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Carbon Dioxide and Hydrogen Sulfide Emission Factors Applicable to Wastewater Wet Wells

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Carbon Dioxide and Hydrogen Sulfide Emission Factors Applicable to Wastewater Wet Wells

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LIST OF ABBREVIATIONS

CO_2	Carbon dioxide
H_2S	Hydrogen Sulfide
%	Percent
Kg/hr	Kilograms per second
ppm	Parts per Million
^{o} F	Degree Fahrenheit
^{o} C	Degree Centigrade
Kg/m^3	Kilogram per cubic meter
Kg/m^3-sec	Kilogram per Cubic meter per second
mg/m^3-hr	Milligram per Cubic meter per hour
V_1	Initial volume of wastewater present in the wet well
V_2	Final volume of wastewater present in the wet well
LS	Lift Station
C_{mass}	Mass concentration, $\mu g/m^3$
C_{ppm}	Volume of molar concentration, ppm
MW_p	Molecular weight of pollutant gas, g/gmol
T	Temperature
R	Gas constant, 0.08206 L-atm/(gmol-K)
P	Pressure, atm
L-atm/ (gmol-K)	(Litre-atmosphere)/(gram mole-Kelvin)
gmole	Gram mole

K	Kelvin
WW	Wastewater
MRL	Minimal Risk Level

ABSTRACT

Transport of wastewater in sewer networks causes potential problems associated with gases which include ammonia, carbon dioxide, carbon monoxide, hydrogen sulfide and methane, in regard to odor nuisance, irritation, toxicity, and microbially induced corrosion. The extent of these problems depends on the emission rates of gases in the sewer atmosphere. To limit these kinds of problems an estimate of the gases emitted from the sewer network is to be known.

In consideration to the above mentioned problems, a research has been taken up to estimate the two gases, namely, carbon dioxide and hydrogen sulfide from sewer wet wells. In this method, using Landtec GEM-2000 plus a multi-gas analyzer, the sample gases were collected from the wet well of pump stations for five days. Using the collected samples the emission rates of carbon dioxide and hydrogen sulfide are estimated.

Keywords: Carbon dioxide, Hydrogen Sulfide, Emission Factors, Pump Stations, Wet Wells, Wastewater, Landtec Gas Analyzer, CO_2 and H_2S Health Effects, Corrosion due to H_2S gas.

CHAPTER ONE
INTRODUCTION

Pumping stations in sewage collection systems, also known as lift stations, are normally designed to handle raw sewage that is fed from underground gravity pipelines. Sewage is fed into and stored in an underground pit, commonly known as a wet well. The well is equipped with electrical instrumentation to detect the level of sewage present. When the sewage level rises to a predetermined point, a pump is started to lift the sewage upward through a pressurized pipe system called a sewer force main from where the sewage is discharged into a gravity manhole. From here the cycle repeats until the sewage reaches its point of destination – usually a treatment plant.

During the storage time under anaerobic conditions, the wastewater has a potential to generate and release several gases to the surrounding area that are asphyxiating, irritating, toxic or flammable. These gases include ammonia (NH_3), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulfide (H_2S) and methane (CH_4). Out of these gases, monitoring is done for two pollutants namely CO_2 and H_2S. Of the two CO_2 is a greenhouse gas and H_2S is a toxic gas.

The whole and soul of this research is the methodology, to determine CO_2 and H_2S emission rates from the wastewater wet wells. This is a new technique to calculate emission rates of gases which are emitted from a confined place such as the interior of lift stations.

This is a very useful method to quickly calculate the emission rate for a closed wet well by knowing the dimensions of the well, the concentration of a specific gas and its molecular weight.

SCOPE OF WORK

This method is completely new and the first of its kind. This is an approximate method which will give quick results.

The main scope of this research work is as follows:

- Identify selective wet wells in the city of Kenner that are ideal for CO_2 and H_2S gas monitoring.
- Develop a methodology to quantify CO_2 and H_2S emissions from wet wells.
- Determine CO_2 and H_2S emission factors applicable to wastewater wet wells.

CHAPTER TWO
LITERATURE REVIEW

This chapter discusses the literature that is relevant to objectives and experiments of this thesis. As the proposed wet well gas quantification methodology is a new methodology, there is no literature available on the proposed topic for predicting the emission rates of CO_2 and H_2S for wet wells.

2.1 A Brief Introduction to the Monitored Gases

CARBON DIOXIDE:

Carbon dioxide (CO_2) is a colorless, odorless, non-flammable gas and is the most prominent greenhouse gas in Earth's atmosphere. It is recycled through the atmosphere by the process of photosynthesis, which makes human life possible. It is an asphyxiant. When carbon dioxide accumulates in large amounts in the atmosphere, narcosis may occur when an individual breathe carbon dioxide. Carbon dioxide is heavier than air and collects in the lower levels of confined spaces. Under anaerobic conditions, carbohydrates are converted into acetate, hydrogen and carbon dioxide.

Human activities such as the production and consumption of fossil fuels, as well as agricultural and industrial activities have caused an increase in the atmospheric concentration of harmful greenhouse gases (GHG), particularly CO_2, CH_4, and N_2O (El-Fadel and Massoud, 2001). The increase in atmospheric GHG concentration has led to climate change and global warming effect. The contribution of a GHG to global warming is commonly expressed by its global warming potential (GWP), which enables the comparison of global warming impact of the gas and that of a reference gas, typically carbon dioxide. On a 100-year basis, the GWP of carbon dioxide, methane and nitrous oxide are 1, 23, and 296, respectively (IPCC, 2001).

HYDROGEN SULFIDE:

In most instances, the odors associated with collection systems and primary treatment facilities are generated as a result of an anaerobic or "septic" condition, which occurs when oxygen transfer to wastewater is limited, such as in a force main. In an anaerobic state, the microbes present in wastewater have no dissolved oxygen available for respiration. This allows microbes known as "sulfate-reducing bacteria" to thrive. These bacteria utilize the sulfate ion (SO_4^-) that is naturally abundant in most waters as an oxygen source for respiration. The by-product of this activity is hydrogen sulfide (H_2S), which has a low solubility in wastewater and a strong, offensive, rotten-egg odor. In addition to its odor, H_2S can cause severe corrosion problems in the collection system. Due to its low solubility in wastewater, it is released to the atmosphere in areas such as wet wells, head works, grit chambers and primary clarifiers. There are typically other "organic" odorous compounds, such as mercaptans and amines, present in these areas, but H_2S is the most prevalent compound.

2.2Health Effects of CO_2

CO_2 effects range from physiological to toxic, anesthetic and lethal. The effects of CO_2 in a specific individual depend on the concentration and duration of exposure. In addition, the individual factors, such as age, health, physiologic make-up, physical activity, occupation, and lifestyle will also have considerable effects.

Short Term High-Level CO_2 Exposure:

With high-level CO_2 exposure, the displacement of O_2 by CO_2 significantly contributes to toxicity. Signs of asphyxia are evident when the atmospheric O_2 is $\leq$16%. Several studies

reported that immediate unconsciousness leading to death occurs in humans at rest when O_2 is reduced to 10-13%. High-level CO_2 exposure (in the presence of low-level O_2) can produce adverse health effects including headaches, attacks of vertigo, poor memory and the ability to concentrate, difficulty sleeping, double vision, photophobia, loss of eye movement, and personality changes. Due to the high level CO_2 exposure at Lake Nyos in 1986, about 1,700 people died and a maximum 5,000 survived with a rapid loss of consciousness. The atmospheric CO_2 was estimated to be ≥8-10% as oil lamps were extinguished. (SUSAN, 2004)

Prolonged Low-Level CO_2 Exposure:

Prolonged low-level CO_2 exposure (generally <3%) in the presence of normal O_2 can produce mild short term effects in healthy, young adults. TABLE 1 lists some of the outcomes of low-level CO_2 exposure with the potential to cause immediate or long-term, adverse effects. Though prolonged exposure to low level CO_2 is not immediately life threatening, it may have health consequences for healthy individuals as well as sensitive populations. (SUSAN, 2004)

Percentage	Duration of Exposure	Potentially Adverse Outcome
0.85	20 days	↑ Lung dead space volume
1.2	3 days	35% ↑ Cerebral blood flow
1.2	5 days	~ 20% ↑ Blood pressure
1.2	25 days	Significant ↓ Biomarkers of bone formation Slight ↑ bone resorption
1.5	42 days	↑ Urine volume & Na, K, Cl excretion Slight ↑ Hct, RBC count, Hemoglobin
1.5	42 days	Significant ↑ Lung dead space volume
2.0	30 days	Slight ↑ Lung dead space volume
3.0	8 days	Significant performance decrements Erratic, abnormal behavior

TABLE 1: POTENTIALLY ADVERSE OUTCOMES OF PROLONGED LOW-LEVEL CO_2 EXPOSURE (SUSAN, 2004)

2.3 Health Effects of H_2S

Inhalation is the major route of exposure to hydrogen sulfide as it is a gas. Most of the past literature about the effects of hydrogen sulfide is derived from acute poisoning case reports, occupational exposures, and limited community studies. Single inhalation exposures to high concentrations of hydrogen sulfide cause health effects in many systems. Health effects that have been observed in humans following exposure to hydrogen sulfide include death as well as respiratory, ocular, neurological, cardiovascular, metabolic, and reproductive effects. A summary of human health effects resulting from exposure to hydrogen sulfide are listed in TABLE 2.

