL EXECUTIVE OFFICERRonald DeRossett
Operations Manager

TYPED OR PRINTED

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

SIGNATURE OR PRINCIPLE EXECUTIVE
OFFICER OR AUTHORIZED AGENT

Telephone

Date

(340)714-5171

04/08/17

Area Code / No.

Yr / Mo / Day

COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here):

THERE SHALL BE NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS. FECAL COLIFORM SHALL ALSO BE MONITORED AT THE END OF THE 400 METER

Table A.4 Daily Operations Log for the Airport Lagoon Treatment Plant for August 2004

DAILY OPERATIONS LOG
CHARLOTTE AMALIE WWTP
(AIRPORT LAGOON)
August 2004

Date	TIME		Operator Signature	Influent					Aeration Units No. 1			Aeration Units No. 2			Effluent					
	IN	OUT		Totalizer	Flow	D.O.	pH	Temp.	D.O.	pH	Temp.	D.O.	pH	Temp.	Totalizer	Flow	D.O.	pH	Temp.	TRC
1	6:30	7:30	CF	356.03	0.900	0.06	7.0	29.5	0.1	7.0	29.6	0.0	7.0	29.7	798860	3.1	0.0	7.1	29.8	
2	7:00	15:30	SA	357	0.970	0.03	7.0	29.4	0.01	6.9	29.6	0.01	7.0	29.8	802163	3.303	0.02	7.0	29.8	
3	7:00	15:30	SA	357.85	0.850	0.04	7.0	29.6	0.02	6.9	29.7	0.01	7.0	29.8	805669	3.506	0.02	7.0	29.8	
4	7:00	15:30	SA	358.79	0.940	0.08	7.0	31.8	0.02	7.0	29.7	0.02	7.0	29.6	809126	3.457	0.03	7.0	29.8	
5	13:00	13:55	RD	359.43											814145	4.919	1.67	7.4	32.1	
6	7:00	15:30	SA	360.18	2.793	0.02	7.0	31.8	0.02	7.0	30.8	0.02	7.0	30.8	816938	2.793	0.08	7.0	30.3	
7	11:00	7:30	CF	361.70	0.152	0.02	7.0	29.7	0.02	7.0	27.8	0.02	7.0	29.7	820697	3.759	0.05	7.0	29.7	
8	7:30	8:30	CF	362.61	0.910	0.05	7.1	29.8	0.02	7.1	29.6	0.02	7.0	29.6	824566	3.969	0.04	7.0	29.9	
9	7:00	15:30	SA	363.42	0.810	0.03	7.0	29.7	0.02	7.1	29.5	0.02	7.0	29.7	828128	3.562	0.04	7.0	29.9	
10	7:00	15:30	SA	364.24	0.820	0.03	7.0	29.8	0.02	7.1	29.6	0.02	7.0	29.5	832015	3.887	0.03	7.0	29.6	
11	7:00	15:30	SA	365.06	0.820	0.03	7.0	29.7	0.02	7.1	29.5	0.02	7.0	29.6	835865	3.850	0.03	7.0	29.7	
12	10:15	11:45	RD	365.98	0.920	0.13	7.0	31.2							840253	4.388	0.02	6.9	31.0	
13	7:00	15:30	SA	366.74	0.760	0.04	7.0	30.1	0.02	7.1	29.7	0.02	7.0	29.6	843586	3.333	0.02	7.0	30.9	
