Fall 12-15-2012

Odor Monitoring at Wastewater Treatment Plants

Natasha Halageri
University of New Orleans, nhalager@uno.edu

Recommended Citation

Halageri, Natasha, "Odor Monitoring at Wastewater Treatment Plants" (2012). *University of New Orleans Theses and Dissertations*. 1580.
https://scholarworks.uno.edu/td/1580

Odor Monitoring at Wastewater Treatment Plants

THESIS

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
in
Environmental Engineering

By

Natasha Halageri

B.E., R.V. College of Engineering, 2011

December, 2012

This thesis is dedicated to my wonderful parents, **Uday** and **Veena Halageri** for their constant support and encouragement, my brother, **Rohan** and my mentor and guide, **Sanjeev Kulkarni**.

ACKNOWLEDGEMENT

Words are inadequate in offering my thanks to my advisor – Dr. Bhaskar Kura. I appreciate his contributions of time, ideas, and funding to make my graduate experience productive and stimulating. He has been an encouraging mentor and has had a huge positive influence on both my academic research as well as personal life and has always motivated me towards excellence. His mentorship was paramount in providing me a well-rounded experience consistent with my long-term career goals. For everything you've done for me, Dr. Kura, I thank you.

I also wish to thank my committee members- Dr. Patricia Williams and Dr. Gianna Cothren for their timely support, help and valuable inputs throughout my graduate research.

I would like to take this opportunity to express my gratitude to Ms. Linda Daley from Jefferson Parish for providing us access into the facility and timely data. I wish to thank Mr. Kurt LeBlue for his help and guided tour of the facility.

I am also grateful to the research team working under Dr. Kura for their help and encouragement. In particular, I would like to thank Mr. Deekshit Kura for his help with the data collection required in this research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Hydrogen sulfide (H_2S) is notable for its toxicity and corrosion is one of the major sources of odor in wastewater treatment plants. Evaluation of existing or potential odor problems requires knowledge of the type of compounds likely to cause such problems and the mechanism of their formation in wastewater systems which is discussed in this paper. For the present study, the East Bank wastewater treatment plant was chosen since it is the largest wastewater treatment facility within Jefferson Parish, Louisiana. To combat the odor problems in this facility, a monitoring program was designed and developed to characterize the severity of the problem. The program involved continuous ambient monitoring followed by careful evaluation of the data obtained from sample collection and analysis. Different instruments were strategically placed within the facility after a hot-spot analysis to determine the major sources of odor generation.

Keywords: Wastewater treatment plant, odor, hydrogen sulfide, monitoring

1. INTRODUCTION

1.1 Municipal Facilities

A properly managed municipal facility plays an important role in safeguarding community health and local water quality. A number of NPDES permit program areas affect how a municipality handles its sanitary wastewater and stormwater runoff. A municipal corporation helps manage and optimize water resources to meet growing population needs, overcome scarcity challenges and comply with regulatory requirements. Wastewater treatment is an essential public service.

Satisfactory disposal of wastewater, whether by surface, subsurface methods or dilution, is dependent on its treatment prior to disposal. Adequate treatment is necessary to prevent contamination of receiving waters so that they can be put to their best or intended use.

1.2 Wastewater Treatment Process

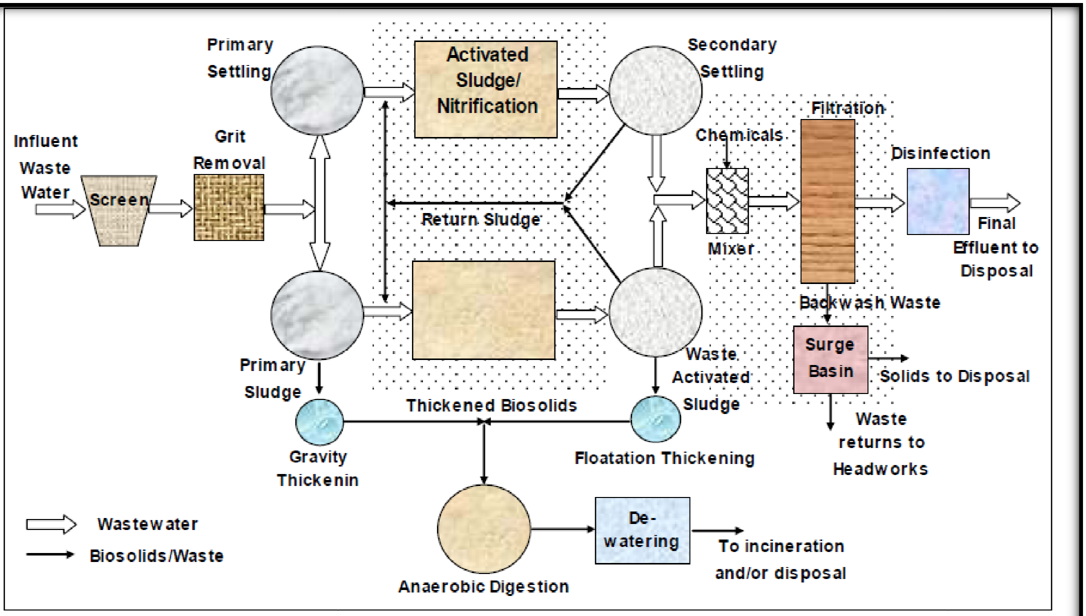
Wastewater is water that has been adversely affected in quality by anthropogenic influence. Its treatment consists of applying known technology to improve or upgrade the quality. Usually, wastewater treatment involves wastewater collection in a central, segregated location and subjecting the wastewater to various treatment processes. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants.

Pre-treatment removes materials that can be easily collected from the raw sewage before they damage or clog the pumps and sewage lines of primary treatment clarifiers. It may involve use of screens to remove the large objects like cans, rags, sticks, plastic packets etc. carried in the sewage stream. Grit chambers enable the settlement of sand, grit, stones, and broken glass. Equalization basins may be used for temporary storage of diurnal or wet-weather flow peaks. Sewage treatment generally involves three stages, called primary, secondary and tertiary treatment.

Primary treatment consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.

Secondary treatment removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment in order to allow rejection into a highly sensitive or fragile ecosystem (estuaries, low-flow rivers, and coral reefs). Treated water is sometimes disinfected chemically or physically prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.



Source: From Burton, 1996, pp. 2-23 and 2-25.

Figure 1: Typical wastewater treatment procedure using activated sludge as a unit operation

EPA's enforcement of the Clean Water Act protects the nation's water quality by curbing municipal and industrial wastewater discharges, managing biosolids from sewage treatment plants, polluted runoff from urban and rural areas, and prevents habitat destruction. Overflows of raw sewage from aging municipal sewer systems and urban stormwater runoff are significant sources of pollutants, contributing to the contamination of drinking water sources, beach and shellfish bed closures, and other environmental and health concerns.

Two final products are created as the result of wastewater treatment: the treated wastewater, or effluent, and the removed solids, or sludge. The effluent can be discharged into receiving waters or reclaimed for nondomestic uses. Four basic methods of sludge disposal are available to wastewater treatment operators: disposal by sanitary landfill, land application, composting, and incineration.

Sludge disposal by sanitary landfill entails the burial of wastewater solids at a solid waste disposal site. Land application is the utilization of sludge as a soil enricher for agricultural land, park land or disturbed land (such as construction sites, gravel pits, strip-mined lands or clear-cut forests). Composting refers to the decomposition of organic wastes in sludge until a final nuisance free product is created. Composted sludge is also used as a soil enricher. Incineration of sludge involves drying and burning processes that reduce wastewater solids to ash.

1.3 Wastewater Treatment Facilities

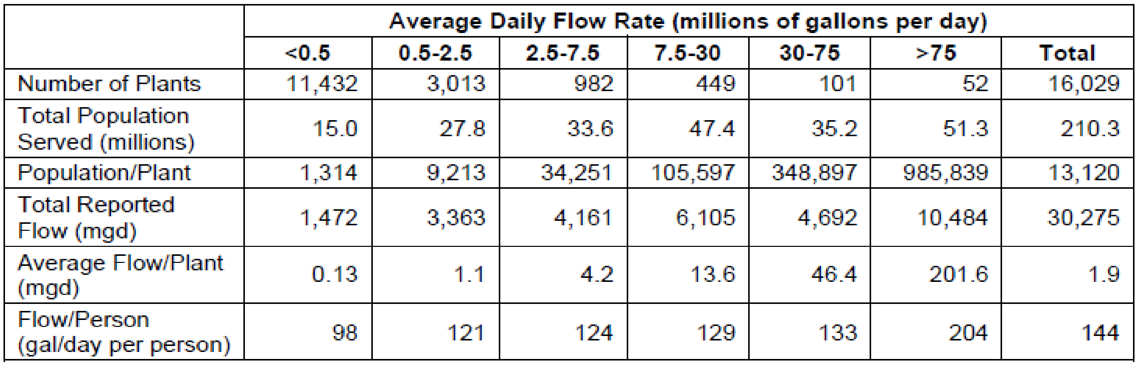
Table 1 lists the number of wastewater treatment plants by state and size, and Table 2 lists the number of people served and total flow rate. In 2000, about 210 million people were served by POTWs. The approximately 1,600 plants with flows greater than 2.5 million gallons per day (mgd) served about 167 million people or about 105,000 people per plant on average.

Twenty-two plants serve more than 1 million people each, with flow rates typically above 100 mgd. The 14,500 plants that reported flows of less than 2.5 mgd served a total population of about 42.8 million, with an average of about 3,000 people served per plant. The average flow rate per person increases with plant size, from about 98 gallons per person per day (gal/person-day) for the smallest plants to more than 200 gal/person-day for the largest plants (see Table 2).

Table 1: Number of Wastewater Treatment Plants by State and Size

	Average Daily Flow Rate (millions of gallons per day)					
State	**<0.5**	**0.5-2.5**	**2.5-7.5**	**7.5-30**	**30-75**	**>75**
California	318	131	63	47	7	7
Florida	82	96	69	24	6	1
Georgia	219	83	28	17	2	1
Illinois	525	127	35	29	0	3
Louisiana	243	68	33	7	2	2
Mississippi	230	55	10	4	1	0
New York	350	140	50	25	10	9
Ohio	524	144	59	21	8	4
Pennsylvania	937454	209	60	12	1	4
Texas	149937	300	73	32	9	6
Washington	149	56	19	13	2	1

Table 2: Population served by wastewater treatment plant size



	Average Daily Flow Rate (millions of gallons per day)						
	<0.5	**0.5-2.5**	**2.5-7.5**	**7.5-30**	**30-75**	**>75**	**Total**
Number of Plants	11,432	3,013	982	449	101	52	16,029
Total Population Served (millions)	15.0	27.8	33.6	47.4	35.2	51.3	210.3
Population/Plant	1,314	9,213	34,251	105,597	348,897	985,839	13,120
Total Reported Flow (mgd)	1,472	3,363	4,161	6,105	4,692	10,484	30,275
Average Flow/Plant (mgd)	0.13	1.1	4.2	13.6	46.4	201.6	1.9
Flow/Person (gal/day per person)	98	121	124	129	133	204	144

Industrial and municipal wastewater treatment generates odors that can be strong, persistent, and a nuisance to employees, residents, businesses, and industries located near the wastewater treatment plant. Odors are generated in varying degrees throughout the wastewater treatment process. In addition to the problems odors can create for plant personnel and plant equipment, odors can adversely impact the community surrounding the treatment plant. Not only is this a problem for the community, but it also puts a strain on treatment plant resources to solve the problem and appease the community. Proper facility design, operation, management, control and careful oversight are necessary to minimize odors.

2. BACKGROUND AND LITERATURE REVIEW

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.

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), 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.

The Wastewater Treatment Plant process employs a headwork's structure with mechanical bar screens, a grit removal chamber combined with an odor control system for wastewater pretreatment of the plant influent. The wastewater flow is then measured and sent to the aeration tanks and clarifier basins which perform the biological treatment process and solids separation respectively. The clarified effluent then passes through filters to remove any remaining suspended solids before entering the chlorine contact chamber for disinfection and final flow measuring before reuse or disposal applications.

Bar screens are typically at the headworks (entrance) of a wastewater treatment plant (WWTP), bar screens are used to remove large objects such as rags, plastics bottles, bricks, solids, and toy action Figures from the waste stream entering the treatment plant. Bar screens are vital to the successful operation of a plant, they reduce the damage of valves, pumps, and other appurtenances. Floatables are also removed at the entrance to a treatment plant.

Wastewater usually contains a relatively large amount of inorganic solids such as sand, cinders and gravel which are collectively called grit. Grit will damage pumps by abrasion and cause serious operation difficulties in sedimentation tanks and sludge digesters by accumulation around and plugging of outlets and pump suctions.

Aeration tanks provide secondary treatment to wastewater. They help in storage handling and provide artificial aeration to promote the biological oxidation of wastewaters. In an aerated basin system, the aerators provide two functions: they transfer air into the basins required by the biological oxidation reactions, and they provide the mixing required for dispersing the air and for contacting the reactants (that is, oxygen, wastewater and microbes). Typically, the floating surface aerators are rated to deliver the amount of air equivalent to 1.8 to 2.7 kg O_2/kW·h. Surface-aerated basins achieve 80 to 90 percent removal of BOD with retention times of 1 to 10 days.

Regardless of the method of secondary treatment used, the end result is a mixture of microorganisms and partially treated wastewater. The organic material that was dissolved or suspended in the wastewater is broken down and consumed by these microorganisms. These microorganisms, while very small, are still large enough to settle out of the wastewater. The effluent is sent to secondary clarifiers (settling tanks) where the microorganisms settle out. At this point, the wastewater treatment process is nearly completed.

Secondary treatment processes are highly effective in reducing the BOD in wastewater. However, the secondary clarifiers used to settle out microorganisms are not totally effective. The filters used in wastewater treatment often use large, lightweight aggregates (such as coal) at the top to improve efficiency and facilitate cleaning.

2.2 Odor nuisance in wastewater treatment plants

Odor nuisance is a common occurrence at wastewater treatment plants. Sewage treatment plants located near residential areas can be subject to political and legal problems if these facilities produce unpleasant odors. The substances responsible for the diffusion of odors into the atmosphere in the vicinity of treatment plants are generally gaseous inorganic products or highly volatile organic compounds. The former are mainly the result of biological activity in the sewage, the latter are often caused by the presence in the sewer of industrial wastes.

The raw sewage influent pump station wet well is where wastewater first enters the plant after traveling many miles in the sanitary sewer mains. At this site raw wastewater is exposed to the air on its way to treatment sites. Raw wastewater is transferred to the primary clarifiers where most solids are separated from the liquid portion of wastewater in the treatment process. At this site odors are volatized by the turbulence in the center wells and as the wastewater cascades over the effluent weirs and through the effluent channel.

Wastewater undergoing aerobic digestion in the aeration basins emits a characteristically musty odor due to the particular type of biogases released in the process. In a similar fashion as in the primary clarifiers, odors from the partially treated organic solid portion of the wastewater in the sludge thickeners are volatized by the turbulence in the center wells and effluent weirs and channel.

There are a number of sources for odors within wastewater treatment and solids management facilities. Significant potential sources at treatment facilities include:

1. Headworks area
2. Primary clarifiers
3. Solids holding and thickening tanks
4. Aerobic digesters
5. Dewatering systems
6. Solids loading areas

Odorous compounds originate from the microbial decomposition of compounds with a high molecular weight, especially proteins. The following compounds are associated with bad odors: mercaptans, skatoles, indoles, inorganic acids, aldehydes, ketones and organic compounds containing nitrogen or sulfur atoms. Among the inorganic compounds, ammonia and hydrogen sulfide are considered to be the main causes of odor when the sewage comes from mainly households.

2.3 Parameters to measure Odor

The following are some parameters to express the concentration of odors:

1. Perceptibility Threshold (ATC: Absolute Threshold Concentration), defined as the minimum concentration that can be detected by 100% (in some cases by 50%) of the persons involved with an olfactory analysis. In some cases the geometric mean of the measurements of the single members is used.
2. Odor Number (TON: Threshold Odor Number), or the number of dilutions needed to reduce the concentration of the sample to the ATC.
3. Maximum Exposure Concentration (TLV: Threshold Limit Value). This represents the maximum concentration at which persons can be exposed for a period of 8 hours a day, 5

days a week and 50 weeks a year (weighted average over 8 hours), for a work life of 40 years.