Exposure (mg/m^3)	Effect / observation
0.011	Odour threshold
2.8	Bronchial constriction in asthmatic individuals
5.0	Increased eye complaints
7 or 14	Increased blood lactate concentration, decreased skeletal muscle citrate synthase activity, decreased oxygen uptake
5–29	Eye irritation
28	Fatigue, loss of appetite, headache, irritability, poor memory, dizziness
>140	Olfactory paralysis
>560	Respiratory distress
≥700	Death

TABLE 2: HUMAN HEALTH EFFECTS AT VARIOUS HYDROGEN SULFIDE CONCENTRATIONS (W.H.O 2003)

The World Health Organization air quality guideline for hydrogen sulfide is 150 µg/m^3 average concentration over 24 hours. To avoid odor annoyance, a 30-minute average ambient air concentration not exceeding 7 µg/m^3 is recommended (WHO, 2000).

According to Agency for Toxic Substances and Disease Registry (ATSDR):

The minimal risk level (MRL) is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure.

The inhalation MRL of 0.02 ppm has been derived for intermediate-duration inhalation exposure to hydrogen sulfide.

The inhalation MRL of 0.07 ppm has been derived for acute-duration inhalation exposure to hydrogen sulfide.

2.4 Domestic Wastewater Characteristics

A typical medium strength domestic wastewater consists of the characteristics listed in TABLE 3:

Contaminants	Concentration (mg/l)
Total Solids (TS)	720
Total Dissolved Solids (TDS)	500
Total Suspended Solids (TSS)	210
Biochemical Oxygen Demand (BOD_5)	190
Total Organic Carbon (TOC)	140
Chemical Oxygen Demand(COD)	430
Sulfate	50

TABLE 3: TYPICAL DOMESTIC WASTEWATER CHARACTERISTICS (Metcalf & Eddy 2003)

2.5 Corrosion Due to H_2S in the Sewer System

The presence of H_2S can lead to quick and massive damage to concrete and metals used in the construction of wastewater treatment and collection system. Sewer lift stations and treatment facilities, including electrical controls, instrumentation, process equipment, storage tank and ventilation systems can be affected. In the United States, the problem is not limited to warm climates, and it is rarely brought to the attention of the public until a disastrous event occurs, such as a sewer collapse resulting in street cave-in. This corrosion in the wastewater systems often results in costly, premature replacement or rehabilitation of the systems. Sewers designed to last 50 to 100 years have failed due to hydrogen sulfide corrosion in as little as 10 to 20 years.

Electrical and mechanical equipment with an expected source life of 20 years has required replacement in as little as 5 years.

Hydrogen sulfide corrosion can occur by two mechanisms. One is from acid attack resulting from the biological conversion of H_2S gas to sulfuric acid in the presence of moisture and the other is from direct chemical reaction with metals such as copper, iron and silver with H_2S gas. The first mechanism is the one which is the primary cause of internal sewer corrosion, while the second can cause premature failure of electrical and instrumentation system and mechanical equipment used in transport and treatment of wastewater. (EPA, 1991)

Factors Affecting Corrosion of Sewers:

There are four conditions for H_2S corrosion to take place in sewers:

1. Absence or very low levels of dissolved oxygen in the wastewater
2. Generation of sulfide in the wastewater and release of H_2S gas from solution
3. Presence of moisture on the material to be corroded
4. Material which is subjected to corrosion by sulfuric acid attack.

Dissolved oxygen depletion is affected by sewage velocity, wastewater characteristics, detention time and temperature. The rate of corrosion is governed by the temperature, the quantity of H_2S available to be biologically converted to sulfuric acid, and the material's inherent resistance to acid attack.

Even at less than 1 ppm concentration in the atmosphere, H_2S can cause extensive damage to electrical contacts and circuits present in controls, switchgear, and computer equipment. (EPA, 1991)

2.6 Methods to Control H_2S Emissions Wastewater

There are several methods available to control the rate of hydrogen sulfide corrosion. These include:

1. Reducing the dissolved sulfide content of the wastewater
2. Using corrosion-resistant materials and coatings
3. Providing ventilation of the enclosed area of the sewer and
4. Conducting routine preventive maintenance.

Three basic techniques to control dissolved sulfide:

a) Oxidation by addition of chemical oxidants such as hydrogen peroxide, chlorine or potassium permanganate, or by the introduction of air or oxygen.
b) Precipitation of dissolved sulfide by the addition of metallic salts such as ferrous chloride and ferrous sulfate
c) pH elevation through the addition of sodium hydroxide. Since low pH is favorable to produce H_2S gas, so it has to be increased.(EPA, 1991)

2.7 Terminology

Biochemical Oxygen Demand (BOD) measures the rate of oxygen uptake by micro-organisms in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.

Chemical Oxygen Demand (COD) is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. It does not differentiate between biologically available and inert organic matter.

Total Organic Carbon (TOC) is a measure of organically bonded carbon in the water sample.

Total Solids (TS) are a measure of the suspended and dissolved solids in water.

Total Dissolved Solids (TDS) are those that pass through a water filter. They include some organic materials, as well as salts, inorganic nutrients, and toxins.

Total Suspended Solids (TSS) are those that can be retained on a water filter and are capable of settling out of the water column onto the stream bottom when stream velocities are low. They include silt, clay, organic wastes, and inorganic precipitates such as those from acid mine drainage.

Flooded Suction Type Lift Station**:** In this type of station, liquid flows to pump inlet from an elevated source by means of gravity.

Suction Type Lift Station: In this type of station, the liquid is taken from an open to atmosphere tank where the liquid level is below the centerline of the pump suction.

2.8 Landtec GEM 2000 Plus Instrument

The GEM 2000 Plus instrument designed by Landtec is a landfill gas analyzer which samples and analyzes methane, carbon dioxide and oxygen content in percentage and carbon monoxide and hydrogen sulfide in parts per million. The gas readings are displayed and can be stored in the instrument and downloaded to a personal computer for reporting, analyzing and archiving. The best thing about this instrument is the data logging function which it has. A time interval

between the readings can be set in the instrument, and the instrument will take the readings by turning on and off itself to the time interval specified. Figure 1 shows the Landtec GEM 2000 Plus instrument.

This instrument measures CO_2 in percent (%) which has to be converted to parts per million by multiplying the percentage with 10^4. The H_2S readings are measured directly in ppm by the instrument. The Range of CO_2 and H_2S for this instrument are 0 - 100% and 0 - 500ppm respectively.

Figure 1: Landtec GEM 2000 Plus

2.9 Mission SCADA

The city of Kenner has 79 lift stations. To keep an eye on all these stations, a system has been implemented which monitors and controls various functions within the stations from a remote centralized location. This system is known as the supervisory control and data acquisition system or SCADA for short. With the aid of this system the wet well level readings can be checked at any instance.

CHAPTER THREE

METHODOLOGY

3.1 Experimental Setup

There are two main things required for calculating emissions using this method. One is the concentration measurements and the other is the water level in the well at a small time interval to be able to predict emissions.

For collecting gas concentrations from the wells, the Landtec GEM- 2000 Plus is used. The city of Kenner has 79 lift stations out of which three wells were ideal for monitoring. These three lift stations were safe to leave the instrument there for monitoring. These had a superstructure above it, so they can be treated as closed wet wells where anaerobic conditions exist. These three stations were continuously monitored for 7 hours from 10 A.M. to 5 P.M. each day for 5 days. The one end of the hose (sample collecting tube) is connected to the instrument and the other is kept inside the wet well to collect the gases inside the well.

For recording the water level in the well, www.123mc.com website is used. Authorization is required to use this website which keeps an analog data (continuous data) of water level in the well for all lift stations equipped with the SCADA system.