14	7:30	8:30	CF	367.70	0.960	0.04	7.1	29.6	0.03	7.1	29.6	0.02	7.0	29.6	847867	4.181	0.04	7.0	29.6	
15	8:00	9:00	CF	368.61	0.102	0.04	7.0	29.7	0.04	7.0	29.6	0.02	7.1	29.8	851901	4.034	0.03	7.1	29.0	
16	7:00	15:30	SA	369.41	0.800	0.04	7.0	29.8	0.03	7.0	29.6	0.02	7.1	29.7	855472	3.571	0.02	7.1	29.7	
17	7:00	15:30	SA	370.21	0.800	0.03	7.0	29.8	0.03	7.0	29.6	0.02	7.1	29.5	859343	3.871	0.02	7.1	29.5	
18	7:00	15:30	SA	370.79	0.770	0.04	7.0	29.4	0.03	7.0	29.6	0.02	7.1	29.5	863222	3.879	0.02	7.1	29.6	
19	7:00	15:30	SA	371.79	1.000	0.03	7.0	29.5	0.03	7.0	29.5	0.02	7.1	29.4	867199	3.977	0.02	7.1	29.7	
20	7:00	15:30	SA	372.65	0.860	0.03	7.0	29.6	0.03	7.0	29.5	0.02	7.1	29.3	871342	4.143	0.02	7.1	29.6	
21	8:00	9:00	CF	373.46	0.810	0.03	7.0	29.6	0.03	7.0	29.6	0.02	7.1	29.4	875506	4.164	0.02	7.0	29.5	
22	6:30	7:30	SA	374.17	0.710	0.03	7.0	29.8	0.03	7.1	29.6	0.02	7.0	29.6	879332	3.826	0.02	7.0	29.6	
23	7:00	15:30	SA	374.92	0.750	0.04	7.1	29.6	0.03	7.1	29.6	0.02	7.0	29.5	883333	4.001	0.02	7.0	29.5	
24	7:00	15:30	SA	376.30	1.380	0.04	7.1	29.7	0.05	7.1	29.7	0.02	7.0	29.6	889010	6.323	0.02	7.0	29.6	
25	7:00	15:30	SA	377.37	1.070	0.03	7.1	29.6	0.03	7.1	29.6	0.02	7.0	29.4	893166	4.156	0.02	7.0	29.5	
26	7:00	15:30	SA	378.36	0.990	0.03	7.0	29.8	0.02	7.1	26.7	0.02	7.0	29.6	897291	4.125	0.02	7.0	29.7	
27	7:00	15:30	SA	379.49	1.130	0.03	7.0	29.9	0.02	7.1	29.5	0.02	7.0	29.5	901631	4.340	0.02	7.0	29.8	
28	8:00	9:00	CF	380.89	0.140	0.03	7.1	29.8	0.02	7.0	29.9	0.02	7.0	29.8	906648	5.017	0.02	7.0	29.7	
29	8:30	9:30	CF	382.27	0.138	0.03	7.0	29.9	0.03	7.1	29.8	0.02	7.0	29.8	911453	5.805	0.03	7.1	28.9	
30	7:00	15:30	SA	383.41	1.140	0.03	7.0	29.7	0.03	7.1	29.6	0.02	7.0	29.8	915490	4.037	0.02	7.0	29.3	
31	7:00	15:30	SA	384.59	1.180	0.02	7.0	29.7	0.03	7.1	29.7	0.02	7.0	29.7	919932	4.442	0.02	7.0	29.6	
Total					24.505											119.315				
Avg.					0.875	0.038	7.021	29.9	0.03		29.5	0.02	7.0	29.6		4.114	0.08	7.0	29.8	#####
Min.					0.102	0.020	7.000	29.4	0.02	6.9	26.7	0.01	7.0	29.3		2.793	0.02	6.9	28.9	0.0
Max					2.793	0.130	7.100	31.8	0.05	7.1	30.8	0.02	7.1	30.8		6.323	1.67	7.4	32.1	0.0