4. Maximum Allowable Concentration (MAC: Maximum Allowable Concentration): Maximum concentration which should never be exceeded.

Table 3 below reports the values of these indices relative to a series of compounds found in the atmosphere of sewage treatment plants.

Table 3: Odor measurement of compounds found in the atmosphere of sewage treatment plants

Compounds	**ATC (ppm)**	**TLV (ppm)**	**MAC (ppm)**	**Olfactory sensation**
Hydrogen sulfide	.00047	10	50 (USA) 20 (UK)	Rotten Eggs
Ammonia	46.8	25	37.5 (UK)	Pungent
Methyl mercaptan	.0021	10		Rotting cabbage
Carbon disulfide	.21	20		Sweet/pungent
Biphenyl sulfide	.0047			Burned rubber
Dimethyl sulfide	.001			Rotting vegetables

Sewer collection systems offer a variety of environments for microorganisms to perform a wide range of microbial transformation processes. This variability is induced by the large flow fluctuations typically observed in most sewer networks, causing changes to the dissolved oxygen (DO) availability in the collection system and promoting erosion or deposition of sewer sediments and erosion and growth of biofilms.

2.4 Odor causing mechanism

Anaerobic hydrolysis is an important precursor to the other anaerobic processes involving the transformation of large, complex organic molecules into smaller, simpler molecules that can be directly utilized by other microorganisms as a substrate. The organic products of anaerobic hydrolysis generally do not contribute directly to odor emissions from sewers, with the exception of the hydrolysis of organic sulfur-containing compounds by bacteria resulting in the production of hydrogen sulfide, organic sulfides, and disulfides.

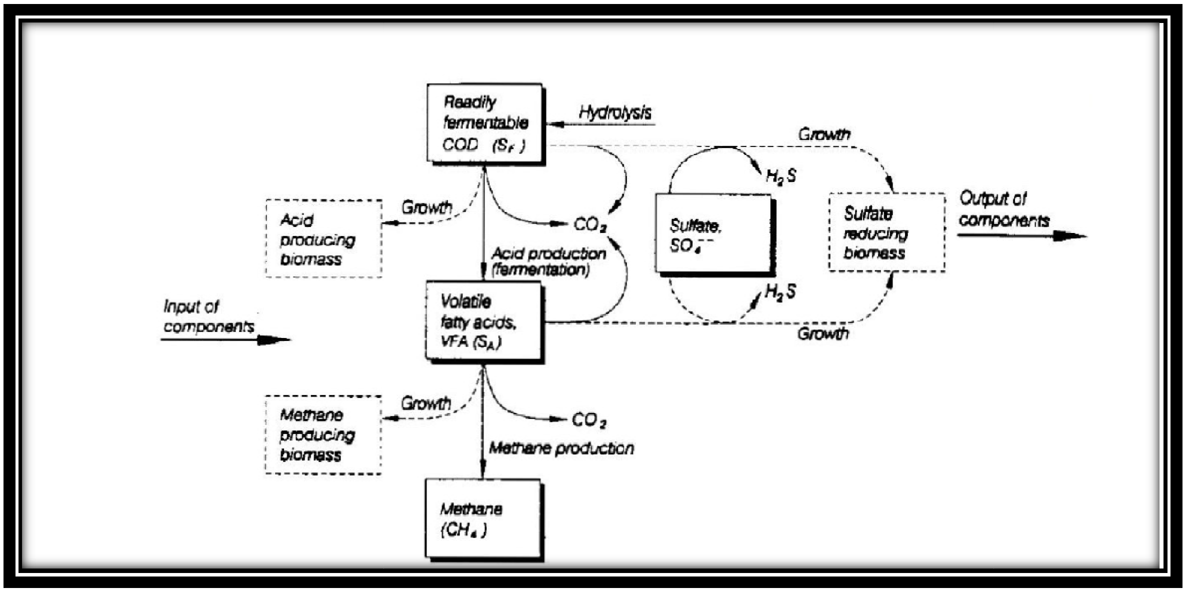


Figure 2: Anaerobic carbon transformations in sewer systems

2.5 Hydrogen Sulfide

Hydrogen sulfide is the most commonly known and prevalent odorous gas associated with domestic wastewater collection and treatment systems. It has a characteristic rotten egg odor, that can be detected by the human nose at concentrations as low as 4.7 x 10-4ppm, is extremely toxic, and is corrosive to metals such as iron, zinc, copper, lead and cadmium. Hydrogen sulfide is also a precursor to sulfuric acid formation, which corrodes lead-based paint, concrete, metals and other materials.

The conditions leading to H_2S formation generally favor production of other malodorous organic compounds. Thus, solving H_2S odor problems can often solve other odor problems as well. Many of the odors detected in wastewater collection and treatment systems result from sulfur-bearing compounds being present.

Sulfate reducing bacteria (SRB) are anaerobes and some common species of SRB include *Desulfovibrio spp*. and *Desulfotamaculum spp*.(Hvitved-Jacobsen, 2002). They utilize sulfate as their oxygen source, ammonia as their sole source of nitrogen, and various forms of organic matter as a food supply including amino acids, carbohydrates, organic acids, etc., in an oxygen limited environment. These reactions often take place in the slime layer on collection pipes and in the sludge of lagoons, etc.

The serious odor and corrosion problems associated with the collection, handling and treatment of domestic wastewater are primarily the result of sulfate reduction to hydrogen sulfide under anaerobic conditions, as shown by the following reactions:

1)

$$\text{Sulfite ion + organic matter + water} \xrightarrow{d.d.\ bacteria} \text{bicarbonate ion + hydrogen sulfide gas}$$

$$SO_4^{2-} + 2C + 2H_2O \xrightarrow{d.d.\ bacteria} 2HCO_3^- + H_2S$$

2)

$$\text{Elemental sulfur + hydrogen ions} \xrightarrow{\textit{d.d. bacteria}} \text{hydrogen sulfide}$$

$$S + 2H^+ \xrightarrow{\textit{d.d. bacteria}} H_2S$$

3)

$$\text{Sulfite ion + hydrogen ions} \xrightarrow{\textit{d.d. bacteria}} \text{hydrogen sulfide + water}$$

$$SO_4^{2-} + 10H^+ \xrightarrow{\textit{d.d. bacteria}} H_2S + 4H_2O$$

2.6 Parameters that govern the production of H_2S

Hydrogen sulfide generation is inversely related to flow rate, so that waste streams with low flow rates are more likely to possess high levels of hydrogen sulfide. The rate of sulfide production is dependent upon environmental conditions in the slime layer. The following wastewater conditions are the most critical parameters impacting the rate of sulfide production:

- ***Concentration of organic material and nutrients.*** These materials diffuse into the slime layer and are consumed by the SRB.

- ***Sulfate concentration.*** Sulfate and organic matter will be used by the SRB in the ratio of approximately 2:1, depending upon the relative concentrations of each.

- ***Dissolved oxygen.*** DO is critical in determining whether anaerobic or aerobic bacteria will dominate the breakdown of organic material in the wastewater. If the DO concentration is in excess of 1.0 mg/L, aerobic bacteria will likely dominate the activity, particularly on the outer layers of an attached biofilm. Consequently, increased DO will reduce the production of sulfide by limiting the food reaching the anaerobic bacteria.

- ***pH.*** The pH determines the proportions of HS- and H_2S found in the wastewater and directly influences the amount of hydrogen sulfide gas available for release into the atmosphere.

- ***Temperature.*** Each degree Celsius increase in temperature represents a 7 percent increase in the biological activity of the SRB (up to 30°C).

- ***Wastewater velocity.*** Velocity of the wastewater in the sewer influences the thickness of the slime layer and deposition rates for organic material.

- ***Surface area.*** The flow depth influences the free water surface and determines the submerged pipe surface in which the slime layer may form.

- ***Detention time.*** This is particularly important in force mains, submerged sewers, and sewers with little DO present. As the detention time increases, more oxygen is consumed, oxidation-reduction potential (ORP) decreases, and organic material becomes more solubilized, a condition that favors the SRB.

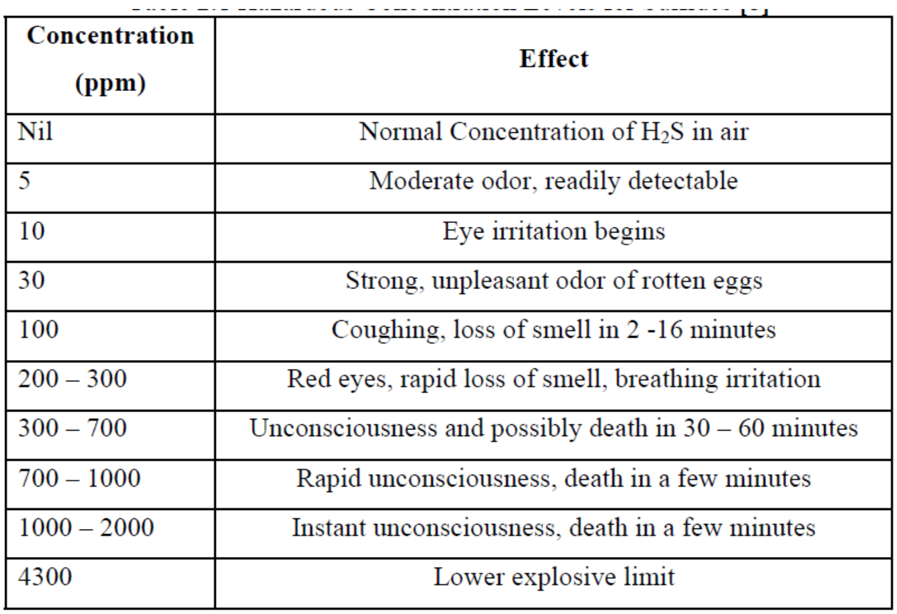
These bacteria use oxygen in the most readily available form: first, from elemental oxygen; then, nitrate oxygen; then, sulfate oxygen. As nitrate is usually not available in wastewater, bacteria will consume sulfate oxygen after depleting elemental oxygen, leaving bi-sulfide ions to combine with hydrogen to form aqueous H_2S. Figure 3 illustrates these reactions. At pH 7, the bi-sulfide ion and aqueous H_2S, in solution, are equally proportionate. pH, Henry's Law, and the turbulence of the waste stream govern the rate at which aqueous H_2S is converted to atmospheric H_2S. A lower pH produces more aqueous H_2S and increases the rate of H_2S transfer to the gas phase. Turbulent wastewater also facilitates the release of H_2S to the atmosphere.

2.7 Toxicity of H_2S

Hydrogen sulphide (H_2S) is a toxic gas and the health hazard depends upon both the duration of exposure and the concentration. The gas is an irritant of the lungs and at low concentrations irritates the eyes and the respiratory tract. Exposure may result in headache, fatigue, dizziness, staggering gait, and diarrhoea, followed sometimes by bronchitis and bronchopneumonia (Sax and Lewis, 1989). There is some evidence of elevated presence of adverse health symptoms in communities exposed to long-term low levels of H_2S in the environment (Bates et al., 2002; Legator, 2001), such as in geothermal areas, and the unpleasant smell of H_2S can be a nuisance. Asthmatic subjects do not appear to respond as readily to low levels of H_2S as they may do to SO_2. Sense of smell to H_2S is lost at concentrations below those of harm so people may have little warning of the presence of the gas at dangerous concentrations. Very large concentrations result in paralysis of the respiratory centre, causing breathing to stop and may potentially lead to death. If death does not occur during the exposure time, recovery generally occurs without later medical complications, although symptoms may occur for several months (Snyder et al., 1995). The concentration thresholds for health effects are outlined in the table.

The EPA recommends a lifetime exposure limit of 0.7 parts per billion (ppb), a residential limit of 15 ppb, a property line limit of 70 ppb and a 0.14 ppb limit for children and the elderly. 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 4. The American Conference of Governmental Industrial Hygienists however, recommends a Threshold Limit Value of 10ppm and a short-term exposure (STEL) limit of 15 ppm averaged over 15 minutes. Exposure at the STEL should not be repeated more than four times per day with at least 60 minutes between successive exposures in this range.

Table 4: Hazardous concentration levels for sulfides



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

2.8 Corrosion problems caused by H_2S

The presence of hydrogen sulfide can lead to rapid and extensive damage to concrete and metals used in the construction of wastewater treatment collections and treatment systems. Sewers, pump stations, and treatment facilities, including electrical controls, instrumentation, process equipment, tankage and ventilation systems can be affected. In the U.S. the problem is not limited to warm climates, and it I rarely brought to the attention of the public until a catastrophic event occurs, such as a sewer collapse resulting in street cave-in. Sewers designed to last 50 to 100 years have failed due to hydrogen sulfide corrosion in as little as 10 to 20 years.

The economic implications of hydrogen sulfide corrosion are staggering. A 1989 study conducted by the Sanitation Districts of Los Angeles County estimated that over $150 million is currently needed to repair or replace 25 miles of extensively damaged sewers. An additional $35 million may also be required to repair or replace 16 miles with moderate corrosion unless it can be controlled. The report further states that if the additional 500 miles of sewers were to be severely damaged by corrosion, their replacement cost would be $1 billion. Similarly, the City of Houston currently estimates the cost of its sewer rehabilitation program at $477 million. Seventy percent of the problem is attributed to hydrogen sulfide corrosion. On a national scale, sewer rehabilitation alone is estimated to cost $6 billion. It is clearly evident that a means to detect, control and correct hydrogen sulfide corrosion in existing wastewater systems is the preferred alternative to premature replacement of system components.

Once sulfides are produced in the wastewater as the result of sulfate reduction, hydrogen sulfide gas will be released into the atmosphere. The hydrogen sulfide gas is oxidized on the pipe surface above the water line as described by the following equation:

$$H_2S + O_2 \longrightarrow H_2SO_4$$

Oxidizing bacteria, such as *Thiobacillus concretivorous*, *Thiobacillus neapolitanus*, *Thiobacillus ferro-oxidans*, or *Thiobacillus thioxidans*, are aerobic and thrive in low-pH environments. To grow, they require a source of sulfur (H_2S), a moist surface (the pipe walls above the water surface), and a carbon source (CO_2). The surface pH of new concrete pipe is generally in the range of 11 to 13. Cement contains calcium hydroxide which neutralizes the acids and inhibits formation of oxidizing bacteria when the concrete is new. However, as the pipe ages, the neutralizing capacity of the pipe is consumed, the surface pH drops, and the sulfuric acid–producing bacteria become dominant. In active corrosion areas, the surface pH can drop below 2.0. As sulfides are formed and sulfuric acid is produced, calcium hydroxide is converted to calcium carbonate (gypsum), which is easily eroded by wastewater.

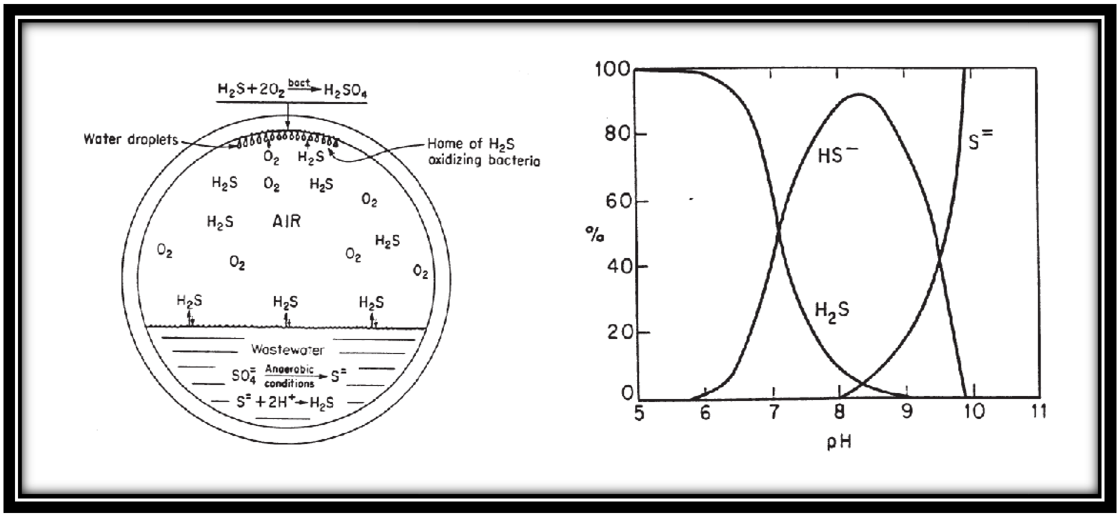


Figure 3: Hydrogen sulfide chemistry

Dissolved oxygen depletion is affected by sewage velocity, wastewater characteristics, detention time and temperature. When the dissolved oxygen is depleted, the rate of sulfide generation is controlled by the concentration of organic materials, nutrients and temperature. The subsequent release of hydrogen sulfide gas to the atmosphere of a sewer, wet well or other confined space is dependent upon the sewage pH, extent of turbulence and wastewater temperature. Finally, the rate of corrosion is governed by the temperature, the quantity of hydrogen sulfide available to be biologically converted to sulfuric acid, and the material's inherent resistance to acid attack.