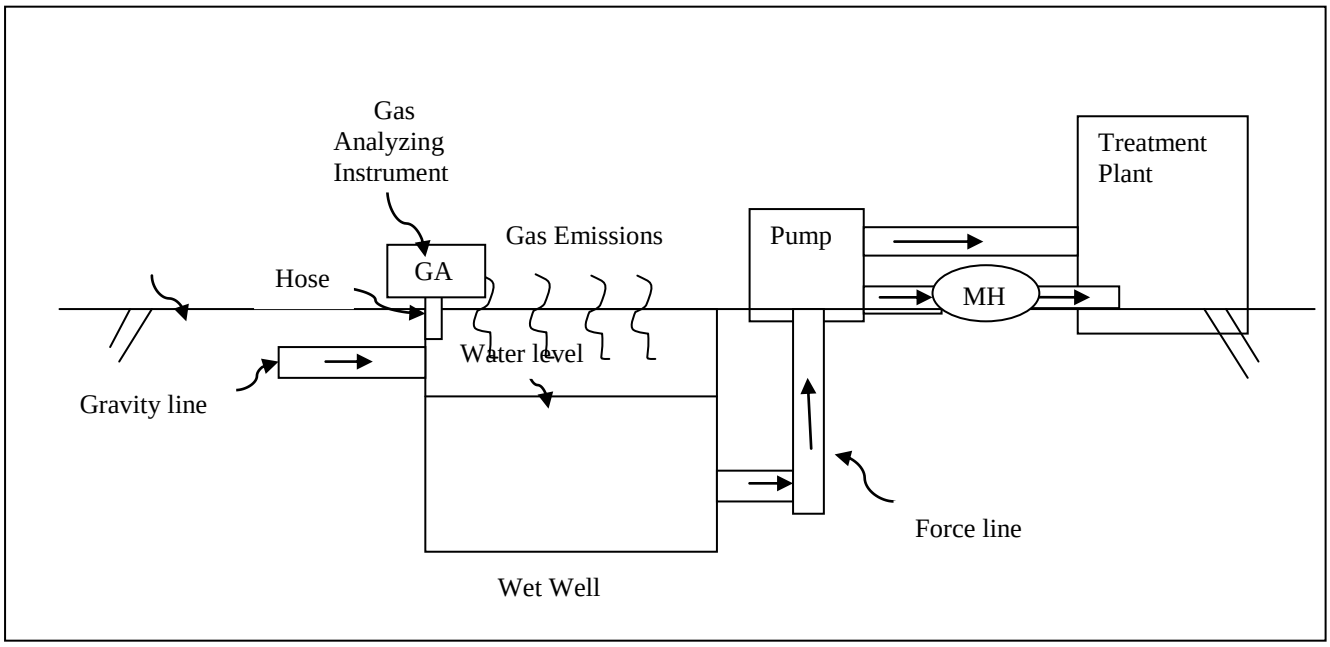


Figure 2: Schematic sketch of wastewater collection system

Figure 2 shows how wastewater through a gravity line gets in to the wet well and leaves the well generating gaseous emissions. The wastewater from the wet well can be dumped into a manhole (MH) or sent directly to the treatment plant through a force main, also known as a force line. The concentrations were measured using a gas analyzer (GA) with the help of a hose (tube). One end of the hose was inserted into the well and the other was connected to the instrument.

A gravity line or gravity main means a pipeline carrying wastewater or treated effluent which flows exclusively under the influence of gravity (i.e., no pump station). A force main means a pipeline carrying wastewater or treated effluent in which the flow in the pipeline is dependent on and driven by a pump station.

3.2 Lift Station Details

All the lift stations are assumed to be flat at the bottom.

NAME OF THE LIFT STATION: WEST ESPLANADE & CANAL NO. 17

The station is a three - pump, flooded suction type station. The station is enclosed in a block wall superstructure and consists of a rectangular wet well, approximately 11 meter long, 6.2 meter wide and 5.7 meter deep.

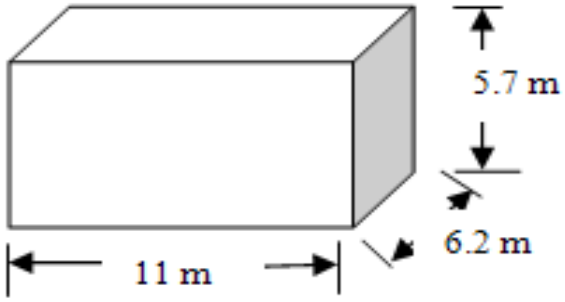


Figure 3: Schematic Sketch of the Lift Station 1

NAME OF THE LIFT STATION: 39th STREET & CALIFORNIA

The station is a three - pump, suction lift type station. The station is enclosed in a block wall superstructure and consists of a circular wet well, approximately 2.4 meter in diameter and 6.2 meter deep.

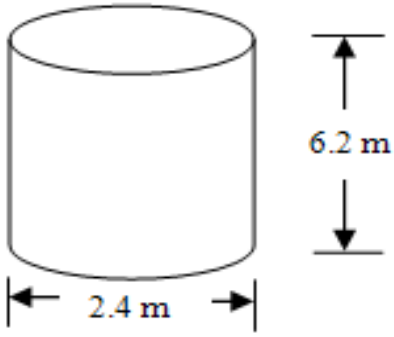


Figure 4: Schematic Sketch of the Lift Station 2

NAME OF THE LIFT STATION: 39th STREET & POWER

The station is a two pump, suction lift type station. The station is enclosed in a block wall superstructure and consists of a rectangular wet well, approximately 3.3 meter long, 2.7 meter wide and 6.3 meter deep.

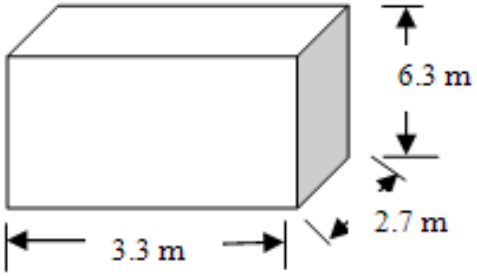


Figure 5: Schematic Sketch of the Lift Station 3

3.3 Experimental Procedure

CO_2 and H_2S EMISSIONS FROM A WASTEWATER WET WELL:

Wastewater during its stay in a wet well produces CO_2 and H_2S gas. When the volume of the wastewater increases in the well, the gases are expelled into the surrounding sewer atmosphere. The Landtec GEM- 2000 Plus, a CO_2 and H_2S detecting instrument, is used to measure the gases inside the wet well. This instrument gives the concentration of CO_2 in percentage and H_2S in ppm (parts per million). The percentage measure is converted in to ppm by multiplying it by 10^4 (0.1% = 1000 ppm). Parts per million means that "one part of CO_2 or H_2S present in one million parts of air."

As the volume of water in the wet well increases, the gases are pushed out and when the volume of water decreases, the surrounding ambient air is dragged in to the well to fill the water column

with air. Hence the concentrations in the air volume of the wet well change depending upon the water level in the well.

CO_2 and H_2S emissions from the wet well in terms of pounds can be calculated as below:

CO_2 expelled out of the wet well (Kg/sec) = Volume of air expelled due to increase in the water level *Average hourly concentration of CO_2/H_2S in the wet well * CO_2/H_2S mass concentration.

From the Ideal gas law, the mass concentration of gas is given by

$$Cmass = \frac{1000 * Cppm * MWp}{R * \frac{T}{P}}$$

where C_{mass} = Mass concentration, µg/m^3

C_{ppm} =Volume of molar concentration, ppm

MW_p = Molecular weight of pollutant gas, g/gmol

T = Temperature in Kelvin

R = Gas constant, 0.08206 L-atm/ (gmol-K)

P = atm

All the tables are calculated assuming absolute pressure P = 1 atm.

CO_2 and H_2S emissions from the wet well in terms of pounds per cubic foot can be calculated as below:

CO_2 or H_2S emitted per unit volume of wastewater (Kg/m^3-sec) = Mass of CO_2 or H_2S emitted/ average hourly volume of wastewater present in the wet well

$$= \text{mass of } CO_2 \text{ or } H_2S / [(V_1 + V_2) / 2]$$

where V_1 = Initial volume of wastewater present in the wet well

V_2 = Final volume of wastewater present in the wet well

If a gas (CO_2 or H_2S) measurement is taken at 8 A.M. and another gas measurement at 9 A.M., the volume of wastewater present in the wet well at 8 A.M. is considered as the initial volume of wastewater and the volume of wastewater present in the wet well at 9 A.M. is considered as the final volume of wastewater. If another gas measurement is taken at 10 A.M. for the next calculation the volume of wastewater present in the wet well at 9 A.M. will become the initial volume of wastewater present in the wet well and the volume of wastewater present in the wet well at 10 A.M. will be the final volume of wastewater present in the well.