Influent flow meter inoperable * Operator unable to gain entry into facility.

Table A.5 Discharge Monitoring Report for the Airport Lagoon Treatment Plant for August 2004 (p1)

DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS: Department of Public Works

Charlotte Amalie WWTP

8244 Subbase

St. Thomas

VI00802

FACILITY: Charlotte Amalie WWTP

LOCATION: Charlotte Amalie

VI 00801

VI0020044

PERMIT NUMBER

001 A

DISCHARGE NUMBER

MAJOR

F - FINAL

MONITORING PERIOD

YEAR	MO	DAY	TO	YEAR	MO	DAY
2004	08	01		2004	08	31

*** NO DISCHARGE ☐ ***

ATTN: Director

PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX.	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
Temperature, Water Deg. Centigrade 00010 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	29.8	32.1	(04)	0	1/1	Grab
	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Average	32.2 Daily Maximum	Deg. C		Daily	GRAB
BOD, 5-DAY (20 DEG. C) 00310 G 0 0 Raw Sewage Influent	SAMPLE MEASUREMENT	*****	*****	*****	*****	540.6	1700	(19)	0	1/7	24 Hr Composite
	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Monthly Avg.	Report Weekly Max.	mg/l		Weekly	COMPOSITE
BOD, 5-DAY (20 DEG. C) 00310 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	106.8	*****	(19)	2	1/7	24 Hr Composite
	PERMIT REQUIREMENT	*****	*****	*****	*****	100 Monthly Avg.	*****	mg/l		Weekly	COMPOSITE
pH 00400 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	6.9	*****	7.4	(12)	0	1/1	Grab
	PERMIT REQUIREMENT	*****	*****	*****	6.0 Minimum	*****	9.0 Maximum	SU		Daily	GRAB
Solids, Total Suspended 00530 G 0 0 Raw Sewage Influent	SAMPLE MEASUREMENT	*****	*****	*****	*****	632.3	1990	(19)	0	1/7	24 Hr Composite
	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Monthly Avg.	Report Weekly Max.	mg/l		Weekly	COMPOSITE
Solids, Total Suspended 00530 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	25.9	*****	(19)	0	1/7	24 Hr Composite
	PERMIT REQUIREMENT	*****	*****	*****	*****	40 Monthly Avg.	*****	mg/l		Weekly	COMPOSITE
Toxicity 03598 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****		*****	*****	CODE 9	(2F)			
	PERMIT REQUIREMENT	*****	*****		*****	*****	Report Daily Mx	Acute Toxicity		Quarterly	GRAB
NAME/TITLE		I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.								Telephone	Date
PRINCIPAL EXECUTIVE OFFICER								(340)714-5171			
Ronald DeRossett Operations Manager								SIGNATURE OR PRINCIPLE EXECUTIVE OFFICER OR AUTHORIZED AGENT		Area Code / No.	Yr / Mo / Day
TYPED OR PRINTED											

COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here):

THERE SHALL BE NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS. FECAL COLIFORM SHALL ALSO BE MONITORED AT THE END OF THE 400 METER MIXING ZONE. SEE PERMIT FOR ADDITIONAL REQUIREMENTS.

Table A.6 Discharge Monitoring Report for the Airport Lagoon Treatment Plant for August 2004 (p2)

Page 1 of 2

DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS: Department of Public Works

Charlotte Amalie WWTP

8244 Subbase

St. Thomas

VI 00802

FACILITY: Charlotte Amalie

LOCATION: Charlotte Amalie

VI00801

VI0020044

PERMIT NUMBER

001 A

DISCHARGE NUMBER

Major

F - FINAL

MONITORING PERIOD

YEAR	MO	DAY	TO	YEAR	MO	DAY
2004	08	01		2004	08	31

*** NO DISCHARGE

ATTN: Director

PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX.	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
Flow, in conduit or thru treatment plan 50050 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	4.057	*****	(03)	*****	*****	*****		0	99/99	Continuous
	PERMIT REQUIREMENT	4.0 Mo Avg	*****	MGD	*****	Report Average	Report Daily Max.	*****		Continuous	CALCULATED
Chlorine, Total Residual 50060 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	*****	0.0	(20)	0	1/1	Grab
	PERMIT REQUIREMENT	*****	*****	*****	*****	*****	2.0 Daily Max.	PPM		Daily	GRAB
Coliform, Fecal General 74055 1 0 0 Effluent Gross Value	MEASUREMENT	*****	*****	*****	*****	*****	228	(13)	0	1/7	Grab
	REQUIREMENT	*****	*****	*****	*****	*****	10000 Daily Mx	#/100ml		Weekly	GRAB
BOD, 5-day Percent Removal 81010 K 0 0 Percent Removal	MEASUREMENT	*****	*****	*****	*****	80.2	*****	(23)	0	01 / 30	Calculated
	REQUIREMENT	*****	*****	*****	*****	30 Mo Avg	*****	Per-Cent		Once/Month	CALCULATED
Solids, Suspended 81011 K 0 0 Effluent Gross Value	MEASUREMENT	*****	*****	*****	*****	95.9	*****	(23)	0	1/30	Calculated
	REQUIREMENT	*****	*****	*****	*****	60 Mo Avg	*****	Per-cent		Once/Month	CALCULATED

NAME/TITLE
PRINCIPAL EXECUTIVE OFFICERRonald DeRossett
Operations Manager

TYPED OR PRINTED

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

SIGNATURE OR PRINCIPLE EXECUTIVE
OFFICER OR AUTHORIZED AGENT

Telephone

(340)714-5171

Date

04/09/15

Area Code / No.