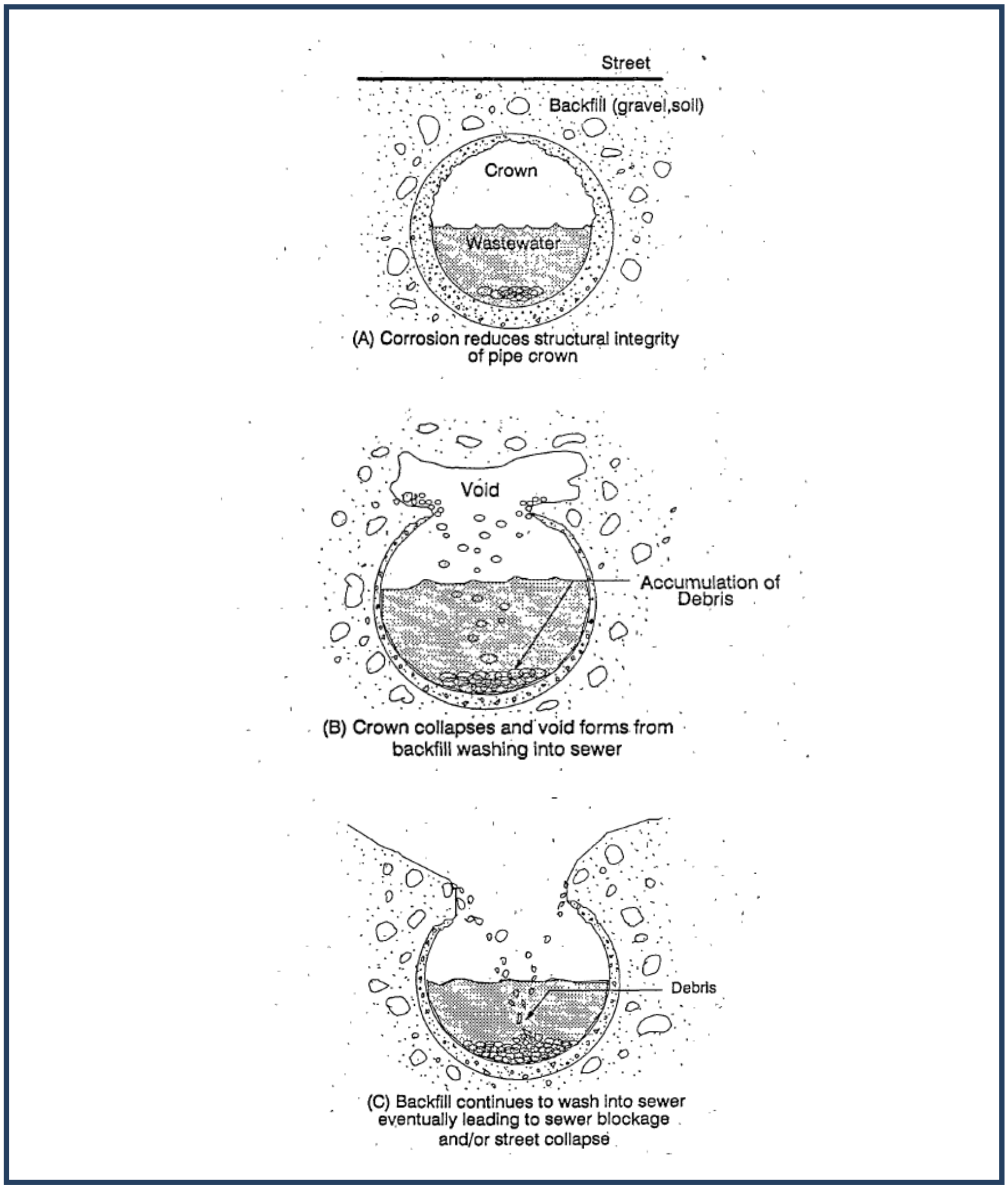


Figure 4: Sewer system de-stabilization because of hydrogen sulfide corrosion

It is essential that corrosion problems be identified early while the corrosion can still be controlled. Otherwise you may be faced with the high cost of sewer replacement or rehabilitation, and/or premature replacement or reconstruction of mechanical equipment, structures and electrical controls used in wastewater pumping stations and treatment plants. Corrosion detection and monitoring can be conducted economically, and the cost of such programs is only a small fraction of the cost to repair damage caused by hydrogen sulfide corrosion.

Knowing the chemical composition of malodorous gas mixtures, the contribution of individual odorants to odor thresholds and intensity, and the mechanisms by which odorants are generated in sewers is key to developing optimal odor-monitoring and -control strategies. From the discussion above, it is fairly evident that there is a need to monitor and control the H_2S

emissions from wastewater treatment plants. This study provides a preliminary understanding and insight into monitoring of H_2S and identifying suitable odor control strategies.

3. SCOPE OF WORK

3.1 Overall Objectives

Understand current odor levels and ambient concentrations of odor causing compounds within the wastewater treatment facility through air and meteorological monitoring to identify hot spots and important sources.

3.2 Specific Objectives

1. Identify ambient monitors suitable for measurement of odors and odor causing compounds
2. Identify suitable meteorological monitoring equipment
3. Perform ambient air monitoring as well as meteorological monitoring
4. Identification of Important Sources within the Wastewater Treatment Plant Monitored
5. Identification of Hot Spots within the WWTP Complex and Immediate Vicinity Including Perimeter
6. Preliminary Assessment of Odor Nuisance Levels and Compliance with Current Regulations
7. Recommend Strategies for Odor Management
8. Conduct ambient air quality monitoring using commercially available equipment

4. METHODOLOGY

4.1 Site Selection

The East Bank Water Treatment Plant (EBWWTP) located in Harahan, Louisiana, 10 miles west of New Orleans, Louisiana was chosen for this study. The EBWWTP is the largest wastewater treatment facility within Jefferson Parish, Louisiana - the principal suburban community adjacent to New Orleans. This facility, constructed in 1988, has an average daily design capacity of 33 mgd during dry weather conditions and 56 mgd for wet weather flows. The hourly peak wet weather flow is 156 mgd with a peak hydraulic capacity of 165 mgd. The plant provides wastewater services to over 60,000 connections. The plant layout is shown in Figure 5 below.

Figure 5: Layout of the East Bank wastewater treatment facility

1: Operations Building
2: Headworks
3: Primary clarifier tank
4: Oxidation tank
5: Filter press building
6: Storage tanks (3)
7: Secondary clarifier tank (8)
8: Odor Control System: This is manufactured by Seimens and uses the chemical scrubbing technology to eliminate odors.

4.2 Experimental Design

1. Ambient Monitoring:

Air quality monitoring is a complex technical task, requiring not only direct measurement, but also measurement standards and quality assurance to ensure that the information provides a correct understanding of air quality. Ambient air quality reports provide the data and interpretations to the technical community and the public.

The ambient air quality monitoring was carried out at three locations in the facility identified as high priority areas during the preliminary survey conducted. The locations identified were the filter press building, the aerated basins and at a location between the plant and a residential community.

The ambient air quality monitors, i.e. OdaLog and CairClip are used for this purpose. Continuous data logging was carried out to check compliance with standards and to ensure good quality data. Meteorological monitoring of the variables such as wind speed, direction, average daily temperature and precipitation was also done to understand the correlations in a better way and make sense of how the plume disperses. The equipment used is discussed in the following section.

2. Source Monitoring:

Odors are present in some form at all wastewater facilities, but particular problems are encountered at treatment plant headworks facilities. This is due in part to the multiple odor sources contained in a typical headworks facility (screens, screenings conveyors, washers, grit basins, grit classifiers, residuals containers, etc.) and the often complicated multiple-source air handling and ventilation requirements inside a headworks building. The ventilation of headworks buildings becomes even more complicated when you consider the overlapping regulations, building codes and ventilation standards that are applicable to headworks facilities.

Researchers have identified that friction drag on the sewer headspace by the flowing water moves air downstream in a sewer. This airflow is dependent upon the wastewater velocity, the diameter/size of the sewer and the area of the available headspace, but the air in a sewer is all moving downstream and enters the headworks with the flow. This odorous volume of air is forced into the wet well/influent works where it slightly pressurizes the receiving airspace.

Since headworks majorly contributes to the odor nuisance at a facility, the higher range H_2S monitors such as Multigas analyzer, Gas Badge Pro and PID were used which have been discussed below. The OSHA guidelines direct that the ceiling limit for H_2S within a plant be less than 20 ppm. Hence, continuous monitoring and data quality assessment was carried out. Since infiltration and inflow inversely affects the H_2S concentration, the average daily temperature along with daily precipitation was used to gain a better insight.

3. Hot-spot Analysis:

Hot spots are locations where concentrations of H_2S are higher compared to others. A hot-spot analysis is an estimation of likely future localized pollutant concentrations and a comparison of those concentrations to the National Ambient Air Quality Standards (NAAQS) set by the U.S. EPA.

To carry out the hot-spot analyses, a portable equipment CairClip was used since the concentrations can be directly read out. A standard GPS was used to get the latitude and longitude of the location and the readings were taken for 5 minutes and then averaged out to evaluate the hot-spots.

4. Perimeter Analysis:

The perimeter air monitoring was done to measure the fugitive hydrogen sulfide concentration and ensure that they do not exceed the EPA perimeter limit of 70 ppb. Wind direction, wind speed, temperature, and daily weather observations were collected using an on-site meteorological monitoring station and recorded daily. Latitude and longitude were recorded using a GPS for each location where measurement was observed.

To get accurate measure, 5 minute observations were made using CairClip at each location so as to obtain an average reading for both the instruments. The perimeter of the utility was first covered with importance to specific source buildings, such as the headworks and the filter press to get a better idea of the concentration of H_2S present around the buildings. These concentrations could be instrumental in calculating the emissions generated by the buildings using a suitable modeling technique.

4.3 Equipment

Mentioned below is a description of the different variables measured and the equipment used for each of them.

Odor measurement:

An odor is caused by one or more volatilized chemical compounds, that is perceived by the sense of olfaction. The measurement of odor concentration is the most widespread method to quantify odors. The method is based on dilution of an odor sample to the odor threshold (the point at which the odor is only just detectable to 50% of the test panel). The numerical value of the odor concentration is equal to the dilution factor that is necessary to reach the odor threshold.

The Nasal Ranger Olfactometer was used for odor detecting and measuring device. The instrument directly measures and quantifies odor strength in the ambient air using the Operating Principle of mixing odorous ambient air with odor-free filtered air in discrete volume ratios. The discrete volume ratios are called “Dilution-to-Threshold” ratios (D/T ratios).

$$D/T = \frac{\text{Volume of Carbon-Filtered Air}}{\text{Volume of Odorous Air}}$$

The user's nose is placed firmly inside the nasal mask and inhales at a comfortable breathing rate while standing at rest. The nasal mask has an outlet for exhaled air to exhaust downward. Therefore, the user inhales through the Nasal Ranger and exhales downward through the outlet check valve.

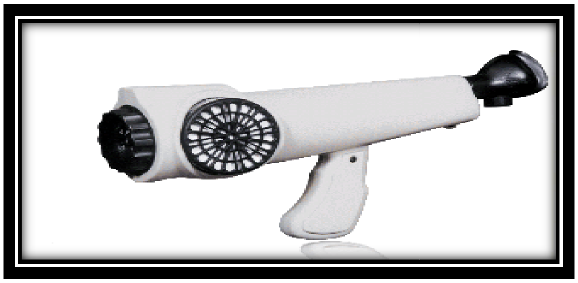


Fig 6: Olfactometer from Nasal Ranger

To measure intensity, the olfactometer introduces an odorous gas as a baseline against which other odors are compared. The instrument has an accuracy of +/-10% and a response time of 2 seconds. The olfactometer however, was not found to be a very accurate means to measure and quantify odors since the olfaction varied from person to person and was extremely subjective.

The Table 5 below gives the ratio of amount of odorous air to carbon filtered air and the inlet size for the odorous air for each dilution to threshold ratio. Table 6 correlates the categories in which each of the D/T ratios fall.

Table 5: Odorous air volume, carbon filtered air volume and the odorous air inlet size associated with each D/T

Dilution to Threshold (D/T)	**Carbon Filtered Air Volume***	**Odorous Air Volume****	**Odorous Air Inlet Size (in. dia.)**
2	2	1	½
7	2	0.285	¼
15	2	0.1333	3/16
31	2	0.0645	1/8
170	2	0.0118	1/16
350	2	0.0057	1/32

* Two 1/2 inch diameter holes for the "Carbon Filtered Air Flow Path"

** Odorous Air Volume calculated from the D/T column. [Huey, 1960]

Table 6: Categories associated with each of the D/Ts

D/T	Category
2	Noticeable
7	Objectionable
15	Nuisance
31	Nauseating

Monitoring of Odor Causing Substances:

As discussed in the previous chapter, a wide variety of odor-producing substances are found in municipal and industrial wastewater treatment and collection systems, usually as the result of biological activity. Anaerobic degradation processes contribute to the generation of hydrogen sulfide (H_2S), often at quite high concentrations; thus, the presence of this chemical compound in the atmosphere is a good indicator of the occurrence and intensity of the impact in a specific area. The monitoring of H_2S has been carried out with the following instruments:

1. CairClip:

Cairclip is an integrated system comprising of an amperometric sensor, dynamic air sampling, filter, and an electronic circuitry which allows a direct real time display of the measured value and status complete with internal data logging. It gives a direct measurement of the sulfides and mercaptans. It has a detection range of 0-20 ppm with an accuracy of +/-10 ppb and can go as low as 5 ppb and has been u8sed for ambient air quality monitoring.

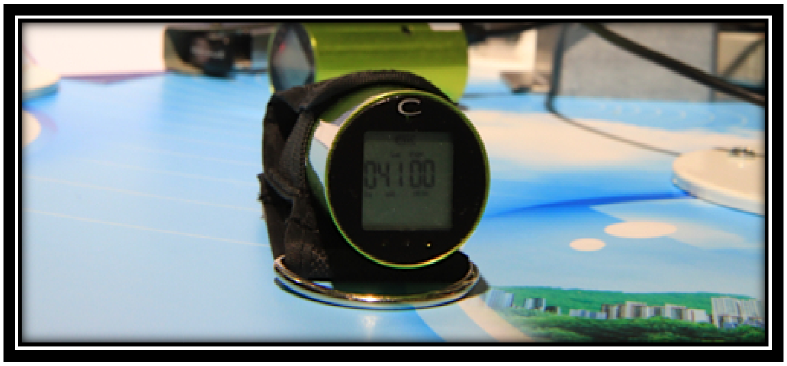


Figure 7: Ambient air monitoring using CairClip

The amperometric sensor consists of three electrodes: the working electrode (anode) and the counter-electrode (cathode) and the reference electrode. The gas to be analyzed is diffused through a membrane to the sensitive electrode. Depending of the gas, oxidation takes place at the anode, or reduction at the cathode. The electrical signal generated between the two electrodes is proportional to the concentration.

2. LandTec Multigas Analyzer:

The multigas analyzer samples and analyzes methane, carbon dioxide, oxygen, carbon monoxide and hydrogen sulfide. The readings are directly displayed and can be stored in the instrument. It measures hydrogen sulfide in the range of 0-200ppm with an accuracy of +/- 10%. Because of the high range of measurement, it has been used for source monitoring in the headworks.