TABLES AND CALCULATIONS

The calculations below are made assuming the wet well is closed completely and anaerobic conditions exist within the well. The measurements of the concentrations were taken under different weather conditions.

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 06/12/2009) (1)	WW Level in the Wet Well (m) (2)	Volume of WW in the Wet Well (m^3) (3)	Volume of Air in the Wet Well (m^3) (4)	Volume of Air Expelled Due to Increase in WW Level (m^3) (5)	Concentration of CO_2 in the Air in the Wet Well (ppm) (6)	Average Hourly Concentration of CO_2 in the Wet Well (ppm) (7)	CO_2 Expelled out of the Wet Well (Kg/sec) (8)	Average Hourly Volume of WW Present in the Wet Well (m^3) (9)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec) (10)
10 .00 AM	1.01	68.88	319.86	-	3000.0	-	-	-	-
11.00 AM	1.25	85.25	303.49	16.37	1000.0	2000.0	1.61E-05	77.07	2.09E-07
12 NOON	1.58	107.76	280.98	22.51	4000.0	2500.0	2.76E-05	96.50	2.86E-07
1.00 PM	1.10	75.02	313.72	0.00	3000.0	3500.0	0.00E+00	91.39	0.00E+00
2.00 PM	1.68	114.58	274.16	39.56	2000.0	2500.0	4.83E-05	94.80	5.10E-07
3.00 PM	1.40	95.48	293.26	0.00	0.0	1000.0	0.00E+00	105.03	0.00E+00
4.00PM	0.91	62.06	326.68	0.00	1000.0	500.0	0.00E+00	78.77	0.00E+00
5.00 PM	1.37	93.43	295.31	31.37	1000.0	1000.0	1.53E-05	77.75	1.96E-07
Average CO_2 Expelled out of the Wet Well per one second =							1.53E-05		1.72E-07

TABLE 4: DAY 1 CO_2 EMISSION RATE FROM LIFT STATION 1 (SAMPLE)

Sample calculation for TABLE 4:

Column 1: Time at which the CO_2 reading is taken

Column 2: Wastewater level in the wet well at the time of reading = 3.3 ft

Dimensions of the wet well:

Length = 11 m

Width = 6.2 m

Depth = 5.7 m

Column 3:

Volume of wastewater present in the wet well = Length * Width* Wastewater level in the wet well

= 11m* 6.2m * 1.01m

= 68.88 m^3

Total volume of the wet well = Length * Width * Total Depth

= 11m * 6.2 m * 5.7m

= 388.74 m^3

Column 4:

Volume of air in the wet well = Total Volume of the wet well – Volume of water in the wet well

= 388.74 m^3 – 68.88 m^3

= 319.86 m^3

Column 5:

Volume of air expelled out due to increase in the water level = Difference between two consecutive air volumes

= 319.86 ft^3 – 303.49 ft^3

=16.37 m^3

Column 6:

Concentration of CO_2 in the Air in the Wet Well (ppm) = 3000 ppm, CO_2 reading in the Landtec GEM-2000 Plus instrument inside the wet well

Column 7:

Average hourly concentration of CO_2 in the wet well = Sum of two consecutive readings/2

= (3,000 ppm +1,000 ppm)/2

= 2,000 ppm

Column 8:

Assuming absolute pressure = 1 atm.

To calculate Cmass,

$$Cmass = \frac{1000 * Cppm * MWp}{R * \frac{T}{P}}$$

Molecular weight for CO_2 is 44 g/gmol and for H_2S 34g/mol.

R = 0.08206 L-atm/(gmol-K)

T is the temperature in Kelvin. The temperature values are taken from Table 32 and are converted into Kelvin while calculating.

$$Cmass = \left\{\frac{1000 * 2000ppm * 44 * 1\ atm}{0.08206 * (273 + 29.4)}\right\} * 10^{-9}$$

$$= 3.546*10^{\wedge-3}\ Kg/m^3$$

Where 29.4 is the measured temperature in ^oC. To convert this into ^{o}Kelvin 273 is added and $10^{\wedge-9}$ is the conversion factor to convert 1µg/m^3 into Kg/m^3

Now, CO_2 expelled out of the wet well per sec (Kg/sec) = Volume of Air Expelled due to increase in the water level * C_{mass} for CO_2

$$= \frac{\left\{16.37m^3 * 3.546 * \frac{(10^{-3})Kg}{m^3}\right\}}{(60 * 60)sec}$$

$$= 1.61 * \frac{10^{-5}Kg}{sec}$$

Column 9:

Average Hourly Volume of Water present in the Wet Well (m^3) = (68.88 m^3 + 85.25 m^3)/2

= 77.07 m^3

Column 10:

CO_2 Emitted per unit volume of wastewater (Kg/m^3-sec) = (CO_2 expelled out of the wet well (Kg/sec) / Average Hourly Volume of Water present in the Wet Well (m^3))

$$= \frac{1.61 * \frac{10^{-5} Kg}{sec}}{77.07\ m^3}$$

= 2.09E-07 Kg/m^3-sec

Every second 1.61E-05 Kilograms of CO_2 is emitted out of the wet well.

For every cubic meter of wastewater 2.09E-07 Kg/sec of CO_2 is emitted.

Similarly, CO_2 expelled out for the other wet well and H_2S expelled out for the same wet well are calculated.

CHAPTER FOUR

RESULTS, ANALYSES AND DISCUSSION

4.1 Calculations

The tables below are the CO_2 and H_2S emission rates, calculated for all three lift stations on the 5 monitored days.

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 06/12/2009)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.01	68.88	319.86	-	3000.0	-	-	-	-
11.00 AM	1.25	85.25	303.49	16.37	1000.0	2000.0	1.61E-05	77.07	2.09E-07
12 NOON	1.58	107.76	280.98	22.51	4000.0	2500.0	2.76E-05	96.50	2.86E-07
1.00 PM	1.10	75.02	313.72	0.00	3000.0	3500.0	0.00E+00	91.39	0.00E+00
2.00 PM	1.68	114.58	274.16	39.56	2000.0	2500.0	4.83E-05	94.80	5.10E-07
3.00 PM	1.40	95.48	293.26	0.00	0.0	1000.0	0.00E+00	105.03	0.00E+00
4.00PM	0.91	62.06	326.68	0.00	1000.0	500.0	0.00E+00	78.77	0.00E+00
5.00 PM	1.37	93.43	295.31	31.37	1000.0	1000.0	1.53E-05	77.75	1.96E-07
Average CO_2 Expelled out of the Wet Well per one second =							1.53E-05		1.72E-07

TABLE 5: DAY 1 CO_2 EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 11/30/2009)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.51	103.86	286.30	-	3000.0	-	-	-	-
11.00 AM	1.87	127.89	262.27	24.03	3000.0	3000.0	3.66E-05	115.88	3.16E-07
12 NOON	1.63	112.01	278.15	0.00	0.0	1500.0	0.00E+00	119.95	0.00E+00
1.00 PM	1.65	112.85	277.31	0.84	0.0	0.0	0.00E+00	112.43	0.00E+00
2.00 PM	1.70	116.40	273.76	3.55	0.0	0.0	0.00E+00	114.62	0.00E+00
3.00 PM	1.73	118.91	271.25	2.51	0.0	0.0	0.00E+00	117.66	0.00E+00
4.00PM	1.80	123.51	266.66	4.60	3000.0	1500.0	3.56E-06	121.21	2.94E-08
5.00 PM	2.05	140.22	249.94	16.72	3000.0	3000.0	2.60E-05	131.87	1.97E-07
Average CO_2 Expelled out of the Wet Well per one second =							9.45E-06		7.75E-08

TABLE 6: DAY 2 CO_2 EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 02/18/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.48	101.35	288.81	-	5000.0	-	-	-	-
11.00 AM	1.30	88.82	301.35	0.00	4000.0	4500.0	0.00E+00	95.09	0.00E+00
12 NOON	1.00	68.55	321.62	0.00	5000.0	4500.0	0.00E+00	78.68	0.00E+00
1.00 PM	1.18	80.87	309.29	12.33	1000.0	3000.0	1.93E-05	74.71	2.58E-07
2.00 PM	1.97	135.00	255.16	54.13	1000.0	1000.0	2.81E-05	107.94	2.61E-07
3.00 PM	1.58	108.46	281.70	0.00	1000.0	1000.0	0.00E+00	121.73	0.00E+00
4.00PM	1.50	103.03	287.14	0.00	0.0	500.0	0.00E+00	105.74	0.00E+00
5.00 PM	1.44	98.64	291.53	0.00	5000.0	2500.0	0.00E+00	100.83	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second =							6.77E-06		7.41E-08