Yr / Mo / Day

COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here):

THERE SHALL BE NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS. FECAL COLIFORM SHALL ALSO BE MONITORED AT THE END OF THE 400 METER

Table A.7 Daily Operations Log for the Airport Lagoon Treatment Plant for June 2006

Airport MOL
June 2006

Date	TIME		Operator Name					Effluent					
	IN	OUT		Rain	D.O.	pH	Temp.	Totalizer	Flow	D.O.	pH	Temp.	TRC
1	7:02	9:02	Tarantino	0.000	0.8	6.8	31.4	2014243	2.890	0.5	6.9	30.0	0.04
2	7:02	8:50	Tarantino	0.000	0.76	7.1	31.6	2017133	3.203	0.73	7.2	29.6	0.02
3	10:00	12:00	Lewis	0.000	0.36	7.6	31.8	2020336	3.004	0.25	7.4	30.1	0.03
4	10:00	11:30	Lewis	0.000	0.70	7.6	32.7	2023340	2.545	0.28	7.9	30.8	0.01
5	5:43	7:00	Smalls	0.000	0.33	7.3	31.9	2025885	2.990	0.19	7.3	29.9	0.06
6	5:45	7:00	Smalls	0.000	0.38	7.1	31.4	2028875	3.183	0.48	7.9	29.5	0.34
7	7:00	3:30	Lewis	0.000	0.36	7.3	32	2032058	2.894	0.14	7.5	29.0	0.01
8	7:00	3:30	Lewis	0.000	0.35	7.6	32.3	2034947	2.957	0.20	7.6	30.3	0.01
9	7:00	3:30	Lewis	0.000	0.48	7.7	28.2	2037902	2.140	0.24	7.8	27.9	0.13
10	12:00	2:00	Lewis	0.000	0.51	7.6	28.0	2038116	3.000	0.21	7.8	28.2	0.03
11	10:00	12:00	Lewis	0.000	0.52	7.6	28.8	2038116	3.000	0.26	7.7	28.7	0.01
12	5:45	7:00	Smalls	0.100	0.48	7.3	32	2038116	2.900	0.62	7.3	29.3	0.06
13	5:45	7:00	Smalls	0.000	0.26	7.4	31.4	2038116	2.900	0.14	7.5	30.6	0.02
14	7:00	3:30	Lewis	0.000	0.59	6.5	31.8	2041861	3.991	0.20	6.8	30.5	0.01
15	7:00	3:30	Lewis	0.000	0.44	7.4	29.6	2045352	3.542	0.21	7.1	30.4	0.01
16	7:00	3:30	Lewis	0.000	0.47	7.4	32.2	2048895	3.590	0.17	7.6	29.8	0.01
17	10:00	11:30	Lewis	0.000	0.60	7.6	29.9	2052485	3.356	0.22	7.7	29.9	0.02
18	10:00	12:00	Lewis	0.000	0.53	7.6	29.3	2055841	3.336	0.13	7.8	29.0	0.01
19	5:45	7:00	Smalls	0.400	0.41	7.4	28.9	2059177	3.640	0.25	7.4	28.5	0.07
20	5:45	7:00	Smalls	0.200	0.58	7.0	31.3	2062817	4.345	0.42	7.0	29.1	0.02
21	7:00	3:30	Lewis	0.060	0.56	7.6	28.1	2067171	3.921	0.30	7.6	29.4	0.01
22	7:00	3:30	Lewis	0.030	0.46	7.6	30.3	2071092	3.839	0.23	7.8	29.7	0.01
23	7:00	3:30	Lewis	0.000	0.33	7.5	30.5	2074931	3.862	0.21	7.7	30.0	0.01
24	9:00	11:30	Lewis	0.040	0.59	7.6	29.9	2078793	3.489	0.23	7.6	29.9	0.01
25	10:00	12:00	Lewis	0.000	0.52	7.6	30.3	2082282	3.165	0.24	7.7	29.9	0.01
26	5:45	7:00	Smalls		0.24	7.2	32.2	2085447	3.436	0.46	7.4	29.8	0.09
27	5:45	7:00	Smalls		0.31	7.3	31.7	2088883	3.439	0.72	7.4	29.9	0.08
28	7:00	3:30	Lewis	0.000	0.57	7.2	30.7	2092322	3.537	0.32	7.4	30.0	0.01
29	7:00	3:30	Lewis	0.050	0.51	7.6	27.3	2095859	3.417	0.28	7.9	28.0	0.01
30	7:00	3:30	Lewis	0.070	0.66	7.7	28.8	2099276	5.145	0.30	8.0	28.3	0.03
31													
Total				0.950					100.656				
Avg.				0.034	0.49	7.4	30.5		3.355	0.31	7.5	29.5	0.04
Min.				0.000	0.24	6.5	27.3		2.140	0.13	6.8	27.9	0.01
Max				0.400	0.80	7.7	32.7		5.145	0.73	8.0	30.8	0.34