It provides automatic sampling and analysis of gas composition percent by volume. The measurements are based on the galvanic cell principle. The GEM2xxx Plus employs two internal electrochemical cells to measure Hydrogen Sulfide (H_2S) and Carbon Monoxide (CO). The CO cell used in the GEM2xxx Plus also utilizes an internal H_2S filter to eliminate H_2S cross gas interference.

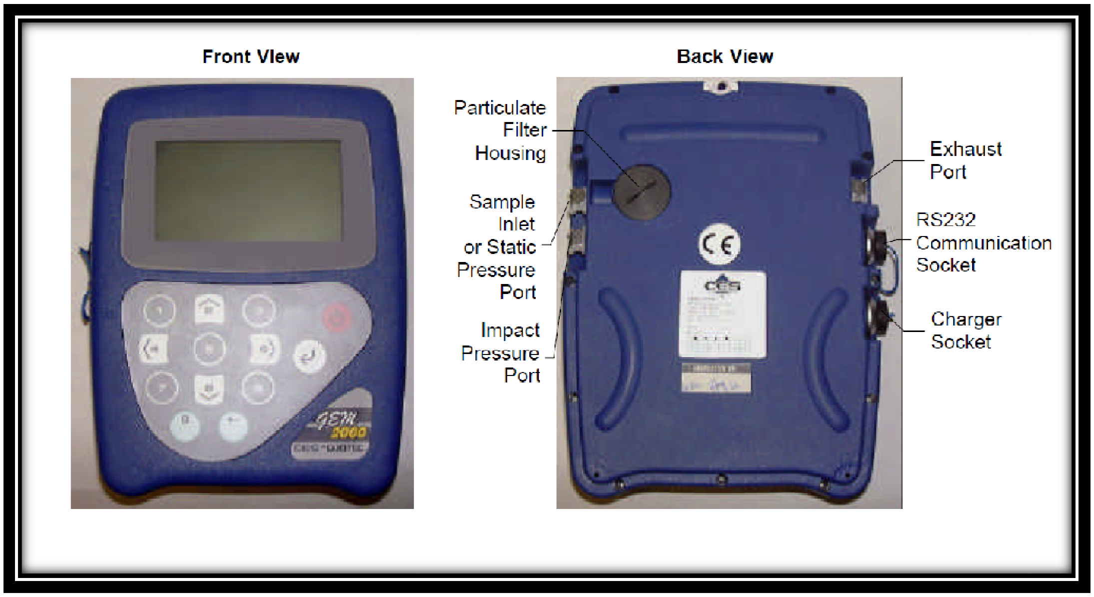


Figure 8: The front and back view of a multi-gas analyzer

3. OdaLog:

OdaLog is a portable gas detector specifically designed for the wastewater industry. It is primarily used at a location close to the source of Hydrogen Sulfide (H_2S) emissions such as those found within sewerage pumping stations, receiving manholes and inside sewer collection lines. With a measurement range of 0.01-2.00ppm and accuracy of +/- 10%, it is used for ambient air quality monitoring.

Figure 9: Ambient air monitoring using OdaLog

4. Photo-ionization Detector:

The PhoCheck+ Photo-ionization Detector is used to detect VOCs in the range of 1 ppb to 10,000 ppm. When a certain gas is to be measured, i.e hydrogen sulfide, the instrument calculates the equivalent level for that selected gas against an isobutylene calibration. For hydrogen sulfide, the correction factor is provided by the manufacturer as 4.0.

In a photoionization detector high-energy photons break molecules into positively charged ions. UV light excites the molecules, resulting in temporary loss of electrons in the molecules and the formation of positively charged ions. The gas becomes electrically charged and the ions produce an electric current, which is the signal output of the detector. The greater the concentration of the component, the more ions are produced, and the greater the current.

Figure 10: Photo-ionization detector for Source Monitoring

Although many PID manufacturers provide the ability to program an instrument with a correction factor for quantitative detection of a specific chemical, the broad selectivity of the PID means that the user must know the identity of the gas or vapor species to be measured with high certainty.

5. Gas Badge Pro:

It is a single gas monitor which measures H_2S in the range of 0-500 ppm with an accuracy od +/- 0.1 ppm. This makes it ideal to measure concentration inside the treatment plant like the headwork where high concentrations are expected. It provides direct gas reading and even logs alarm events, i.e., when the concentration exceeds the STEL limits. It uses an electrochemical cell to determine the potentiometry of the pollutant and then assigns it a concentration as per the calibration performed.

Figure 11: Gas Badge Pro from Industrial Scientific Corporation

Meteorological Monitoring:

1. Anemometer:

The wind logger provides average speed, wind gust and average direction. It can measure the wind speed in the range of 0-67 m/s with an accuracy of +/- 2% and measures the wind direction with an accuracy of +/- 22.5 degrees. It works on the same principle as an anemometer. It is a cup-type anemometer mounted on a vertical axis and is provided with a sensor to log the wind speed and direction.

Figure 12: Anemometer from Raintree

2. Windrose:

A freeware available online called the WRPlot View developed by the Lakes Environmental Software was used for this purpose. This provides visual wind rose plots, frequency analysis, and plots for several meteorological data formats. A wind rose depicts the frequency of occurrence of winds in each of the specified wind direction sectors and wind speed classes for a given location and time period.

5. RESULTS AND DISCUSSIONS

5.1 Data observed for ambient H_2S concentration monitoring

(a) Using CairClip:

CairClip has been used for ambient monitoring of H_2S and mercaptans concentration. The equipment was used for monitoring at three locations, i.e., the filter press building, near the aeration tank and at the perimeter. The detailed monitoring results are attached in the appendix. The Figures 13, 15 and 17 below give the distribution of the concentrations at filter press, aeration tank and perimeter respectively. This gives an idea about the percentage of concentrations that exceed the limit set by the regulatory agencies. The tables 8, 10 and 12 is a summary of the average concentrations seen on a daily basis at the locations.

Table 7: Frequency distribution of concentration ranges near filter press using CairClip

Sl. No.	Concentration range (ppb)	Percentage
1	0-5	92.09
2	5-15	2.47
3	15-30	1.63
4	30-60	0.88
5	60-90	0.55
6	90-150	0.55
7	150-250	0.68
8	250-500	0.90
9	500-1000	0.23
10	1000-1600	0.02

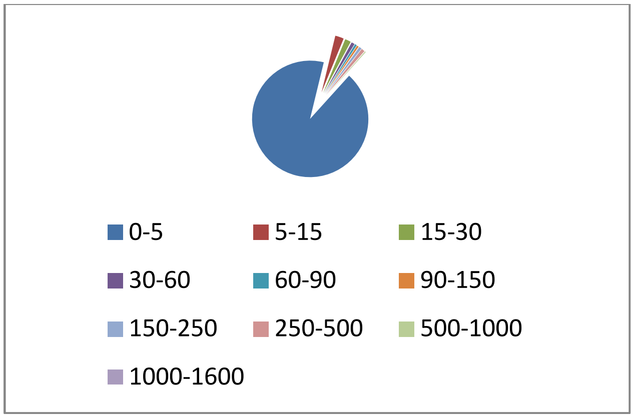


Figure 13: Pie-chart distribution of concentration ranges near filter press using CairClip

Table 8: Daily maximum, minimum and average H_2S concentrations using CairClip near filter press

Date	H_2S concentration, max (ppb)	H_2S concentration, min (ppb)	H_2S concentration, avg (ppb)
5/28	61.00	0.00	2.27
5/29	79.00	0.00	4.85
5/30	21.00	0.00	0.29
5/31	0.00	0.00	0.00
6/4	1563.00	0.00	183.88
6/5	795.00	0.00	75.43
6/6	38.00	0.00	0.34
6/7	235.00	0.00	2.64
6/8	29.00	0.00	0.16
6/9	13.00	0.00	0.33
6/10	21.00	0.00	0.52
6/11	235.00	0.00	3.65
6/12	167.00	0.00	4.15
6/13	21.00	0.00	1.69
6/14	253.00	0.00	4.22
6/15	61.00	0.00	1.26
6/16	45.00	0.00	0.64
6/17	13.00	0.00	0.63
6/18	54.00	0.00	5.10
6/26	210.00	0.00	1.94
6/27	38.00	0.00	1.11
6/28	239.00	0.00	5.88
6/30	0.00	0.00	0.00
7/1	38.00	0.00	1.30
7/2	54.00	0.00	0.94

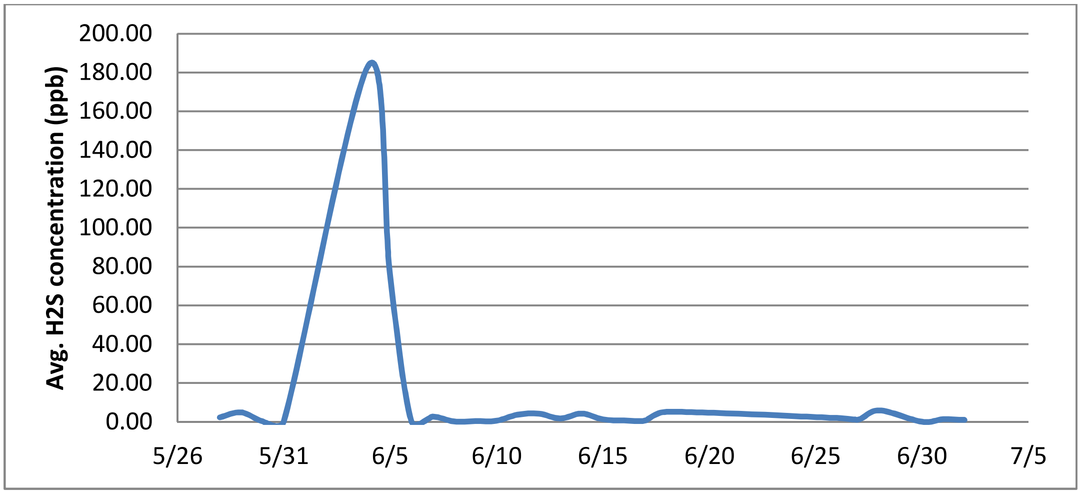


Figure 14: Daily average H_2S concentrations using CairClip near filter press

Table 9: Frequency distribution of concentration ranges near aeration tank using CairClip

Sl. No.	Concentration range (ppb)	Percentage
1	0-5	94.62
2	5-15	4.38
3	15-30	0.92
4	30-60	0.25
5	60-90	0.14
6	90-150	0.06
7	150-250	0.10
8	250-500	0.00
9	500-1000	0.00
10	1000-1600	0.00

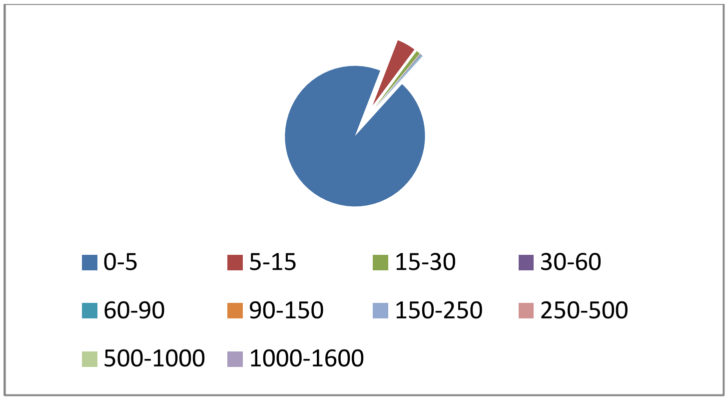


Figure 15: Pie-chart distribution of concentration ranges near aeration tank using CairClip

Table 10: Daily maximum, minimum and average H_2S concentrations using CairClip near aeration tank

Date	H_2S concentration, max (ppb)	H_2S concentration, min (ppb)	H_2S concentration, avg (ppb)
7/4	22.00	0.00	0.08
7/5	22.00	0.00	1.14
7/6	154.00	0.00	1.51
7/7	13.00	0.00	1.18
7/8	231.00	0.00	3.06
7/9	22.00	0.00	0.52
7/10	154.00	0.00	2.28
7/15	63.00	0.00	0.48
7/16	241.00	0.00	1.63
7/17	241.00	0.00	4.53
7/18	243.00	0.00	7.27
7/19	22.00	0.00	1.22
7/20	47.00	0.00	2.07
7/21	13.00	0.00	0.99
7/22	64.00	0.00	1.26
7/23	39.00	0.00	2.54
7/24	30.00	0.00	1.41
7/25	13.00	0.00	1.19
7/26	198.00	0.00	3.94
7/27	56.00	0.00	3.24
7/28	22.00	0.00	2.47
7/29	22.00	0.00	1.27
7/30	22.00	0.00	0.72
7/31	22.00	0.00	1.06
8/1	22.00	0.00	1.28
8/2	73.00	0.00	1.46

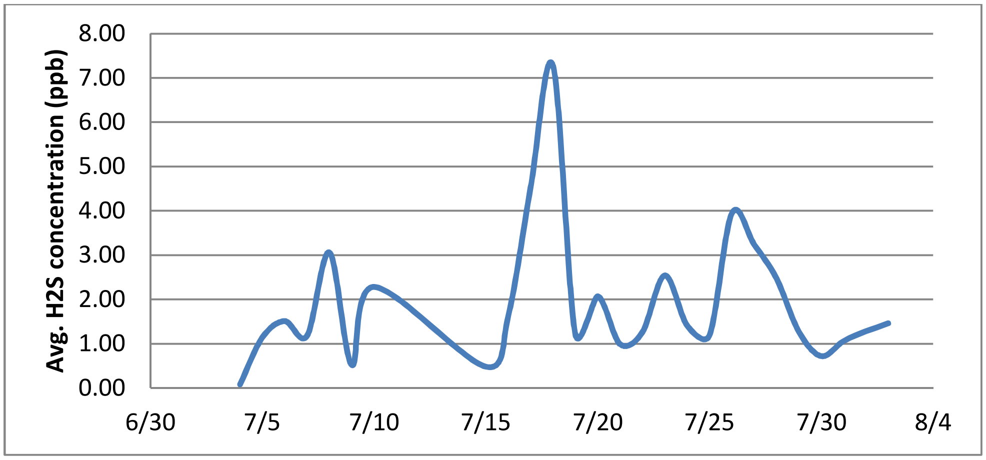


Figure 16: Daily average H_2S concentrations using CairClip near aeration tank

Table 11: Frequency distribution of concentration ranges at perimeter using CairClip

Sl. No.	Concentration range (ppb)	Percentage
1	0-5	91.37
2	5-15	1.35
3	15-30	0.71
4	30-60	0.32
5	60-90	0.17
6	90-150	0.21
7	150-250	0.14
8	250-500	0.00
9	500-1000	0.00
10	1000-1600	0.00

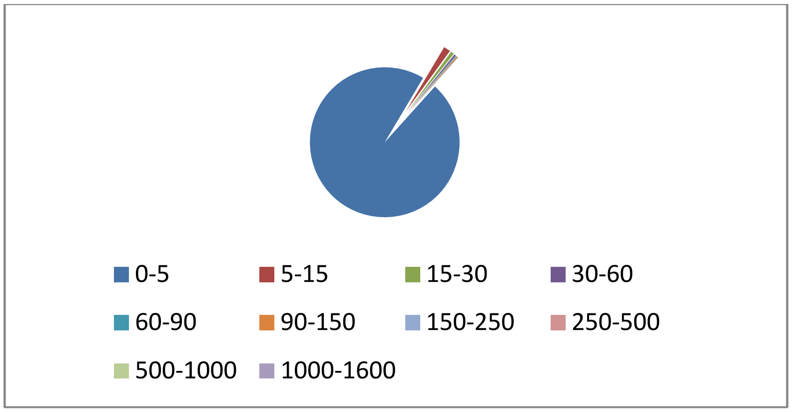


Figure 17: Pie-chart distribution of concentration ranges at perimeter using CairClip

Table 12: Daily maximum, minimum and average H_2S concentrations using CairClip at the perimeter

Date	H_2S concentration, max (ppb)	H_2S concentration, min (ppb)	H_2S concentration, avg (ppb)
8/3	184.00	0.00	5.72
8/4	210.00	0.00	3.09
8/5	73.00	0.00	1.94
8/6	47.00	0.00	2.28
8/7	246.00	0.00	5.93
8/8	255.00	0.00	10.33
8/9	5.00	0.00	0.03
8/10	22.00	0.00	2.64

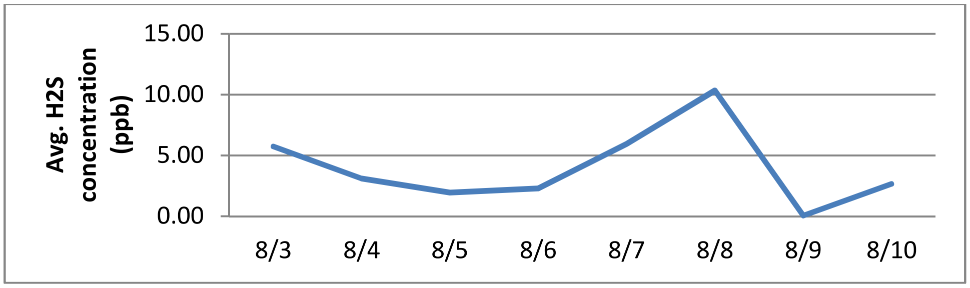


Figure 18: Daily average H_2S concentrations using CairClip at the perimeter

(b) Using OdaLog:

OdaLog has been used for ambient monitoring of H_2S concentration. Similar to CairClip, this equipment was also used for monitoring at three locations, i.e., the filter press building, near the aeration tank and at the perimeter. The detailed monitoring results are attached in the appendix. The Figures 19, 21 and 23 below give the distribution of the concentrations at filter press, aeration tank and perimeter respectively. This gives an idea about the percentage of concentrations that exceed the limit set by the regulatory agencies. The tables 14, 16 and 18 is a summary of the average concentrations seen on a daily basis at the locations.