TABLE 7: DAY 3 CO_2 EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 03/04/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.67	114.52	275.64	-	0.0	-	-	-	-
11.00 AM	2.02	138.55	251.61	24.03	0.0	0.0	0.00E+00	126.54	0.00E+00
12 NOON	1.45	99.47	290.69	0.00	5000.0	2500.0	0.00E+00	119.01	0.00E+00
1.00 PM	1.06	72.93	317.23	0.00	5000.0	5000.0	0.00E+00	86.20	0.00E+00
2.00 PM	1.39	95.09	295.08	22.15	0.0	2500.0	2.90E-05	84.01	3.46E-07
3.00 PM	1.49	102.19	287.97	7.11	6000.0	3000.0	1.11E-05	98.64	1.13E-07
4.00PM	1.65	112.85	277.31	10.66	4000.0	5000.0	2.78E-05	107.52	2.59E-07
5.00 PM	1.57	107.42	282.75	0.00	6000.0	5000.0	0.00E+00	110.13	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second =							9.71E-06		1.02E-07

TABLE 8: DAY 4 CO_2 EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 03/05/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.40	95.92	294.24	-	1000.0	-	-	-	-
11.00 AM	0.98	66.87	323.29	0.00	1000.0	1000.0	0.00E+00	81.40	0.00E+00
12 NOON	1.58	108.46	281.70	41.59	1000.0	1000.0	2.18E-05	87.67	2.48E-07
1.00 PM	1.37	94.25	295.91	0.00	0.0	500.0	0.00E+00	101.35	0.00E+00
2.00 PM	0.98	66.87	323.29	0.00	4000.0	2000.0	0.00E+00	80.56	0.00E+00
3.00 PM	1.16	79.20	310.96	12.33	5000.0	4500.0	2.88E-05	73.04	3.94E-07
4.00PM	1.00	68.55	321.62	0.00	5000.0	5000.0	0.00E+00	73.87	0.00E+00
5.00 PM	1.45	99.47	290.69	30.93	6000.0	5500.0	8.80E-05	84.01	1.05E-06
Average CO_2 Expelled out of the Wet Well per one second =							1.98E-05		2.41E-07

TABLE 9: DAY 5 CO_2 EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 06/12/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.01	68.88	319.86	-	19.0	-	-	-	-
11.00 AM	1.25	85.25	303.49	16.37	6.0	12.5	7.94E-08	77.07	1.03E-09
12 NOON	1.58	107.76	280.98	22.51	69.0	37.5	3.26E-07	96.50	3.36E-09
1.00 PM	1.10	75.02	313.72	0.00	89.0	79.0	0.00E+00	91.39	0.00E+00
2.00 PM	1.68	114.58	274.16	39.56	57.0	73.0	1.09E-06	94.80	1.15E-08
3.00 PM	1.40	95.48	293.26	0.00	2.0	29.5	0.00E+00	105.03	0.00E+00
4.00PM	0.91	62.06	326.68	0.00	26.0	14.0	0.00E+00	78.77	0.00E+00
5.00 PM	1.37	93.43	295.31	31.37	40.0	33.0	3.89E-07	77.75	4.96E-09
Average H_2S Expelled out of the Wet Well per one second =							2.70E-07		2.98E-09

TABLE 10: DAY 1 H_2S EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 11/30/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.51	103.86	286.30	-	28.0	-	-	-	-
11.00 AM	1.87	127.89	262.27	24.03	30.0	29.0	2.65E-07	115.88	2.28E-09
12 NOON	1.63	112.01	278.15	0.00	0.0	15.0	0.00E+00	119.95	0.00E+00
1.00 PM	1.65	112.85	277.31	0.84	0.0	0.0	0.00E+00	112.43	0.00E+00
2.00 PM	1.70	116.40	273.76	3.55	0.0	0.0	0.00E+00	114.62	0.00E+00
3.00 PM	1.73	118.91	271.25	2.51	23.0	11.5	1.09E-08	117.66	9.23E-11
4.00PM	1.80	123.51	266.66	4.60	33.0	28.0	4.84E-08	121.21	3.99E-10
5.00 PM	2.05	140.22	249.94	16.72	42.0	37.5	2.36E-07	131.87	1.79E-09
Average H_2S Expelled out of the Wet Well per one second =							8.00E-08		6.52E-10

TABLE 11: DAY 2 H_2S EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 02/18/2010)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.48	101.35	288.81	-	3.0	-	-	-	-
11.00 AM	1.30	88.82	301.35	0.00	4.0	3.5	0.00E+00	95.09	0.00E+00
12 NOON	1.00	68.55	321.62	0.00	5.0	4.5	0.00E+00	78.68	0.00E+00
1.00 PM	1.18	80.87	309.29	12.33	0.0	2.5	1.24E-08	74.71	1.66E-10
2.00 PM	1.97	135.00	255.16	54.13	0.0	0.0	0.00E+00	107.94	0.00E+00
3.00 PM	1.58	108.46	281.70	0.00	0.0	0.0	0.00E+00	121.73	0.00E+00
4.00PM	1.50	103.03	287.14	0.00	0.0	0.0	0.00E+00	105.74	0.00E+00
5.00 PM	1.44	98.64	291.53	0.00	5.0	2.5	0.00E+00	100.83	0.00E+00
Average H_2S Expelled out of the Wet Well per one second =							1.77E-09		2.37E-11

TABLE 12: DAY 3 H_2S EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 03/04/2010)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.67	114.52	275.64	-	0.0	-	-	-	-
11.00 AM	2.02	138.55	251.61	24.03	0.0	0.0	0.00E+00	126.54	0.00E+00
12 NOON	1.45	99.47	290.69	0.00	1.0	0.5	0.00E+00	119.01	0.00E+00
1.00 PM	1.06	72.93	317.23	0.00	1.0	1.0	0.00E+00	86.20	0.00E+00
2.00 PM	1.39	95.09	295.08	22.15	0.0	0.5	4.49E-09	84.01	5.34E-11
3.00 PM	1.49	102.19	287.97	7.11	1.0	0.5	1.43E-09	98.64	1.45E-11
4.00PM	1.65	112.85	277.31	10.66	0.0	0.5	2.15E-09	107.52	2.00E-11
5.00 PM	1.57	107.42	282.75	0.00	1.0	0.5	0.00E+00	110.13	0.00E+00
Average H_2S Expelled out of the Wet Well per one second =							1.15E-09		1.26E-11

TABLE 13: DAY 4 H_2S EMISSION RATE FROM LIFT STATION 1

LIFT STATION 1: WEST ESPLANADE & CANAL NO. 17									
Time (Date: 03/05/2010)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.40	95.92	294.24	-	1.0	-	-	-	-
11.00 AM	0.98	66.87	323.29	0.00	0.0	0.5	0.00E+00	81.40	0.00E+00
12 NOON	1.58	108.46	281.70	41.59	0.0	0.0	0.00E+00	87.67	0.00E+00
1.00 PM	1.37	94.25	295.91	0.00	0.0	0.0	0.00E+00	101.35	0.00E+00
2.00 PM	0.98	66.87	323.29	0.00	2.0	1.0	0.00E+00	80.56	0.00E+00
3.00 PM	1.16	79.20	310.96	12.33	2.0	2.0	9.88E-09	73.04	1.35E-10
4.00PM	1.00	68.55	321.62	0.00	5.0	3.5	0.00E+00	73.87	0.00E+00
5.00 PM	1.45	99.47	290.69	30.93	3.0	4.0	4.94E-08	84.01	5.89E-10
Average H_2S Expelled out of the Wet Well per one second =							8.47E-09		1.03E-10

TABLE 14: DAY 5 H_2S EMISSION RATE FROM LIFT STATION 1

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/09/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.07	5.00	24.18	-	1000.0	-	-	-	-
11.00 AM	2.10	9.82	19.36	4.83	0.0	500.0	1.24E-06	7.41	1.67E-07
12 NOON	2.06	9.61	19.57	0.00	0.0	0.0	0.00E+00	9.71	0.00E+00
1.00 PM	1.19	5.58	23.60	0.00	0.0	0.0	0.00E+00	7.59	0.00E+00
2.00 PM	1.33	6.22	22.96	0.64	1000.0	500.0	1.62E-07	5.90	2.74E-08
3.00 PM	1.41	6.56	22.62	0.34	1000.0	1000.0	1.73E-07	6.39	2.70E-08
4.00PM	1.49	6.97	22.20	0.41	1000.0	1000.0	2.09E-07	6.77	3.09E-08
5.00 PM	1.00	4.67	24.51	0.00	0.0	500.0	0.00E+00	5.82	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second =							2.54E-07		3.60E-08