Table A.8 Monthly Discharge Report for the Airport Lagoon Treatment Plant for June 2006 (p1)

DISCHARGE MONITORING REPORT																							
PERMITTEE NAME/ADDRESS: Department of Public Works					VI0020044 PERMIT NUMBER			001 A DISCHARGE NUMBER			MAJOR												
Charlotte Amalie WWTP 8244 Subbase St. Thomas					VI00802			F - FINAL															
FACILITY: Charlotte Amalie WWTP																							
LOCATION: Charlotte Amalie					VI 00801																		
ATTN: Director																							
FROM <table border="1" style="font-size: 0.8em;"> <tr><th>YEAR</th><th>MO</th><th>DAY</th></tr> <tr><td>2006</td><td>06</td><td>01</td></tr> </table> TO <table border="1" style="font-size: 0.8em;"> <tr><th>YEAR</th><th>MO</th><th>DAY</th></tr> <tr><td>2006</td><td>06</td><td>30</td></tr> </table> *** NO DISCHARGE ☐ ***												YEAR	MO	DAY	2006	06	01	YEAR	MO	DAY	2006	06	30
YEAR	MO	DAY																					
2006	06	01																					
YEAR	MO	DAY																					
2006	06	30																					
PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX.	FREQUENCY OF ANALYSIS	SAMPLE TYPE												
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS															
Temperature, Water Deg. Centigrade 00010 1 0 0	SAMPLE MEASUREMENT	*****	*****	*****	*****	29.5	30.8	(04)	0	1/1	Grab												
Effluent Gross Value	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Average	32.2 Daily Maximum	Deg. C		Daily	GRAB												
BOD, 5-DAY (20 DEG. C) 00310 G 0 0	SAMPLE MEASUREMENT	*****	*****	*****	*****	145.7	162.4	(19)	0	1/7	24 Hr Composite												
Raw Sewage Influent	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Monthly Avg.	Report Weekly Max.	mg/l		Weekly	COMPOSITE												
BOD, 5-DAY (20 DEG. C) 00310 1 0 0	SAMPLE MEASUREMENT	*****	*****	*****	*****	108.7	*****	(19)	4	1/7	24 Hr Composite												
Effluent Gross Value	PERMIT REQUIREMENT	*****	*****	*****	*****	100 Monthly Avg.	*****	mg/l		Weekly	COMPOSITE												
pH 00400 1 0 0	SAMPLE MEASUREMENT	*****	*****	*****	6.5	*****	7.7	(12)	0	1/1	Grab												
Effluent Gross Value	PERMIT REQUIREMENT	*****	*****	*****	6.0 Minimum	*****	9.0 Maximum	SU		Daily	GRAB												
Solids, Total Suspended 00530 G 0 0	SAMPLE MEASUREMENT	*****	*****	*****	*****	127.2	166.0	(19)	0	1/7	24 Hr Composite												
Raw Sewage Influent	PERMIT REQUIREMENT	*****	*****	*****	*****	Report Monthly Avg.	Report Weekly Max.	mg/l		Weekly	COMPOSITE												
Solids, Total Suspended 00530 1 0 0	SAMPLE MEASUREMENT	*****	*****	*****	*****	73.2	*****	(19)	3	1/7	24 Hr Composite												
Effluent Gross Value	PERMIT REQUIREMENT	*****	*****	*****	*****	40 Monthly Avg.	*****	mg/l		Weekly	COMPOSITE												
Toxicity 03598 1 0 0	SAMPLE MEASUREMENT	*****	*****	*****	*****	*****	CODE 9	(2F)	0		Grab												
Effluent Gross Value	PERMIT REQUIREMENT	*****	*****	*****	*****	*****	Report Daily Mx	Acute Toxicity		Quarterly	GRAB												
NAME/TITLE		I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.					SIGNATURE OR PRINCIPLE EXECUTIVE OFFICER OR AUTHORIZED AGENT			Telephone	Date												
PRINCIPAL EXECUTIVE OFFICER										(340)714-5171													
Marvin Smalls Lead operator										Area Code / No.	Yr / Mo / Day												
TYPED OR PRINTED																							
COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here): THERE SHALL BE NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS. FECAL COLIFORM SHALL ALSO BE MONITORED AT THE END OF THE 400 METER MIXING ZONE. SEE PERMIT FOR ADDITIONAL REQUIREMENTS.																							