Table 13: Frequency distribution of concentration ranges near filter press using OdaLog

Sl. No.	Concentration range (ppb)	Percentage
1	0-10	98.00
2	10-20	0.92
3	20-50	0.51
4	50-100	0.38
5	100-200	0.13
6	200-500	0.06

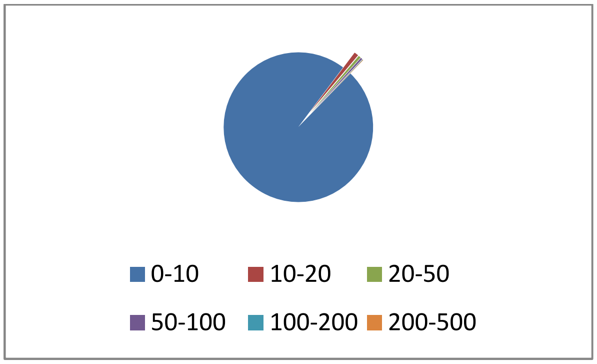


Figure 19: Pie-chart distribution of concentration ranges near filter press using OdaLog

Table 14: Daily maximum, minimum and average H_2S concentrations using OdaLog near filter press

Date	H_2S concentration, max (ppb)	H_2S concentration, min (ppb)	H_2S concentration, avg (ppb)
6/9	50.00	0.00	1.88
6/10	10.00	0.00	0.28
6/11	80.00	0.00	2.43
6/12	140.00	0.00	5.42
6/13	0.00	0.00	0.00
6/14	130.00	0.00	1.81
6/15	20.00	0.00	0.76
6/16	0.00	0.00	0.00
6/17	30.00	0.00	0.28
6/18	20.00	0.00	0.90
6/19	20.00	0.00	1.18
6/20	20.00	0.00	1.55
6/21	10.00	0.00	0.07
6/22	100.00	0.00	2.36
6/23	10.00	0.00	0.07
6/24	0.00	0.00	0.00
6/27	10.00	0.00	0.07
6/28	500.00	0.00	8.33
6/29	0.00	0.00	0.00
6/30	0.00	0.00	0.00
7/1	0.00	0.00	0.00
7/2	210.00	0.00	5.98

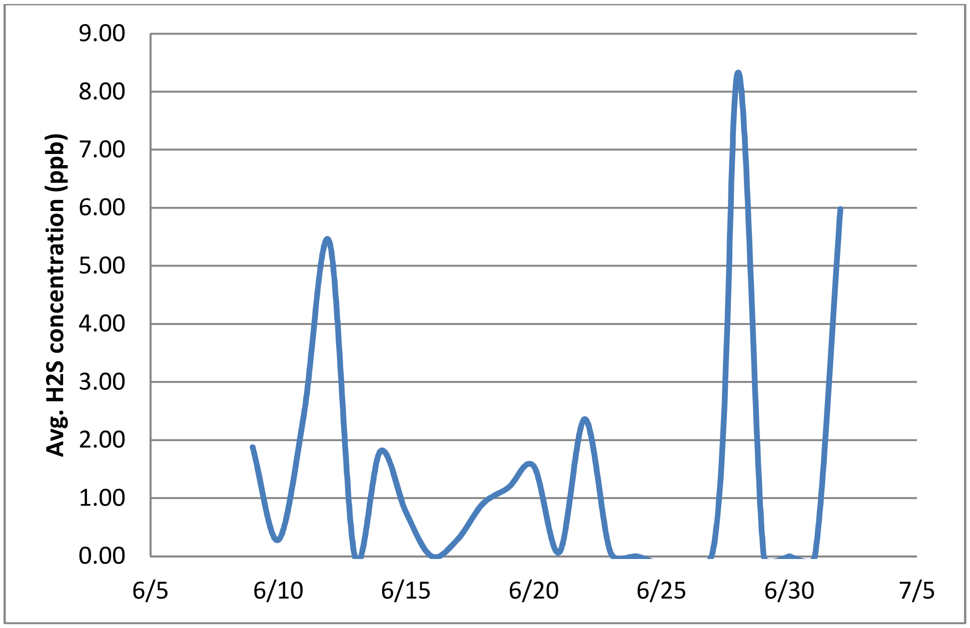


Figure 20: Daily average H_2S concentrations using OdaLog at filter press

Table 15: Frequency distribution of concentration ranges near aeration tank using OdaLog

Sl. No.	Concentration range (ppb)	Percentage
1	0-10	121.79
2	10-20	0.76
3	20-50	1.01
4	50-100	0.60
5	100-200	0.29
6	200-500	0.29

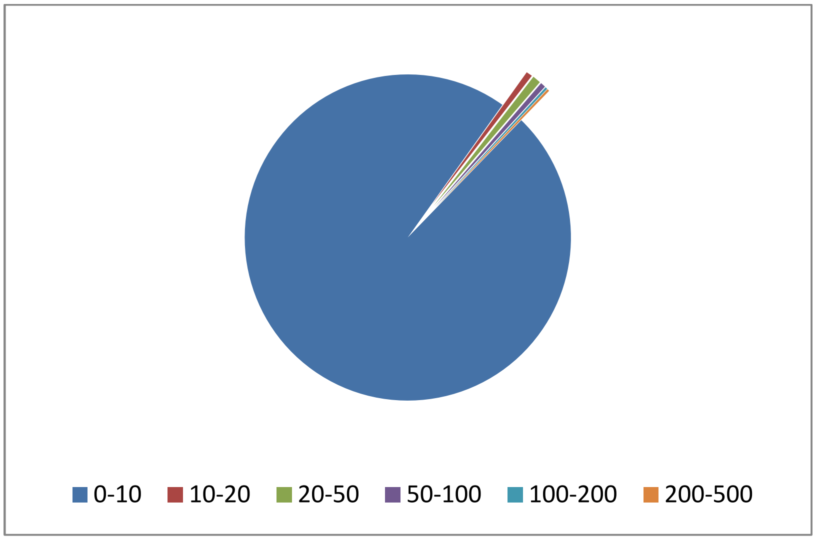


Figure 21: Pie-chart distribution of concentration ranges near aeration tank using OdaLog

Table 16: Daily maximum, minimum and average H_2S concentrations using OdaLog near aeration tank

Date	**H_2S concentration, max (ppb)**	**H_2S concentration, min (ppb)**	**H_2S concentration, avg (ppb)**
7/3	590.00	0.00	10.76
7/4	50.00	0.00	0.43
7/5	0.00	0.00	0.00
7/6	80.00	0.00	2.01
7/7	90.00	0.00	1.53
7/8	10.00	0.00	0.07
7/9	100.00	0.00	2.50
7/10	50.00	0.00	0.35
7/11	0.00	0.00	0.00
7/14	60.00	0.00	2.22
7/15	40.00	0.00	1.18
7/16	20.00	0.00	0.28
7/17	10.00	0.00	0.14
7/18	70.00	0.00	3.68
7/19	30.00	0.00	0.91
7/20	10.00	0.00	0.14
7/21	0.00	0.00	0.00
7/22	0.00	0.00	0.00
7/23	10.00	0.00	0.14
7/24	10.00	0.00	0.14
7/25	10.00	0.00	0.07
7/26	340.00	0.00	10.21
7/27	330.00	0.00	21.93
7/28	70.00	0.00	1.57
7/29	30.00	0.00	2.14
7/30	0.00	0.00	0.00
7/31	0.00	0.00	0.00
8/1	0.00	0.00	0.00
8/2	0.00	0.00	0.00

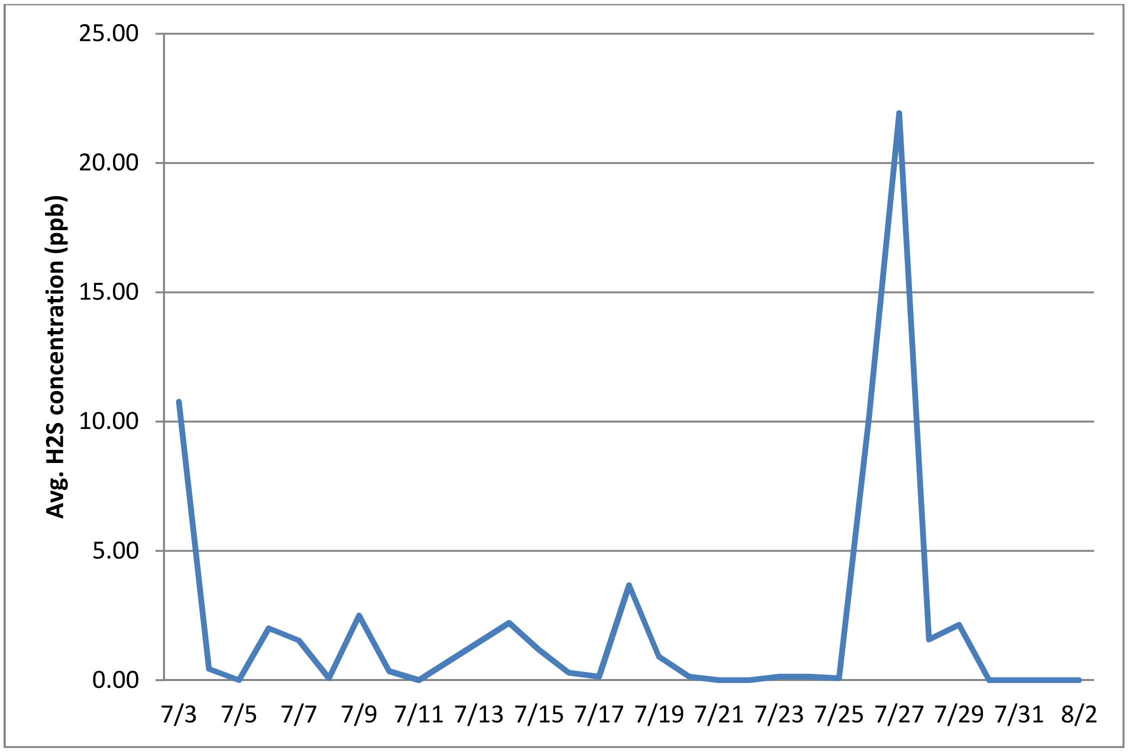


Figure 22: Daily average H_2S concentrations using OdaLog near aeration tank

Table 17: Frequency distribution of concentration ranges at perimeter using OdaLog

Sl. No.	Concentration range (ppb)	Percentage
1	0-10	30.32
2	10-20	0.25
3	20-50	0.51
4	50-100	0.22
5	100-200	0.29
6	200-500	0.22

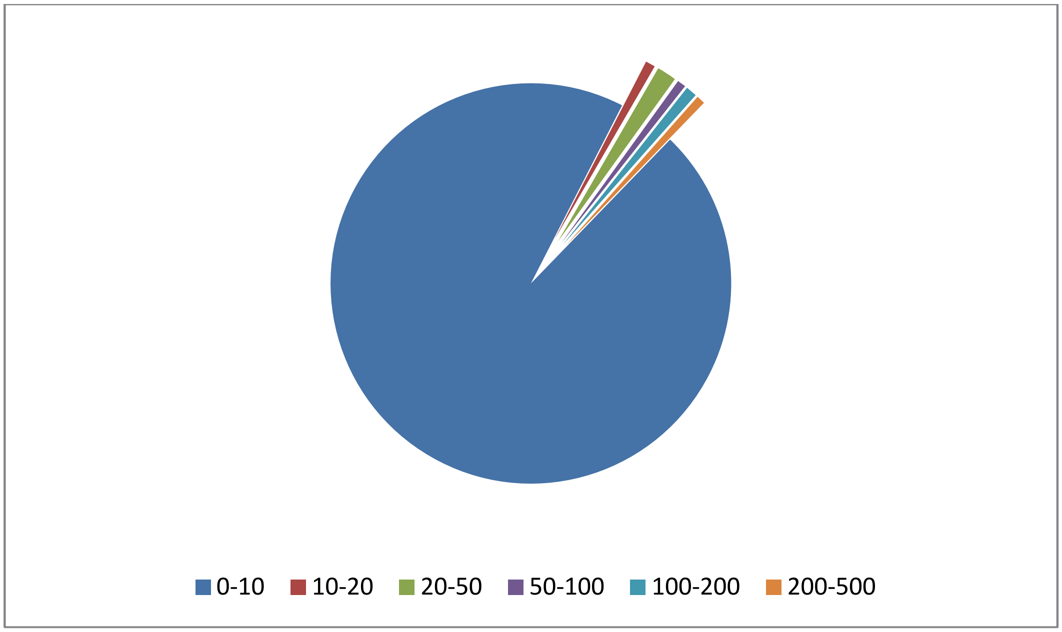


Figure 23: Pie-chart distribution of concentration ranges at the perimeter using OdaLog

Table 18: Daily maximum, minimum and average H_2S concentrations using OdaLog at the perimeter

Date	**H_2S concentration, max (ppb)**	**H_2S concentration, min (ppb)**	**H_2S concentration, avg (ppb)**
8/3	50.00	0.00	0.54
8/4	210.00	0.00	7.13
8/5	20.00	0.00	0.53
8/6	10.00	0.00	0.31
8/7	160.00	0.00	1.75
8/8	440.00	0.00	23.54
8/9	50.00	0.00	0.69
8/10	10.00	0.00	0.07

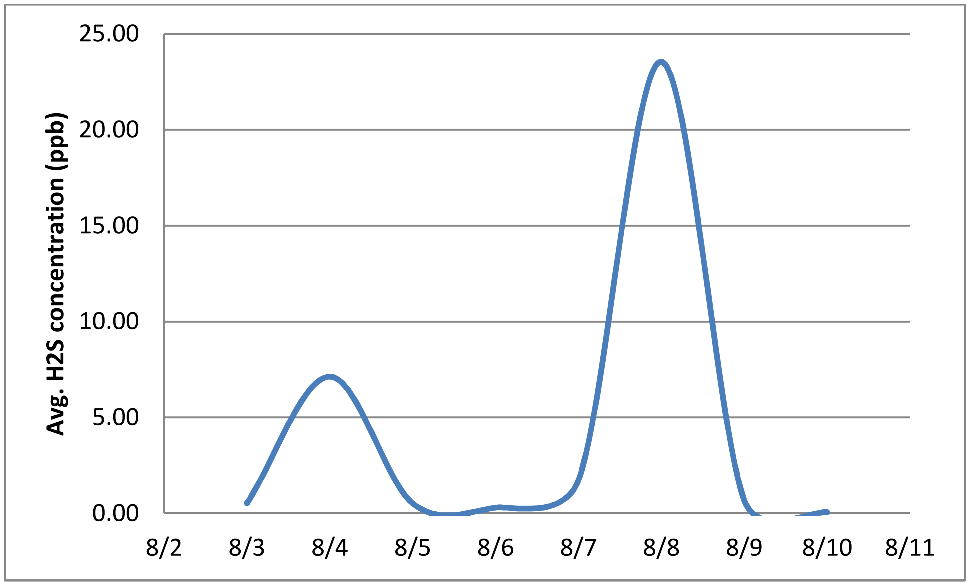


Figure 24: Daily average H_2S concentrations using OdaLog at perimeter

5.2 Data observed for source monitoring

As described above, the multi-gas analyzer was used to measure the concentrations of H_2S on a daily basis in the headworks owing to the source's contribution to the odor nuisance within the facility. The Table 19 below gives the consolidated results for the H_2S concentrations in terms of maximum and minimum concentration recorded.