TABLE 15: DAY 1 CO_2 EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/10/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.75	8.18	20.99	-	1000.0	-	-	-	-
11.00 AM	1.82	8.50	20.68	0.31	0.00	500.0	7.93E-08	8.34	9.50E-09
12 NOON	1.72	8.01	21.17	0.00	0.00	0.00	0.00E+00	8.26	0.00E+00
1.00 PM	1.22	5.68	23.50	0.00	0.00	0.00	0.00E+00	6.85	0.00E+00
2.00 PM	1.09	5.11	24.07	0.00	0.00	0.00	0.00E+00	5.39	0.00E+00
3.00 PM	1.40	6.53	22.65	1.42	1000.0	500.0	3.59E-07	5.82	6.17E-08
4.00PM	1.08	5.04	24.14	0.00	0.00	500.0	0.00E+00	5.79	0.00E+00
5.00 PM	1.80	8.40	20.78	3.36	2000.0	1000.0	1.70E-06	6.72	2.53E-07
Average CO_2 Expelled out of the Wet Well per one second =							3.05E-07		4.63E-08

TABLE 16: DAY 2 CO_2 EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/11/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.84	8.60	20.58	-	3000.0	-	-	-	-
11.00 AM	2.05	9.58	19.60	0.98	3000.0	3000.0	1.49E-06	9.09	1.64E-07
12 NOON	1.41	6.56	22.62	0.00	14000.0	8500.0	0.00E+00	8.07	0.00E+00
1.00 PM	2.06	9.61	19.57	3.05	11000.0	12500.0	1.92E-05	8.08	2.38E-06
2.00 PM	1.33	6.22	22.96	0.00	9000.0	10000.0	0.00E+00	7.91	0.00E+00
3.00 PM	1.86	8.70	20.48	2.48	13000.0	11000.0	1.38E-05	7.46	1.85E-06
4.00PM	1.43	6.66	22.52	0.00	11000.0	12000.0	0.00E+00	7.68	0.00E+00
5.00 PM	1.22	5.68	23.50	0.00	5000.0	8000.0	0.00E+00	6.17	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second =							4.93E-06		6.27E-07

TABLE 17: DAY 3 CO_2 EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/12/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.14	5.34	23.84	-	6000.0	-	-	-	-
11.00 AM	1.48	6.93	22.25	1.59	1000.0	3500.0	2.85E-06	6.13	4.65E-07
12 NOON	1.70	7.96	21.22	1.02	1000.0	1000.0	5.22E-07	7.44	7.01E-08
1.00 PM	1.46	6.83	22.35	0.00	1000.0	1000.0	0.00E+00	7.39	0.00E+00
2.00 PM	1.96	9.17	20.01	2.33	1000.0	1000.0	1.19E-06	8.00	1.48E-07
3.00 PM	1.54	7.20	21.98	0.00	2000.0	1500.0	0.00E+00	8.18	0.00E+00
4.00PM	1.24	5.78	23.40	0.00	8000.0	5000.0	0.00E+00	6.49	0.00E+00
5.00 PM	1.35	6.32	22.86	0.54	1000.0	4500.0	1.24E-06	6.05	2.05E-07
Average CO_2 Expelled out of the Wet Well per one second=							8.28E-07		1.27E-07

TABLE 18: DAY 4 CO_2 EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/13/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.37	6.39	22.79	-	4000.0	-	-	-	-
11.00 AM	1.59	7.44	21.73	1.05	1000.0	2500.0	1.35E-06	6.92	1.95E-07
12 NOON	1.84	8.60	20.58	1.15	2000.0	1500.0	8.86E-07	8.02	1.10E-07
1.00 PM	1.37	6.42	22.76	0.00	1000.0	1500.0	0.00E+00	7.51	0.00E+00
2.00 PM	1.35	6.32	22.86	0.00	2000.0	1500.0	0.00E+00	6.37	0.00E+00
3.00 PM	1.82	8.50	20.68	2.18	1000.0	1500.0	1.67E-06	7.41	2.25E-07
4.00PM	1.43	6.66	22.52	0.00	1000.0	1000.0	0.00E+00	7.58	0.00E+00
5.00 PM	1.82	8.50	20.68	1.84	2000.0	1500.0	1.41E-06	7.58	1.86E-07
Average CO_2 Expelled out of the Wet Well per one second =							7.58E-07		1.02E-07

TABLE 19: DAY 5 CO_2 EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/09/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.07	5.00	24.18	-	0.0	-	-	-	-
11.00 AM	2.10	9.82	19.36	4.83	0.0	0.0	0.00E+00	7.41	0.00E+00
12 NOON	2.06	9.61	19.57	0.00	0.0	0.0	0.00E+00	9.71	0.00E+00
1.00 PM	1.19	5.58	23.60	0.00	0.0	0.0	0.00E+00	7.59	0.00E+00
2.00 PM	1.33	6.22	22.96	0.64	0.0	0.0	0.00E+00	5.90	0.00E+00
3.00 PM	1.41	6.56	22.62	0.34	0.0	0.0	0.00E+00	6.39	0.00E+00
4.00PM	1.49	6.97	22.20	0.41	0.0	0.0	0.00E+00	6.77	0.00E+00
5.00 PM	1.00	4.67	24.51	0.00	0.0	0.0	0.00E+00	5.82	0.00E+00
Average H_2S Expelled out of the Wet Well per one second =							0.00E+00		0.00E+00

TABLE 20: DAY 1 H_2S EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/10/2009) Wet Weather	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.75	8.18	20.99	-	0.0	-	-	-	-
11.00 AM	1.82	8.50	20.68	0.31	0.0	0.0	0.00E+00	8.34	0.00E+00
12 NOON	1.72	8.01	21.17	0.00	0.0	0.0	0.00E+00	8.26	0.00E+00
1.00 PM	1.22	5.68	23.50	0.00	0.0	0.0	0.00E+00	6.85	0.00E+00
2.00 PM	1.09	5.11	24.07	0.00	0.0	0.0	0.00E+00	5.39	0.00E+00
3.00 PM	1.40	6.53	22.65	1.42	0.0	0.0	0.00E+00	5.82	0.00E+00
4.00PM	1.08	5.04	24.14	0.00	0.0	0.0	0.00E+00	5.79	0.00E+00
5.00 PM	1.80	8.40	20.78	3.36	0.0	0.0	0.00E+00	6.72	0.00E+00
Average H_2S Expelled out of the Wet Well per one second=							0.00E+00		0.00E+00

TABLE 21: DAY 2 H_2S EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/11/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.84	8.60	20.58	-	0.0	-	-	-	-
11.00 AM	2.05	9.58	19.60	0.98	0.0	0.0	0.00E+00	9.09	0.00E+00
12 NOON	1.41	6.56	22.62	0.00	1.0	0.5	0.00E+00	8.07	0.00E+00
1.00 PM	2.06	9.61	19.57	3.05	1.0	1.0	1.19E-09	8.08	1.47E-10
2.00 PM	1.33	6.22	22.96	0.00	0.0	0.5	0.00E+00	7.91	0.00E+00
3.00 PM	1.86	8.70	20.48	2.48	1.0	0.5	4.84E-10	7.46	6.48E-11
4.00PM	1.43	6.66	22.52	0.00	1.0	1.0	0.00E+00	7.68	0.00E+00
5.00 PM	1.22	5.68	23.50	0.00	0.0	0.5	0.00E+00	6.17	0.00E+00
Average H_2S Expelled out of the Wet Well per one second =							2.39E-10		3.03E-11

TABLE 22: DAY 3 H_2S EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/12/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	3.75	188.5	841.95	-	2	-	-	-	-
11.00 AM	4.87	244.8	785.65	56.3	0	1.0	5.00E-06	216.64	2.31E-08
12 NOON	5.59	281.0	749.46	36.2	0	0.0	0.00E+00	262.89	0.00E+00
1.00 PM	4.8	241.3	789.17	0.0	0	0.0	0.00E+00	261.13	0.00E+00
2.00 PM	6.44	323.7	706.73	82.4	0	0.0	0.00E+00	282.49	0.00E+00
3.00 PM	5.06	254.3	776.10	0.0	2	1.0	0.00E+00	289.03	0.00E+00
4.00PM	4.06	204.1	826.36	0.0	5	3.5	0.00E+00	229.21	0.00E+00
5.00 PM	4.44	223.2	807.26	19.1	0	2.5	4.22E-06	213.63	1.98E-08
Average H_2S Expelled out of the Wet Well per one second =							1.66E-10		2.72E-11