Table A.9 Monthly Discharge Report for the Airport Lagoon Treatment Plant for June 2006 (p2)

Page 1 of 2

DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS: Department of Public Works

Charlotte Amalie WWTP

8244 Subbase

St. Thomas

VI 00802

FACILITY: Charlotte Amalie

LOCATION: Charlotte Amalie

VI00801

VI0020044

PERMIT NUMBER

001 A

DISCHARGE NUMBER

Major

F - FINAL

MONITORING PERIOD

YEAR	MO	DAY	TO	YEAR	MO	DAY
2006	06	01	TO	2006	01	30

*** NO DISCHARGE

ATTN: Director

PARAMETER		QUANTITY OR LOADING			QUANTITY OR CONCENTRATION				NO. EX.	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
Flow, in conduit or thru treatment plan 50050 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	3.3	*****	(03)	*****	*****	*****		2	99/99	
	PERMIT REQUIREMENT	4.0 Mo Avg	*****	MGD	*****	Report Average	Report Daily Max.	*****		Continuous	CALCULATED
Chlorine, Total Residual 50060 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	*****	0.3	(20)	0	1/1	Grab
	PERMIT REQUIREMENT	*****	*****	*****	*****	*****	2.0 Daily Max.	PPM		Daily	GRAB
Coliform, Fecal General 74055 1 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	*****	540	(13)	0	1/7	Grab
	PERMIT REQUIREMENT	*****	*****	*****	*****	*****	10000 Daily Mx	#/100ml		Weekly	GRAB
BOD, 5-day Percent Removal 81010 K 0 0 Percent Removal	SAMPLE MEASUREMENT	*****	*****	*****	*****	24.5	*****	(23)	3	01 / 30	Calculated
	PERMIT REQUIREMENT	*****	*****	*****	*****	30 Mo Avg	*****	Per-Cent		Once/Month	CALCULATED
Solids, Suspended Percent Removal 81011 K 0 0 Effluent Gross Value	SAMPLE MEASUREMENT	*****	*****	*****	*****	42.4	*****	(23)	2	1/30	Calculated
	PERMIT REQUIREMENT	*****	*****	*****	*****	60 Mo Avg	*****	Per-cent		Once/Month	CALCULATED
NAME/TITLE		I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.						Telephone		Date	
PRINCIPAL EXECUTIVE OFFICER								(340)714-5171			
TYPED OR PRINTED								Area Code / No. Yr / Mo / Day			
SIGNATURE OR PRINCIPLE EXECUTIVE OFFICER OR AUTHORIZED AGENT											
COMMENT AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here):											
THERE SHALL BE NO DISCHARGE OF FLOATING SOLIDS OR VISIBLE FOAM IN OTHER THAN TRACE AMOUNTS. FECAL COLIFORM SHALL ALSO BE MONITORED AT THE END OF THE 400 METER											