To get a better understanding of how the concentrations depend on meteorological parameters like rainfall and temperature, the graphs below were plotted. The Figure 25 clearly shows the positive correlation H_2S concentrations have with temperature. As the temperature increases, the H_2S build up in the sewage also increases as it facilitates the growth of microbes. The inverse correlation with precipitation is owing to the infiltration and inflow problems which increases the volume of wastewater to be treated by the facility and thus does not provide sufficient detention time or the anaerobic conditions required by the bacteria to produce the sulfides.

Table 19: Daily maximum and minimum H_2S concentration along with meteorological parameters

Date	**H_2S - Daily High (ppm)**	**H_2S; Daily Low (ppm)**	**Precipitation (in.)**	**Temp; Daily Max Deg. F**	**Temp; Daily Min Deg. F**	**Temp; Daily Avg. Deg. F**
7/17	5	0	0.00	94.00	77.00	85.50
7/18	6	1	0.21	92.00	75.00	83.50
7/19	7	0	1.77	89.00	75.00	82.00
7/20	1	0	3.57	82.00	72.00	77.00
7/21	0	0	0.37	85.00	73.00	79.00
7/22	1	0	0.00	87.00	77.00	82.00
7/23	3	0	0.00	92.00	78.00	85.00

Table 19 contd.: Daily maximum and minimum H_2S concentration along with meteorological parameters

Date	H_2S - Daily High (ppm)	H_2S; Daily Low (ppm)	Precipitation (in.)	Temp; Daily Max Deg. F	Temp; Daily Min Deg. F	Temp; Daily Avg. Deg. F
7/24	10	1	0.00	91.00	78.00	84.50
7/25	15	2	0.09	92.00	78.00	85.00
7/26	17	4	0.11	92.00	78.00	85.00
7/27	8	2	0.32	88.00	74.00	81.00
7/28	4	1	0.45	90.00	75.00	82.50
7/29	9	1	0.00	93.00	76.00	84.50
7/30	15	4	0.00	94.00	78.00	86.00
7/31	17	3	0.00	92.00	79.00	85.50
8/1	20	7	0.00	93.00	80.00	86.50
8/2	20	6	0.00	93.00	79.00	86.00
8/3	26	6	0.03	90.00	80.00	85.00
8/4	19	0	1.54	90.00	73.00	81.50
8/5	5	0	0.27	90.00	76.00	83.00
8/6	6	1	0.00	92.00	75.00	83.50
8/7	15	0	0.00	92.00	75.00	83.50
8/8	22	3	0.55	92.00	75.00	83.50
8/9	5	1	0.12	92.00	75.00	83.50
8/10	4	0	0.24	92.00	75.00	83.50
8/11	4	1	0.20	92.00	75.00	83.50
8/12	3	1	0.00	92.00	75.00	83.50
8/13	6	3	0.04	91.00	75.00	83.00
8/14	8	5	0.08	91.00	75.00	83.00
8/15	9	3	0.31	91.00	75.00	83.00
8/16	11	4	0.20	91.00	75.00	83.00
8/17	11	5	1.77	91.00	75.00	83.00
8/18	7	5	0.35	91.00	75.00	83.00
8/19	5	0	1.14	91.00	75.00	83.00
8/20	1	0	0.00	91.00	75.00	83.00
8/21	2	1	0.00	91.00	75.00	83.00

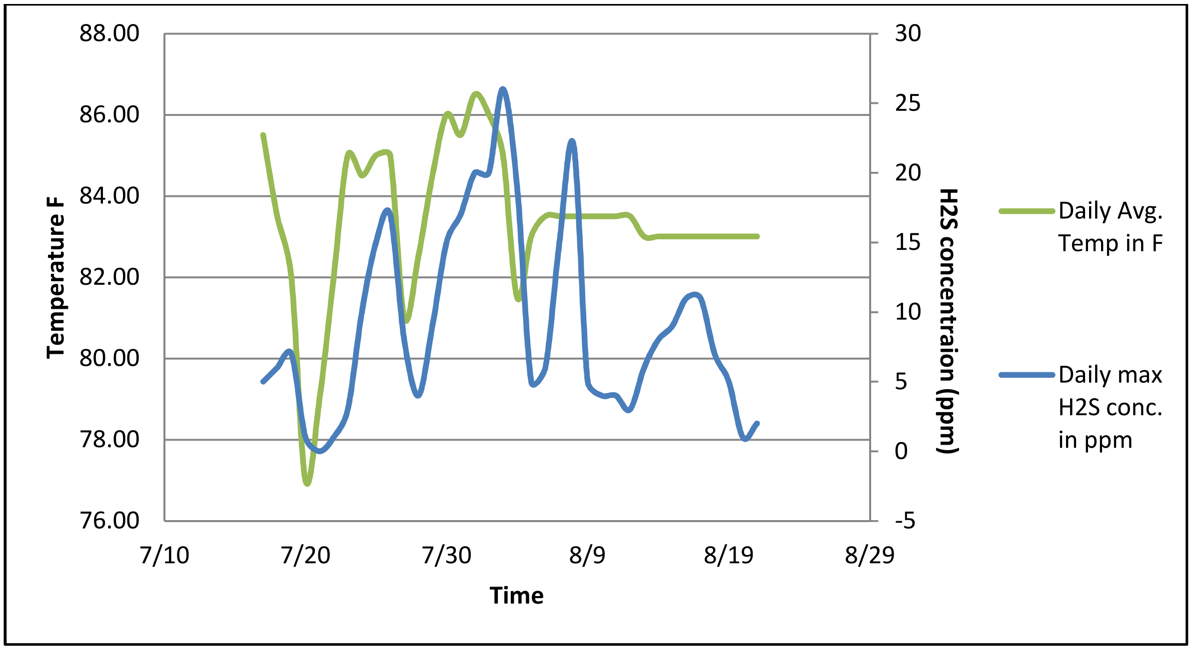


Figure 25: Variation of maximum H_2S concentration with daily average temperature

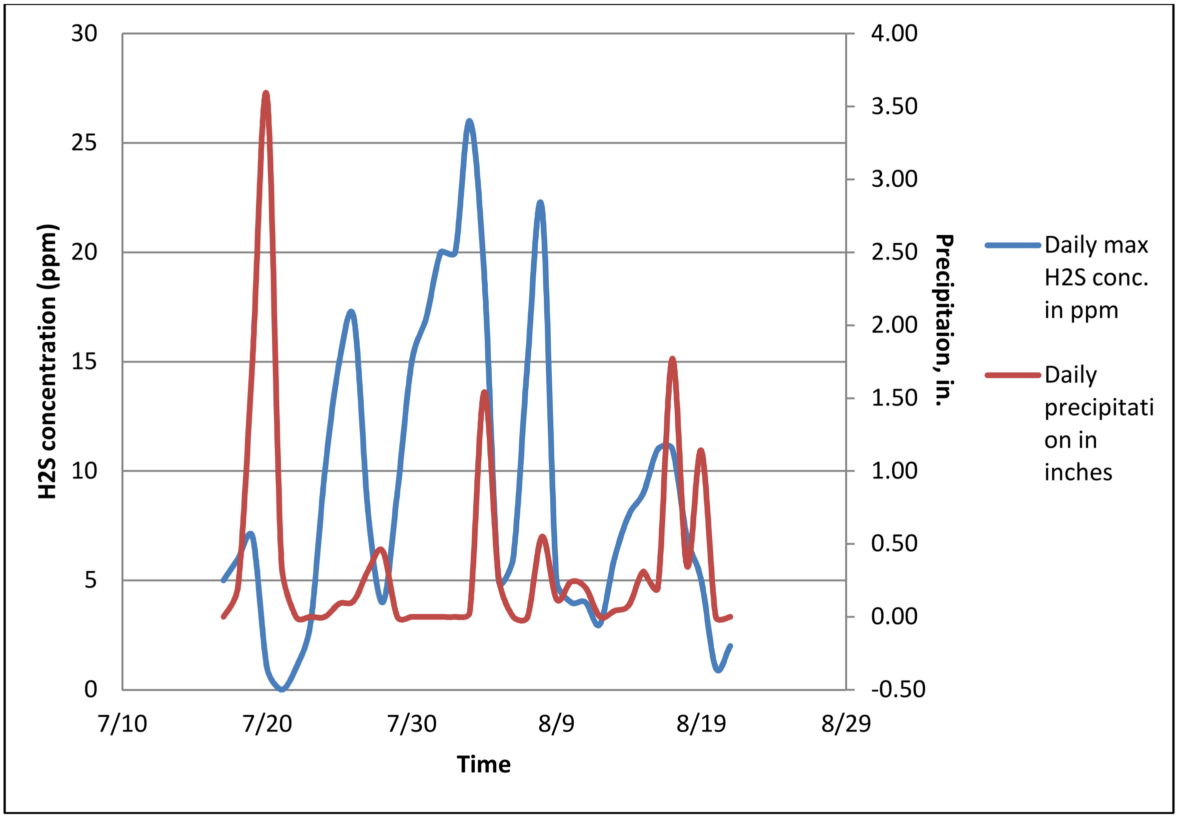


Figure 26: Variation of maximum H_2S concentration with daily precipitation

5.3 Data from the meteorological monitoring on site

The meteorological monitoring was done using a commercially available anemometer, from Rainwise. The anemometer was positioned in the plant in such a way that there would be no obstruction to hamper the readings. The data obtained from the anemometer was used to produce a windrose to get a better understanding of the wind direction and speed for each day. A wind rose depicts the frequency of occurrence of winds in each of the specified wind direction sectors and wind speed classes for a given location and time period. The diagrammatic representation helps analyze the movement of the plume and gives an idea of where the concentration could be high.

For this a freeware from Lakes Environmental called the WRPLOT View was used. Figures 27, 28 and 29 show the windrose during the time periods for which the monitoring was done near the filter press, aeration tanks and the perimeter respectively.

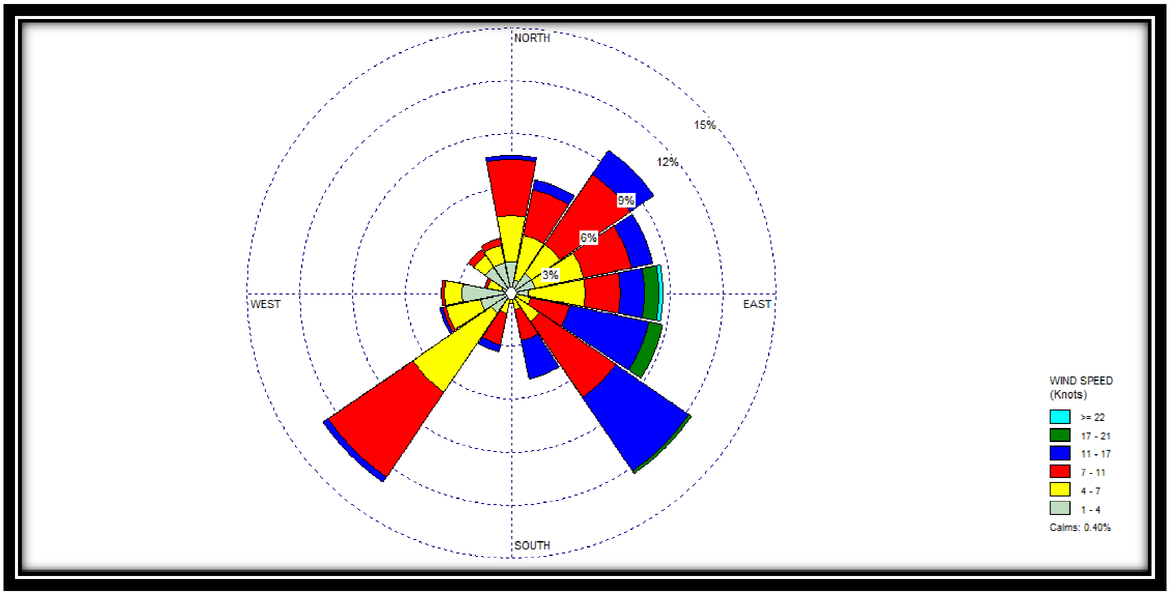


Figure 27: The windrose for the time period when the monitoring was done near filter press

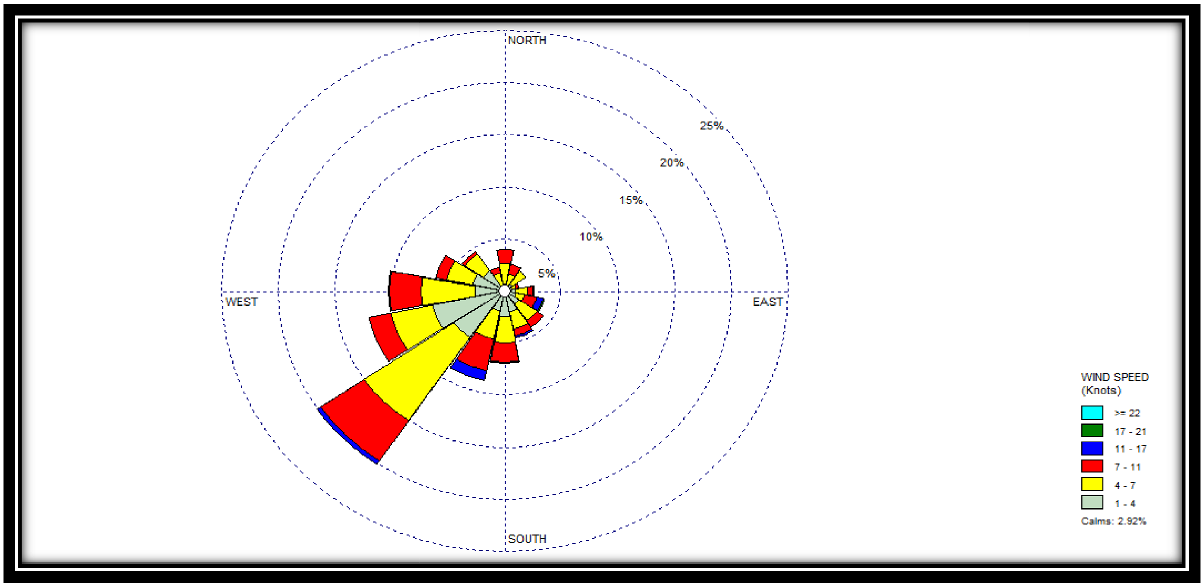


Figure 28: The windrose for the time period when the monitoring was done near aeration tank

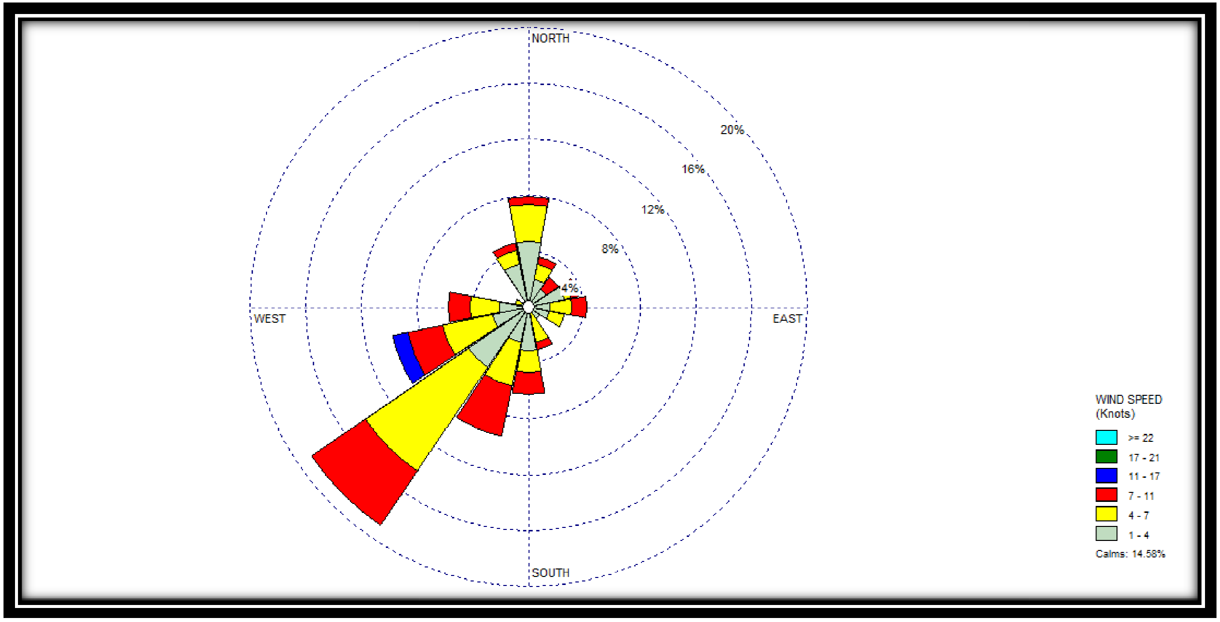


Figure 29: The windrose for the time period when the monitoring was done at the perimeter

5.4 Data from Hot-spot analysis

A preliminary analysis of the waste water treatment plant was carried out to get familiarized with the layout, understand the processing and identify the "hot spots" that require continuous monitoring.