TABLE 23: DAY 4 H_2S EMISSION RATE FROM LIFT STATION 2

LIFT STATION 2: 39TH STREET & CALIFORNIA									
Time (Date: 03/13/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	1.37	6.39	22.79	-	4.0	-	-	-	-
11.00 AM	1.59	7.44	21.73	1.05	0.0	2.0	8.35E-10	6.92	1.21E-10
12 NOON	1.84	8.60	20.58	1.15	2.0	1.0	4.56E-10	8.02	5.69E-11
1.00 PM	1.37	6.42	22.76	0.00	1.0	1.5	0.00E+00	7.51	0.00E+00
2.00 PM	1.35	6.32	22.86	0.00	5.0	3.0	0.00E+00	6.37	0.00E+00
3.00 PM	1.82	8.50	20.68	2.18	2.0	3.5	3.00E-09	7.41	4.05E-10
4.00PM	1.43	6.66	22.52	0.00	1.0	1.5	0.00E+00	7.58	0.00E+00
5.00 PM	1.82	8.50	20.68	1.84	2.0	1.5	1.09E-09	7.58	1.43E-10
Average H_2S Expelled out of the Wet Well per one second =							7.69E-10		1.04E-10

TABLE 24: DAY 5 H_2S EMISSION RATE FROM LIFT STATION 2

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/24/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.81	7.43	50.25	-	1000.0	-	-	-	-
11.00 AM	0.81	7.43	50.25	0.00	1000.0	1000.0	0.00E+00	7.43	0.00E+00
12 NOON	0.80	7.37	50.31	0.00	1000.0	1000.0	0.00E+00	7.40	0.00E+00
1.00 PM	0.76	7.01	50.67	0.00	1000.0	1000.0	0.00E+00	7.19	0.00E+00
2.00 PM	0.77	7.12	50.56	0.11	1000.0	1000.0	5.69E-08	7.06	8.06E-09
3.00 PM	0.74	6.81	50.87	0.00	1000.0	1000.0	0.00E+00	6.97	0.00E+00
4.00PM	0.72	6.59	51.09	0.00	1000.0	1000.0	0.00E+00	6.70	0.00E+00
5.00 PM	0.72	6.64	51.04	0.06	1000.0	1000.0	2.84E-08	6.62	4.30E-09
Average CO_2 Expelled out of the Wet Well per one second =							1.22E-08		1.77E-09

TABLE 25: DAY 1 CO_2 EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/25/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.66	6.03	51.65	-	0.0	-	-	-	-
11.00 AM	0.55	5.02	52.66	0.00	1000.0	500.0	0.00E+00	5.52	0.00E+00
12 NOON	0.57	5.21	52.47	0.20	1000.0	1000.0	9.96E-08	5.12	1.95E-08
1.00 PM	0.55	5.10	52.58	0.00	0.0	500.0	0.00E+00	5.16	0.00E+00
2.00 PM	0.76	6.95	50.73	1.85	0.0	0.0	0.00E+00	6.03	0.00E+00
3.00 PM	0.85	7.79	49.89	0.84	0.0	0.0	0.00E+00	7.37	0.00E+00
4.00PM	0.80	7.37	50.31	0.00	0.0	0.0	0.00E+00	7.58	0.00E+00
5.00 PM	0.77	7.06	50.62	0.00	0.0	0.0	0.00E+00	7.22	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second =							1.42E-08		2.78E-09

TABLE 26: DAY 2 CO_2 EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/26/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.88	8.13	49.55	-	0.0	-	-	-	-
11.00 AM	0.74	6.81	50.87	0.00	0.0	0.0	0.00E+00	7.47	0.00E+00
12 NOON	0.89	8.19	49.50	1.37	1000.0	500.0	3.55E-07	7.50	4.73E-08
1.00 PM	0.87	8.05	49.64	0.00	1000.0	1000.0	0.00E+00	8.12	0.00E+00
2.00 PM	0.85	7.79	49.89	0.00	1000.0	1000.0	0.00E+00	7.92	0.00E+00
3.00 PM	0.80	7.37	50.31	0.00	1000.0	1000.0	0.00E+00	7.58	0.00E+00
4.00PM	0.78	7.20	50.48	0.00	0.0	500.0	0.00E+00	7.29	0.00E+00
5.00 PM	0.77	7.06	50.62	0.00	1000.0	500.0	0.00E+00	7.13	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second=							5.07E-08		6.76E-09

TABLE 27: DAY 3 CO_2 EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/27/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.88	8.10	49.58	-	1000.0	-	-	-	-
11.00 AM	0.60	5.52	52.16	0.00	1000.0	1000.0	0.00E+00	6.81	0.00E+00
12 NOON	0.82	7.57	50.11	2.05	1000.0	1000.0	1.04E-06	6.55	1.60E-07
1.00 PM	0.49	4.49	53.20	0.00	1000.0	1000.0	0.00E+00	6.03	0.00E+00
2.00 PM	0.69	6.34	51.35	1.85	1000.0	1000.0	9.40E-07	5.41	1.74E-07
3.00 PM	0.80	7.37	50.31	1.04	0.0	500.0	2.63E-07	6.85	3.84E-08
4.00PM	0.86	7.93	49.75	0.56	1000.0	500.0	1.42E-07	7.65	1.86E-08
5.00 PM	0.53	4.91	52.78	0.00	1000.0	1000.0	0.00E+00	6.42	0.00E+00
Average CO_2 Expelled out of the Wet Well per one second =							3.41E-07		5.57E-08

TABLE 28: DAY 4 CO_2 EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/28/2010)	WW Level in the Wet Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of CO_2 in the Air in the Wet Well (ppm)	Average Hourly Concentration of CO_2 in the Wet Well (ppm)	CO_2 Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.70	6.45	51.23	-	0.0	-	-	-	-
11.00 AM	0.64	5.89	51.79	0.00	0.0	0.0	0.00E+00	6.17	0.00E+00
12 NOON	0.76	6.95	50.73	1.07	0.0	0.0	0.00E+00	6.42	0.00E+00
1.00 PM	0.88	8.10	49.58	1.15	1000.0	500.0	2.90E-07	7.53	3.86E-08
2.00 PM	0.54	4.96	52.72	0.00	0.0	500.0	0.00E+00	6.53	0.00E+00
3.00 PM	0.65	6.00	51.68	1.04	1000.0	500.0	2.61E-07	5.48	4.77E-08
4.00PM	0.73	6.70	50.98	0.70	1000.0	1000.0	3.54E-07	6.35	5.57E-08
5.00 PM	0.84	7.74	49.94	1.04	2000.0	1500.0	7.87E-07	7.22	1.09E-07
Average CO_2 Expelled out of the Wet Well per one second =							2.42E-07		3.59E-08

TABLE 29: DAY 5 CO_2 EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/24/2010)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.81	7.43	50.25	-	1.0	-	-	-	-
11.00 AM	0.81	7.43	50.25	0.00	0.0	0.5	0.00E+00	7.43	0.00E+00
12 NOON	0.80	7.37	50.31	0.00	3.0	1.5	0.00E+00	7.40	0.00E+00
1.00 PM	0.76	7.01	50.67	0.00	0.0	1.5	0.00E+00	7.19	0.00E+00
2.00 PM	0.77	7.12	50.56	0.11	4.0	2.0	8.80E-11	7.06	1.25E-11
3.00 PM	0.74	6.81	50.87	0.00	0.0	2.0	0.00E+00	6.97	0.00E+00
4.00PM	0.72	6.59	51.09	0.00	0.0	0.0	0.00E+00	6.70	0.00E+00
5.00 PM	0.72	6.64	51.04	0.06	4.0	2.0	4.40E-11	6.62	6.65E-12
Average H_2S Expelled out of the Wet Well per one second =							1.89E-11		2.73E-12