APPENDIX B

The pH correction factors detailed in Table B.1 were used to adequately calculate H₂S concentrations for the given wastewater samples. First, prior testing of the liquid sample is needed in order to obtain pH values and dissolve sulfide concentrations. From the given data, H₂S concentrations can now be calculated by the following equation:

$$\text{ppm H}_2\text{S} = \text{ppm Dissolved Sulfide} \times \text{pH Correction Factor}$$

Table B.1 List of pH Correction Factors for H₂S Determination when using a LaMotte Sulfide Test Kit

pH Correction Factors for Hydrogen Sulfide Determination

pH	Factor	pH	Factor	pH	Factor	pH	Factor
5.0	0.98	6.4	0.67	7.3	0.20	8.4	0.020
5.2	0.97	6.5	0.61	7.4	0.17	8.6	0.012
5.4	0.95	6.6	0.56	7.5	0.14	8.8	0.0079
5.6	0.93	6.7	0.50	7.6	0.11	9.0	0.0050
5.8	0.89	6.8	0.44	7.7	0.091	9.2	0.0032
6.0	0.83	6.9	0.39	7.8	0.073	9.4	0.0020
6.1	0.80	7.0	0.33	7.9	0.059	9.6	0.0013
6.2	0.76	7.1	0.23	8.0	0.048		
6.3	0.72	7.2	0.24	8.2	0.031		

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BIOGRAPHICAL SKETCH

Education

- 2005-Present **FLORIDA STATE UNIVERSITY**, Tallahassee, FL
Master of Science in Civil Engineering (Environmental discipline)
Currently awaiting thesis defense
- 2000-2004 **FLORIDA AGRICULTURAL AND MECHANICAL UNIVERSITY**,
Tallahassee, FL
Bachelor of Science in Civil Engineering (Environmental discipline)
Graduate with Distinction—Cum Laude, December 2004

Experience

- 2003-Present **DEPARTMENT OF ENVIRONMENTAL PROTECTION**, Tallahassee, FL
Records Technician
- Verify the integrity of air pollution engineering projects for completeness.
 - Transpose numerous hard copy air pollution projects into electronic Adobe PDF files.
 - Upload a variety of completed projects to the internet for public record viewing and access.
- 2005-2006 **FLORIDA STATE UNIVERSITY**, Tallahassee, FL
Teaching Assistant
- Took on the duties of major professor in her absence by conducting lectures
 - Proctor exams and grade students homework assignments

Internship

- Summer 2006 **VIRGIN ISLANDS ENVIRO-SYSTEMS CONTROL**, St. Thomas, USVI
Wastewater Operator Researcher
- Conceptualized, lead and collected data necessary to support or reject the thesis hypothesis.
 - Gathered six wastewater grab samples at lift stations for laboratory testing and evaluation.
 - Currently formulating recommendations based on Hydrogen Sulfide (H₂S) levels found at wastewater facilities.
- Summer 2005 **NJR CONSULTING, LLC**, St. Thomas, USVI
Waste Management Consulting Intern
- Implement processes to aid the Waste Management Authority in becoming self-profitable.
 - Generated marginal taxes on solid waste entering the island with future landfill disposal.
 - Referenced and updated public sewer line connection data to determine adequate fee.
- Summer 2004 **VIRGIN ISLANDS ENVIRO-SYSTEMS CONTROL**, St. Thomas, USVI
Wastewater Operator Intern
- Analyzed chemical level treatment combinations for daily wastewater experiments.
 - Collected wastewater field data and documented contamination water findings.

Summer 2002 **VIRGIN ISLANDS PORT AUTHORITY**, St. Thomas, USVI

Engineering Assistant II-Intern

- Inspected an \$11 million dollar Airfield Rehabilitation project.
- Coordinated a cross functional team for the Radio One Shoreline project.

Summer 2001 **VIRGIN ISLANDS PORT AUTHORITY**, St. Thomas, USVI

Engineering Assistant I-Intern

- Monitored and inspected construction engineers completion progress on a \$70,000.00 dollar Emile White Monument project.
- Inspected concrete durability on a \$3 million dollar Crown Bay Bulkhead Expansion project.

Memberships

- White & Gold Honor Society
- Florida-Georgia Louis Stokes Alliance for Minority Participation
- National Society of Black Engineers