Table 20: Concentrations at various locations from hot-spot analysis

Sl. No.	**Date**	**Latitude**	**Longitude**	**Concentration (ppb)**	**Comments**
1	9/28/2012	90^{o} 11.046’W	29 ^{o} 58.244’N	5	Below limits
2	9/28/2012	90^{o} 11.039’W	29 ^{o} 58.243’N	38	Monitoring to be done
3	9/28/2012	90^{o} 11.039’W	29 ^{o} 58.243’N	733	Within enclosed tank
4	9/28/2012	90^{o} 11.057’W	29 ^{o} 58.216’N	17000	Continuous inhalation could lead to fatigue, headache or nausea
5	9/28/2012	90^{o} 11.061’W	29 ^{o} 58.209’N	201	Blower/ Vent provided
6	9/28/2012	90^{o} 11.112’W	29 ^{o} 58.203’N	78	Blower/ Vent provided
7	9/28/2012	90^{o} 11.208’W	29 ^{o} 58.282’N	45	Monitoring to be done
8	6/29/2012	90 11'16" W	29 58'5" N	21	Below limits
9	6/29/2012	90 11'11"W	29 58'32"N	55	Near the storage tanks
10	6/29/2012	90 11'14"W	29 58'4” N	34	Below limits
11	6/29/2012	90 11'07"W	29 75'52"N	5	Below limits
12	6/29/2012	90 11'12" W	29 58'4"N	5	Below limits
13	6/29/2012	90 11'22"W	29 58'4"N	785	Monitoring to be done
14	6/29/2012	90 11'14"W	29 58'3"N	510	Monitoring to be done
15	6/29/2012	90 11'10"W	29 58'4"N	38	Below limits
17	6/29/2012	90 11'21"W	29 58'4"N	21	Below limits

5.5 Data from Perimeter analysis

The instrument used was CairClip for measuring the concentration of. All the data was continuously recorded. The latitude and longitude were recorded using a GPS for each location where concentration was measured. WindLog was used to measure the wind speed and direction. To get an accurate measure, a 5 minute average of the concentration at each location was taken.

We started by covering the perimeter of the complete plant. Then, concentrating on specific source buildings, such as the headworks and the filter press, measurements were taken for the perimeter of the sources. These concentrations could be used to calculate the emissions generated by the buildings using a suitable modeling technique. Perimeter monitoring was carried out on June 29 and July 27, 2012 and the results are shown below.

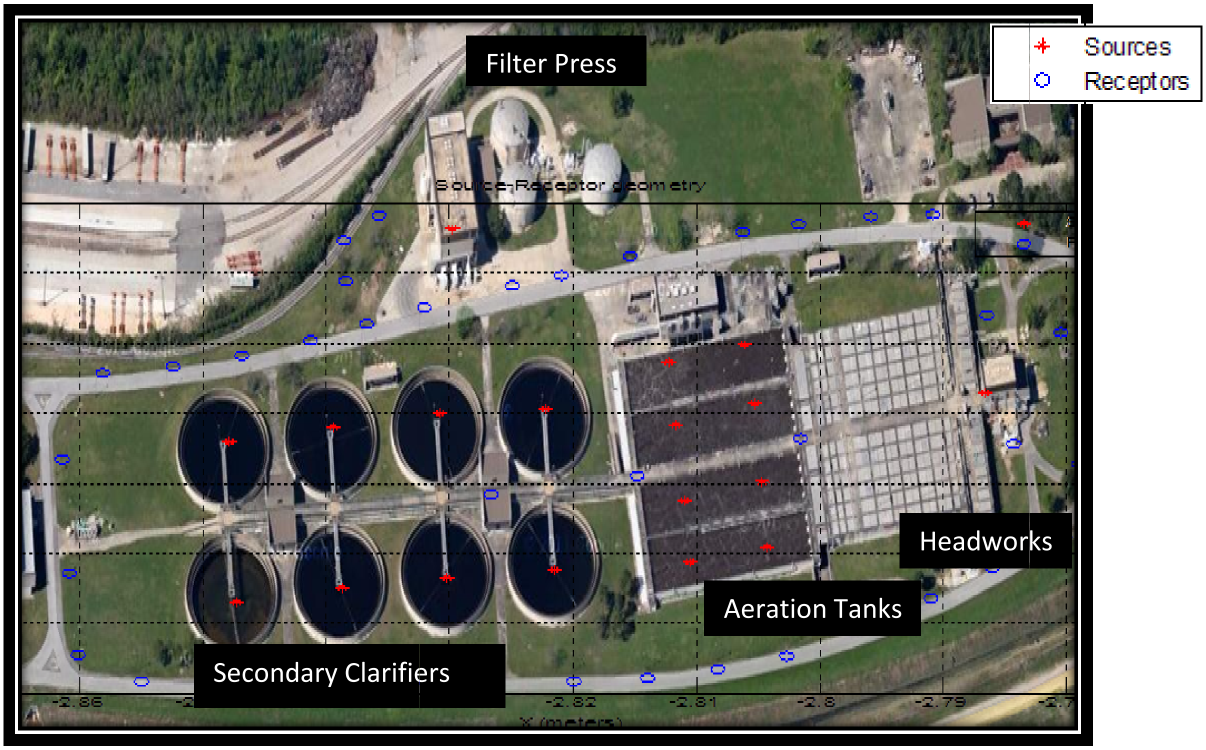


Figure 30: Source – Monitoring Locations Overlaid on Map

Table 21: H_2S concentration measured along the perimeter for June 29, 2012

Sl. No.	Longitude	Latitude	Start Time	Stop Time	CairClip (ppb)
1	90 11'9"	29 57'53"	8:46	8:51	0.00
2	90 11'2"	29 58'10"	8:56	9:02	5.00
3	90 11'1"	29 58'1"	9:03	9:08	0.00
4	90 11'12"	29 58'4"	9:09	9:14	21.00
5	90 11'12"	29 58'4"	9:15	9:20	30.00
6	90 11'11"	29 58'4"	9:21	9:26	20.00

Table 21contd.: H_2S concentration measured along the perimeter for June 29, 2012

Sl. No.	Longitude	Latitude	Start Time	Stop Time	CairClip (ppb)
7	90 11'6"	29 57'57"	9:27	9:32	13.00
8	90 11'6"	29 57'52"	9:33	9:38	13.00
9	90 11'12"	29 58'3"	9:39	9:45	5.00
10	90 11'5"	29 57'57"	9:46	9:54	0.00
11	90 11'14"	29 58'4"	9:55	10:00	0.00
12	90 11'18"	29 58'5"	10:01	10:06	0.00
13	90 11'9"	29 58'8"	10:06	10:12	29.00
14	90 11'10"	29 58'9"	10:13	10:19	0.00
15	90 11'12"	29 58'4"	10:20	10:25	5.00
16	90 11'16"	29 58'5"	10:26	10:31	13.00
17	90 11'1"	29 57'59"	10:32	10:37	0.00
18	90 11'15"	29 58'6"	10:38	10:44	0.00
19	90 11'19"	29 58'5"	10:45	10:50	10.00
20	90 11'18"	29 58'5"	10:51	10:55	13.00
21	90 11'21"	29 58'4"	10:56	11:02	20.00
22	90 11'17"	29 58'5"	11:03	11:08	10.00
23	90 11'19"	29 58'5"	11:09	11:14	5.00
24	90 11'19"	29 58'4"	11:15	11:20	10.00
25	90 11'17"	29 58'5"	11:21	11:26	7.00
26	90 11'1"	29 57'59"	11:27	11:32	5.00
27	90 11'29"	29 58'8"	11:33	11:38	10.00
28	90 11'3"	29 58'2"	11:39	11:49	15.00
29	90 11'14"	29 58'13"	11:50	11:56	13.00
30	90 11'3"	29 57'59"	11:57	12:03	15.00
31	90 11'1"	29 57'59"	12:04	12:09	10.00
32	90 11'1"	29 58'0"	12:10	12:15	15.00
33	90 11'17"	29 58'4"	12:16	12:22	10.00
34	90 11'29"	29 58'9"	12:23	12:28	10.00
35	90 11'28"	29 58'2"	12:29	12:35	10.00
36	90 57'58"	29 57'58"	12:36	12:42	2.00
37	90 11'4"	29 58'0"	12:44	12:49	0.00
38	90 11'3"	29 57'59"	1:58	2:07	10.00
39	90 11'16"	29 57'57"	2:08	2:13	5.00
40	90 11'10"	29 58'4"	2:14	2:21	238.00

Table 22: Hourly wind data for June 29, 2012

Date-Time	Speed	Gust	Direction
6/29/2012 8:00	1.7	5.4	314
6/29/2012 9:00	2	8.6	308
6/29/2012 10:00	2.3	7.7	314
6/29/2012 11:00	3	9.6	345
6/29/2012 12:00	3	10	14
6/29/2012 13:00	3.5	11.4	28
6/29/2012 14:00	3.8	9.6	14
6/29/2012 15:00	4.3	12.8	43
6/29/2012 16:00	2.3	8.6	26
6/29/2012 17:00	2.3	8.6	252

Table 23: H_2S concentrations at different locations on the perimeter for July 27, 2012

Sl. No.	Latitude	Longitude	CairClip (ppb)	ug/m3
1	29.970391	90.184293	1.7	2.369633129
2	29.970334	90.183898	0	0
3	29.969904	90.183801	0	0
4	29.969665	90.183882	2.2	3.066584049
5	29.969967	90.184152	0.8	1.115121472
6	29.969563	90.18427	0.8	1.115121472
7	29.96946	90.1846	1.7	2.369633129
8	29.969363	90.184946	0	0
9	29.969267	90.185365	0.8	1.115121472
10	29.969221	90.185738	0	0
11	29.969191	90.186116	0	0
12	29.969177	90.18651	0	0
13	29.969165	90.187004	0.8	1.115121472
14	29.96917	90.187371	1.7	2.369633129
15	29.96917	90.187747	0.8	1.115121472
16	29.969154	90.188125	0.8	1.115121472
17	29.969165	90.188825	0.8	1.115121472
18	29.969247	90.18916	0	0
19	29.969516	90.189216	0.8	1.115121472
20	29.969888	90.189246	1.7	2.369633129
21	29.970174	90.189037	1.7	2.369633129
22	29.970197	90.188653	3	4.181705521
23	29.970236	90.188286	2.1	2.927193865

Table 23 contd.: H_2S concentrations at different locations on the perimeter for July 27, 2012

Sl. No.	Latitude	Longitude	CairClip (ppb)	ug/m3
24	29.970287	90.187926	0.8	1.115121472
25	29.970343	90.187618	3.8	5.296826994
26	29.970399	90.187309	0.8	1.115121472
27	29.970473	90.18684	0.8	1.115121472
28	29.970508	90.186572	0.8	1.115121472
29	29.970573	90.186207	0.8	1.115121472
30	29.970655	90.185601	0	0
31	29.970682	90.1853	0.8	1.115121472
32	29.97071	90.18492	1.7	2.369633129
33	29.970717	90.184584	0.8	1.115121472
34	29.97071	90.18419	0	0
35	29.970483	90.18773	0.8	1.115121472
36	29.970615	90.187741	1.7	2.369633129
37	29.970699	90.187553	0	0
38	29.969788	90.18695	2.5	3.484754601
39	29.969853	90.186172	2.5	3.484754601
40	29.969978	90.185292	1.7	2.369633129

Table 24: Hourly wind data for July 27, 2012

Date-Time	Speed	Gust	Direction
7/27/2012 8:00	2.6	6.8	251
7/27/2012 9:00	3.2	9.6	247
7/27/2012 10:00	3.6	10	248
7/27/2012 11:00	3.8	10	253
7/27/2012 12:00	3.6	13.3	300
7/27/2012 13:00	4.3	12.4	232
7/27/2012 14:00	3.4	11	272
7/27/2012 15:00	3.3	12.8	235
7/27/2012 16:00	2.8	7.2	242
7/27/2012 17:00	3.3	8.2	232

5.6 Data for Odor measurement using olfactometer

As discussed in the previous section, an olfactometer is used to detect and measure ambient odor dilution. To measure intensity, olfactometers introduce an odorous gas as a baseline against which other odors are compared. Olfactometry generates standard sensory analyses, and the principal tool to measure odor characteristics is a trained jury of "noses" or a group of selected experts chosen according to rigorous and precise criteria. However, olfactometric analyses of ambient air in the field are not recommended because of frequent variations of odor concentrations in ambient air and the low resolution of these methods.

Despite the advantages of the classic analytical methods (accuracy, reproducibility, etc.), olfactometry remains the best available approach to measure odors directly, in order to objectively quantify the perception of odors. Given the readings, one cannot really derive any conclusive results. Perhaps, a better understanding would be obtained if the experiment is repeated. Inter-panel variability also exists which could cause discrepancies.

Table 25 below summarizes the efforts in carrying out the olfactometry analyses and the corresponding H2S concentrations at the location using CairClip. Although the results are not conclusive, it does provide a vague idea of the locations at which the odor nuisance maybe worse in the facility.

Table 25: Comparison of olfactometry analysis with actual readings measured using CairClip

Reading #	Date	CairClip (ppb)	D/T Olfactometer
1	6/29/2012	0	0
2	6/29/2012	5	0
3	6/29/2012	0	0
4	6/29/2012	21	2
5	6/29/2012	30	2
6	6/29/2012	20	2
7	6/29/2012	13	0
8	6/29/2012	13	2
9	6/29/2012	5	0
10	6/29/2012	0	0
11	6/29/2012	0	0
12	6/29/2012	0	0
13	6/29/2012	29	4
14	6/29/2012	0	0
15	6/29/2012	5	0
16	6/29/2012	13	2
17	6/29/2012	0	0
18	6/29/2012	0	2
19	6/29/2012	10	0
20	6/29/2012	13	0
21	6/29/2012	20	0
22	6/29/2012	10	0

Table 25 contd.: Comparison of olfactometry analysis with actual readings measured using CairClip

Reading #	Date	CairClip (ppb)	D/T Olfactometer
23	6/29/2012	5	0
24	6/29/2012	10	0
25	6/29/2012	7	2
26	6/29/2012	5	0
27	6/29/2012	10	0
28	6/29/2012	15	2
29	6/29/2012	13	2
30	6/29/2012	15	2
31	6/29/2012	10	0
32	6/29/2012	15	2
33	6/29/2012	10	0
34	6/29/2012	10	0
35	6/29/2012	10	0
36	6/29/2012	2	0
37	6/29/2012	0	0
38	6/29/2012	10	0
39	6/29/2012	5	0
40	6/29/2012	238	30
41	6/29/2012	15	0
42	6/29/2012	13	0
43	6/29/2012	15	2
44	6/29/2012	10	2
45	6/29/2012	15	0
46	6/29/2012	10	0
47	6/29/2012	10	0
48	6/29/2012	90	15
49	6/29/2012	150	15
50	6/29/2012	200	30
51	6/29/2012	96	15
52	6/29/2012	34	2
53	6/29/2012	185	15
54	6/29/2012	5	0
55	6/29/2012	210	15
56	6/29/2012	21000	60
57	7/17/2012	80	2

Table 25 contd.: Comparison of olfactometry analysis with actual readings measured using CairClip

Reading #	Date	CairClip (ppb)	D/T Olfactometer
58	7/17/2012	150	7
59	7/17/2012	110	4
60	7/17/2012	435	15
61	7/17/2012	96	7
62	7/17/2012	17000	60
63	7/17/2012	72	4
64	7/26/2012	5	0
65	7/26/2012	5	0
66	7/26/2012	5	0
67	7/26/2012	5	2
68	7/26/2012	5	0
69	7/26/2012	0	0
70	7/26/2012	5	0
71	7/26/2012	30	4
72	7/26/2012	0	0
73	7/26/2012	5	0
74	7/26/2012	5	0
75	7/26/2012	5	0
76	7/26/2012	5	2
77	7/26/2012	5	0
78	7/26/2012	5	0
79	7/26/2012	13	0
80	7/26/2012	13	2
81	7/26/2012	13	0
82	7/26/2012	5	0
83	7/26/2012	13	2
84	7/26/2012	13	2
85	7/26/2012	5	0
86	7/26/2012	5	2
87	7/26/2012	13	2
88	7/26/2012	13	2
89	7/26/2012	13	2
90	7/26/2012	22	4
91	7/26/2012	13	0
92	7/26/2012	13	7

Table 25 contd.: Comparison of olfactometry analysis with actual readings measured using CairClip

Reading #	Date	CairClip (ppb)	D/T Olfactometer
93	7/26/2012	13	2
94	7/26/2012	22	4
95	7/26/2012	22	4
96	7/26/2012	5	2
97	7/26/2012	13	0
98	7/26/2012	13	2
99	7/26/2012	13	2
100	7/26/2012	13	2
101	7/26/2012	13	2
102	7/26/2012	13	0
103	7/26/2012	13	2

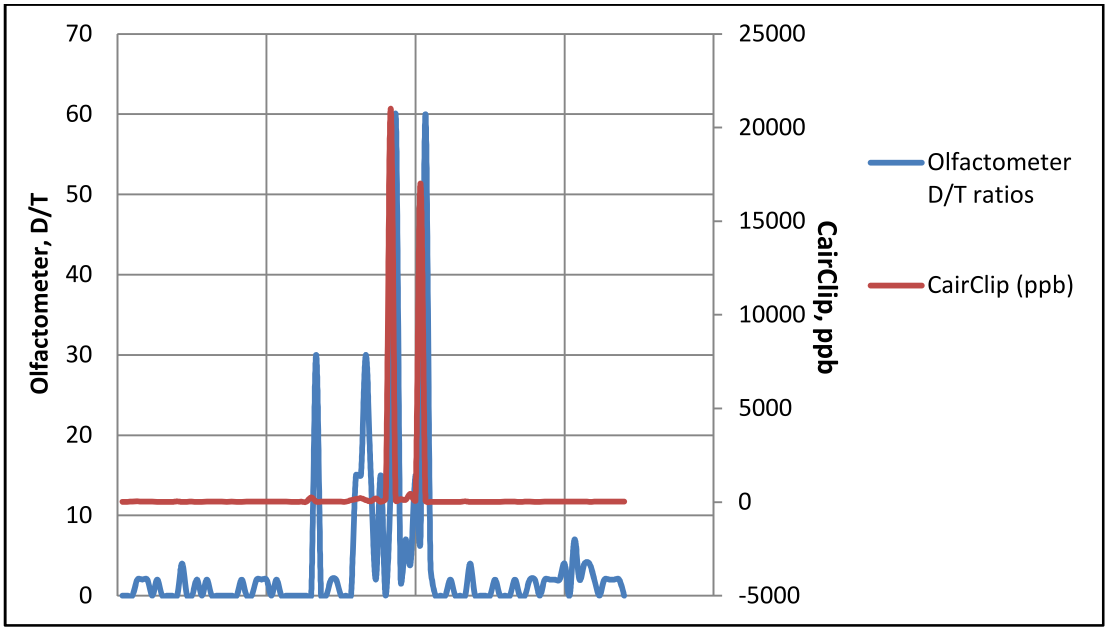


Figure 31: Comparison of Olfactometer readings and concentration of H_2S using CairClip

6. SUMMARY AND CONCLUSIONS

The present study provided a great insight into the intricacies of monitoring for ambient and source concentrations in wastewater treatment plant. It could be used as a preliminary analysis to understand the distribution of odors and effective mechanisms that need to be put into place for odor control management.

Various monitoring equipment were used on a trial and error basis before establishing the best monitors for ambient and source monitoring. The ambient air quality monitors chosen included the CairClip and OdaLog since they were capable of measuring H_2S in ppb range. Since most of the regulations by EPA and OSHA for H_2S are in ppb range, these monitors proved effective. The source monitoring was carried out using multi-gas analyzer since it has a range of 0-500 ppm. The concentration range obtained in the headworks of the facility was between 5-30 ppm.

To understand the movement of the plume from the various odor generating sources, it is important to take into account meteorological parameters as well. This helps establishing the concentration variation with wind speed and direction. This helps predict the location where one may find hot spots and a suitable location to set up the monitoring equipment. The Raintree was used to measure the wind speed and direction on an hourly basis and windrose diagrams were used to map the wind speed.

The ambient monitoring carried out showed that 95% of the H_2S concentration was between 0-5 ppb range. Hence, we see that the plant complies with the standards for most of the time. However, there are a few peaks observed which need to be investigated. The headworks need to comply with the OSHA ceiling limit of 20 ppm. This has a correlation as established in the previous section with the infiltration/inflow and temperature.

Currently, the wastewater treatment facility uses the chemical scrubbing for odor control. Chemical scrubbers provide contact between odorous air, water, and chemicals to provide oxidation or entrainment of the odorous compounds. The odorous compounds are absorbed into the scrubber liquid, where they are oxidized and/or removed from the scrubber as an overflow or blowdown stream.

The chemical scrubber used at this facility uses sodium hypochlorite (bleach) and sodium hydroxide (caustic) to oxidize hydrogen sulfide and other reduced sulfur compounds. The oxidation reactions are dependent on pH, with the optimum scrubber solution pH being in the 9.5 – 10.5 range. Wet scrubbers can remove up to 99.5% of hydrogen sulfide, even at high concentrations. They require a relatively small footprint, but require significant operational and maintenance attention, chemical handling and storage, and require disposal of scrubber effluent wastewater. It could be applied to all liquid treatment plant processes, pump stations, sludge thickening, sludge dewatering.

Mentioned below are the typical design criteria:

1. Air flow velocity < 8.5 feet/sec (500 fpm)
2. Detention time (in packing): 1.5 - 2 sec
3. Packing depth: 6 – 10 feet (dependent on contaminant loading)

4. H_2S removal efficiency: 99%

Figure 32: Odor Control System located at East Bank wastewater treatment plant

The Odor control system used is manufactured by Seimens. It can handle up to 30,000 cfm (50,000 m3/h) of odorous air in a single scrubber. The first stage uses NaOH to remove 70% of the H_2S. Subsequent stages use NaOH and NaOCI to remove the remaining H_2S and organic odors.

Though there are many treatment technologies and options associated with odor control in the vapour phase, wet air scrubbing has proven to be one of the most flexible and reliable. The other methods include include wet chemical scrubbers, biofilters/bioscrubbers, dry chemical scrubbers and activated carbon adsorbers. In addition to treating H_2S and organic odors, wet scrubbing has also proven to be effective for ammonia removal.

Hot-spot and perimeter analysis was conducted using CairClip since it is a direct read-out meter. The monitoring studies indicate that the hot-spots were located near the headworks building, filter press and activated sludge tanks. The perimeter monitoring carried out shows that at certain places around the facility, there may be a violation of the EPA regulatory limit of 70 ppb. But, further monitoring needs to be done to establish this.

The U.S. Clean Air Act has established national air quality goals for the protection of human health and welfare. Tens of billions of dollars are invested each year to reduce air pollution. Air quality assessment is frequently driven by the need to determine whether a standard or guideline has been exceeded. This overshadows another objective of air quality assessment: providing the information needed to estimate population exposure to air pollution and the effects on the health of the population.

Consequently, this research could be used as a basis to design and develop an effective real-time feedback to the operational personnel to identify and rectify problems associated with odor emissions. As a result, an innovative Real-time Odor Monitoring and Management System [RTOMMS] can be developed by employing the following techniques:

[a]Collecting continuous data on odor levels and on-site meteorological conditions using modern commercial devices that are capable of transmitting data to a receiver and then to a server

[b]Developing a software application integrating ambient air quality data [odor levels], meteorological data, and dispersion modeling techniques to assess various sources strengths in real-time to rank sources with high nuisance [with the help of industry partner]

[c]Suggesting strategies to increase capture and control efficiency to alleviate odor nuisance. This project has high scalability because all urban areas have WWTPs with odor nuisance.

The report provides the overall requirements for designing and operating networks for monitoring ambient air required to develop a comprehensive programs for odor control management. Investment in monitoring, assessing and controlling pollution helps to avoid outcomes to health and ecosystems that are usually more costly than preventive action.

7. RECOMMENDATIONS

The present study is a preliminary understanding of odor control management. The study indicates huge research potential as odor has become an increasing problem in urban areas. In the modern world of wastewater treatment, control of odors has moved from an afterthought to a primary design consideration for most collection and treatment facilities. As development encroaches on the facilities and neighboring communities become less tolerant of nuisance odors, wastewater professionals have found the need to address odor as a primary concern in the design and operation of collection and treatment facilities.

Further research in this field could open new windows of opportunities. A real time odor monitoring system needs to be in place to ensure continuous measurement and monitoring and provide feedback as to when there has been a compliance violation. Until now, efforts to manage odor nuisance has been done in a haphazard manner. An initiative in this direction may require extensive monitoring at multiple locations.

Photo-ionization detector used to monitor the ambient concentrations could also be used more extensively. The olfactometer reading is very sensitive and specific to individuals. To get more accurate results, it is recommended to have a “panel-of noses” trained to get a better understanding of the odor levels.

BIBLIOGRAPHY

1. Municipalities and Wastewater Treatment Plants: *NPDES Home.* Environmental Protection Agency, 16 Feb, 2012. Web. 29 Feb, 2012. <http://cfpub.epa.gov/npdes/home.cfm?program_id=13>
2. Facilities and Enforcement Activities related to the CWA NPDES Program: *Compliance and Enforcement.* Environmental Protection Agency, 4 Sept, 2012. Web. 25 Sep, 2012. < http://www.epa.gov/compliance/data/results/performance/cwa/index.html>
3. Masters, G.M. Introduction to Environmental Engineering and Science. New Jersey: Prentice-Hall, Inc., 1997.
4. Beychok, M.R. (1971). "Performance of surface-aerated basins". *Chemical Engineering Progress Symposium Series* **67** (107): 322–339.
5. Crites, R., and Tchobanoglous, G. Small and Decentralized Wastewater Management Systems. Boston: WCB/McGraw-Hill, 1998.
6. Droste, Ronald L. Theory and Practice of Water and Wastewater Treatment New York: John Wiley & Sons, Inc., 1997.
7. CEN EN 13725:2003, Air quality - Determination of odour concentration by dynamic olfactometry.
8. Dincer, Faruk. Journal Of Environmental Science And Health Part A Volume: 43 Issue: 13 (2008-01-01) ISSN: 1093-4529, “Odor-causing volatile organic compounds in wastewater treatment plant units and sludge management areas”.
9. Al-Shammiri, M. “Hydrogen sulfide emission from the Ardiyah sewage treatment plant in Kuwait.” Desalination 170 (2004): 1-13.
10. Barbosa, V.L., Atkins, S.D., Barbosa, V.P., Burgess, J.E., and Stuetz, R.M. “Characterization of Thiobacillus thioparus isolated from an activated sludge bioreactor used for hydrogen sulfide treatment.” Journal of Applied Microbiology (2006): 1–13.
11. Bryliakov, K. and Talsi, E.P. “Asymmetric oxidation of sulfides with H2O2 catalyzed by titanium complexes with aminoalcohol derived Schiff bases.” Journal of Molecular Catalysis A: Chemical (2006): 280–287.
12. Chang, Y., Chang, Y. and Chen, H. “A method for controlling hydrogen sulfide in water by adding solid phase oxygen.” Bioresource Technology (2005).
13. Charron, I., Feliers, C., Couvert, A., Laplanche, A., Patria, L., and Requieme, B. “Use of hydrogen peroxide in scrubbing towers for odor removal in wastewater treatment plants.” Water Science and Technology 50 (2004): 267-274.
14. Crites, R., and Tchobanoglous, G. Small and Decentralized Wastewater ManagementSystems. Boston: WCB/McGraw-Hill, 1998.
15. Droste, Ronald L. Theory and Practice of Water and Wastewater Treatment New York: John Wiley & Sons, Inc., 1997.

16. Duan, H., Koe, L.C.C., Yan, R. and Chen, X. "Biological treatment of H2S using pellet activated carbon as a carrier of microorganisms in a biofilter." Water Research (2006): 2629–2636.
17. Easter, C., Quigley, C., Burrowes, P., Witherspoon, J. and Apgar, D. "Odor and air emission control using biotechnology for both collection and wastewater treatment systems." Chemical Engineering Journal 113 (2005): 93-104.
18. Haaning Nielsen, A., Vollertsen, J., and Hvitved-Jacobsen, T. "Chemical sulfide oxidation of wastewater-effects of pH and temperature." Water Science and Technology 50 (2004): 185-192.
19. Ksibi, M. "Chemical oxidation with hydrogen peroxide for domestic wastewater treatment." Chemical Engineering Journal 119 (2006): 161-165.76
20. Letterman, R.D. Water Quality and Treatment. A Handbook of Community Water Supplies. New York: McGraw-Hill, Inc., 1999.
21. Ma, Y., Zhao, J., and Yang, B. "Removal of H2S in waste gases by an activated carbon bioreactor." International Biodeterioration & Biodegradation 57 (2006): 93-98.
22. Manahan, S.E. Fundamentals of Environmental Chemistry. Boca Raton: Lewis Publishers, 2001.
23. Potivichayanon, S., Pokethitiyook, P., and Kruatrachue, M. "Hydrogen sulfide removal by a fixed–film bioscrubber system." Process Biochemistry (2006): 708–715.
24. Rao, A.G., Prasad, K.K., Naidu, G.V., Rao, N.C., and Sarma, P.N. "Removal of sulfide in integrated anaerobic-aerobic wastewater treatment system." Clean Technologies and Environmental Policy 6 (2003): 66-71.
25. Rittmann, B. and McCarty, P. Environmental Biotechnology: Principles and Applications New York: McGraw-Hill, 2001.
26. Weiner, R.F., and Matthews, R. Environmental Engineering. Amsterdam: Butterworth-Heinemann, 2003.
27. Yongsiri, C., Vollertsen, J. and Hvitved-Jacobsen, T. "Hydrogen sulfide emission in sewer networks: a two-phase modeling approach to the sulfur cycle. Water Science and Technology 50 (2004): 161-168.
28. Yongsiri, C., Vollertsen, J., Rasmussen, M., and Hvitved-Jacobsen, T. "Air – Water Transfer of Hydrogen Sulfide: An Approach for Application in Sewer Networks." Water Environment Research (2004): 81-88.
29. 9 Aug 2004 <http://www.h2o2.com

VITA

Natasha Halageri was born in Mumbai, India. She obtained her B.E. in Chemical Engineering from R.V. College of Engineering in Bangalore in June, 2011 and secured a gold medal for her outstanding performance in academics. She went on to join Hindustan Unilever Limited as a research associate. She later decided to pursue higher studies and joined the Masters program in Environmental Engineering at the University of New Orleans. She worked as a Graduate Assistant for Dr. Kura under whom she also did her Masters' thesis. During her academic program at UNO, she has been awarded the Air and Waste Management scholarship and even participated as a speaker in their 105th Annual Conference held at San Antonio. This work titled "Air Quality in Urban India and the Strategies to Manage Sources" has been published as a conference paper in June 2012.