TABLE 30: DAY 1 H_2S EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/25/2010)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.66	6.03	51.65	-	0.0	-	-	-	-
11.00 AM	0.55	5.02	52.66	0.00	0.0	0.0	0.00E+00	5.52	0.00E+00
12 NOON	0.57	5.21	52.47	0.20	1.0	0.5	3.85E-11	5.12	7.52E-12
1.00 PM	0.55	5.10	52.58	0.00	0.0	0.5	0.00E+00	5.16	0.00E+00
2.00 PM	0.76	6.95	50.73	1.85	3.0	1.5	1.07E-09	6.03	1.78E-10
3.00 PM	0.85	7.79	49.89	0.84	0.0	1.5	4.86E-10	7.37	6.60E-11
4.00PM	0.80	7.37	50.31	0.00	0.0	0.0	0.00E+00	7.58	0.00E+00
5.00 PM	0.77	7.06	50.62	0.00	0.0	0.0	0.00E+00	7.22	0.00E+00
Average H_2S Expelled out of the Wet Well per one second =							2.28E-10		3.59E-11

TABLE 31: DAY 2 H_2S EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/26/2010) Dry Weather	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.88	8.13	49.55	-	0.0	-	-	-	-
11.00 AM	0.74	6.81	50.87	0.00	0.0	0.0	0.00E+00	7.47	0.00E+00
12 NOON	0.89	8.19	49.50	1.37	1.0	0.5	2.74E-10	7.50	3.66E-11
1.00 PM	0.87	8.05	49.64	0.00	0.0	0.5	0.00E+00	8.12	0.00E+00
2.00 PM	0.85	7.79	49.89	0.00	1.0	0.5	0.00E+00	7.92	0.00E+00
3.00 PM	0.80	7.37	50.31	0.00	0.0	0.5	0.00E+00	7.58	0.00E+00
4.00PM	0.78	7.20	50.48	0.00	4.0	2.0	0.00E+00	7.29	0.00E+00
5.00 PM	0.77	7.06	50.62	0.00	5.0	4.5	0.00E+00	7.13	0.00E+00
Average H_2S Expelled out of the Wet Well per one second=							3.92E-11		5.22E-12

TABLE 32: DAY 3 H_2S EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/27/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.88	8.10	49.58	-	1.0	-	-	-	-
11.00 AM	0.60	5.52	52.16	0.00	0.0	0.5	0.00E+00	6.81	0.00E+00
12 NOON	0.82	7.57	50.11	2.05	4.0	2.0	1.61E-09	6.55	2.47E-10
1.00 PM	0.49	4.49	53.20	0.00	0.0	2.0	0.00E+00	6.03	0.00E+00
2.00 PM	0.69	6.34	51.35	1.85	3.0	1.5	1.09E-09	5.41	2.01E-10
3.00 PM	0.80	7.37	50.31	1.04	0.0	1.5	6.09E-10	6.85	8.89E-11
4.00PM	0.86	7.93	49.75	0.56	5.0	2.5	5.49E-10	7.65	7.17E-11
5.00 PM	0.53	4.91	52.78	0.00	2.0	3.5	0.00E+00	6.42	0.00E+00
Average H_2S Expelled out of the Wet Well per one second=							5.52E-10		8.69E-11

TABLE 33: DAY 4 H_2S EMISSION RATE FROM LIFT STATION 3

LIFT STATION 3: 39TH STREET & POWER									
Time (Date: 03/28/2009)	WW Level in the Well (m)	Volume of WW in the Wet Well (m^3)	Volume of Air in the Wet Well (m^3)	Volume of Air Expelled Due to Increase in WW Level (m^3)	Concentration of H_2S in the Air in the Wet Well (ppm)	Average Hourly Concentration of H_2S in the Wet Well (ppm)	H_2S Expelled out of the Wet Well (Kg/sec)	Average Hourly Volume of WW Present in the Wet Well (m^3)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
10 .00 AM	0.70	6.45	51.23	-	0.0	-	-	-	-
11.00 AM	0.64	5.89	51.79	0.00	0.0	0.0	0.00E+00	6.17	0.00E+00
12 NOON	0.76	6.95	50.73	1.07	0.0	0.0	0.00E+00	6.42	0.00E+00
1.00 PM	0.88	8.10	49.58	1.15	2.0	1.0	4.49E-10	7.53	5.96E-11
2.00 PM	0.54	4.96	52.72	0.00	1.0	1.5	0.00E+00	6.53	0.00E+00
3.00 PM	0.65	6.00	51.68	1.04	3.0	2.0	8.08E-10	5.48	1.47E-10
4.00PM	0.73	6.70	50.98	0.70	0.0	1.5	4.10E-10	6.35	6.45E-11
5.00 PM	0.84	7.74	49.94	1.04	5.0	2.5	1.01E-09	7.22	1.40E-10
Average H_2S Expelled out of the Wet Well per one second=							3.83E-10		5.89E-11

TABLE 34: DAY 5 H_2S EMISSION RATE FROM LIFT STATION 3

In TABLE 35, the temperature readings were taken from a www.wunderground.com website for the monitored days for the city of Kenner.

Date	Time								Average Temperature	Weather Condition
	10 A.M.	11 A.M.	12 NOON	1P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.		
	Temperature (^{o}C)									
6/12/2009	29.4	30.6	31.7	31.7	32.2	32.8	33.3	32.8	31.8	Hot and Dry
11/30/2009	21.1	20	20.6	18.9	17.8	15.6	15	13.9	17.9	Rainy
2/18/2010	10.6	11.7	12.2	13.3	13.9	13.3	13.3	12.8	12.6	Mostly Cloudy
3/4/2010	8.3	8.3	9.4	10.6	11.7	12.2	12.8	12.2	10.7	Partly Cloudy
3/5/2010	10.6	11.7	11.7	12.8	13.9	14.4	15.6	14.4	13.1	Clear in the Morning Partly Cloudy in the afternoon
3/9/2010	18	17.8	20	21.7	21.7	21.7	20.6	20	20.2	Rained in the morning
3/10/2010	20.6	21.7	22.2	21.7	21.7	22.2	21.7	21.1	21.6	Lightly Rained afternoon
3/11/2010	21.7	21.1	22.2	21.7	22.2	21.1	21.7	21.7	21.7	Mostly Cloudy
3/12/2010	17.8	18.9	20	20	20.6	20.6	20	19.4	19.7	Partly Cloudy
3/13/2010	16.7	17.8	17.8	18.3	18.9	19.4	18.9	18.3	18.3	Partly Cloudy
3/24/2010	16.7	18.3	18.9	20	20.6	21.1	21.1	20	19.6	Overcast
3/25/2010	17.8	18.9	22.2	24.4	25	26.1	26.1	25.6	23.3	Lightly Rained
3/26/2010	14.4	15	15.6	16.7	18.3	18.9	19.4	20	17.3	Cloudy in the Morning Clear in the afternoon
3/27/2010	17.4	18.3	19.4	20	20.6	21.1	20.6	20	19.7	Mostly Cloudy
3/28/2010	18.9	20	21.7	21.7	22.8	22.2	22.2	20.6	21.3	Partly Cloudy

TABLE 35: HOURLY TEMPERATURE VARIATIONS FOR EXPERIMENTAL DATES

TABLE 36 shows CO_2 and H_2S emission rates for all the three stations on rainy and non-rainy days.

Day	LIFT STATION 1		LIFT STATION 2		LIFT STATION 3	
	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)	CO_2 Emitted per Unit Volume of WW (Kg/m^3-sec)	H_2S Emitted per Unit Volume of WW (Kg/m^3-sec)
Day 1	1.72E-07	2.98E-09	3.60E-08	0.00E+00	1.77E-09	2.73E-12
Day 2	7.74E-08	6.54E-10	4.63E-08	0.00E+00	2.78E-09	3.59E-11
Day 3	7.43E-08	2.38E-11	6.27E-07	3.03E-11	6.76E-09	5.21E-12
Day 4	1.02E-07	1.25E-11	1.27E-07	2.72E-11	5.56E-08	8.68E-11
Day 5	2.41E-07	1.03E-10	1.02E-07	1.04E-10	3.59E-08	5.87E-11
Average	1.33E-07	7.54E-10	1.88E-07	3.22E-11	2.06E-08	3.79E-11
Standard Deviation	7.20E-08	1.27E-09	2.49E-07	4.25E-11	2.41E-08	3.58E-11
Rainy Day Average	7.74E-08	6.54E-10	4.12E-08	0.00E+00	2.78E-09	3.59E-11
Non-Rainy Day Average	1.47E-07	7.80E-10	1.15E-07	5.38E-11	2.50E-08	3.84E-11
Average, after Omitting CO_2 Reading for LS 2 on Day 3			1.15E-07			
Percent of WW in the Well to the Total Volume of the Well	25.4	25.4	24.5	24.5	11.8	11.8

TABLE 36: SUMMARY OF TABLE 2 THROUGH TABLE 31 INCULDES RAINY AND NON RAINY DAYS

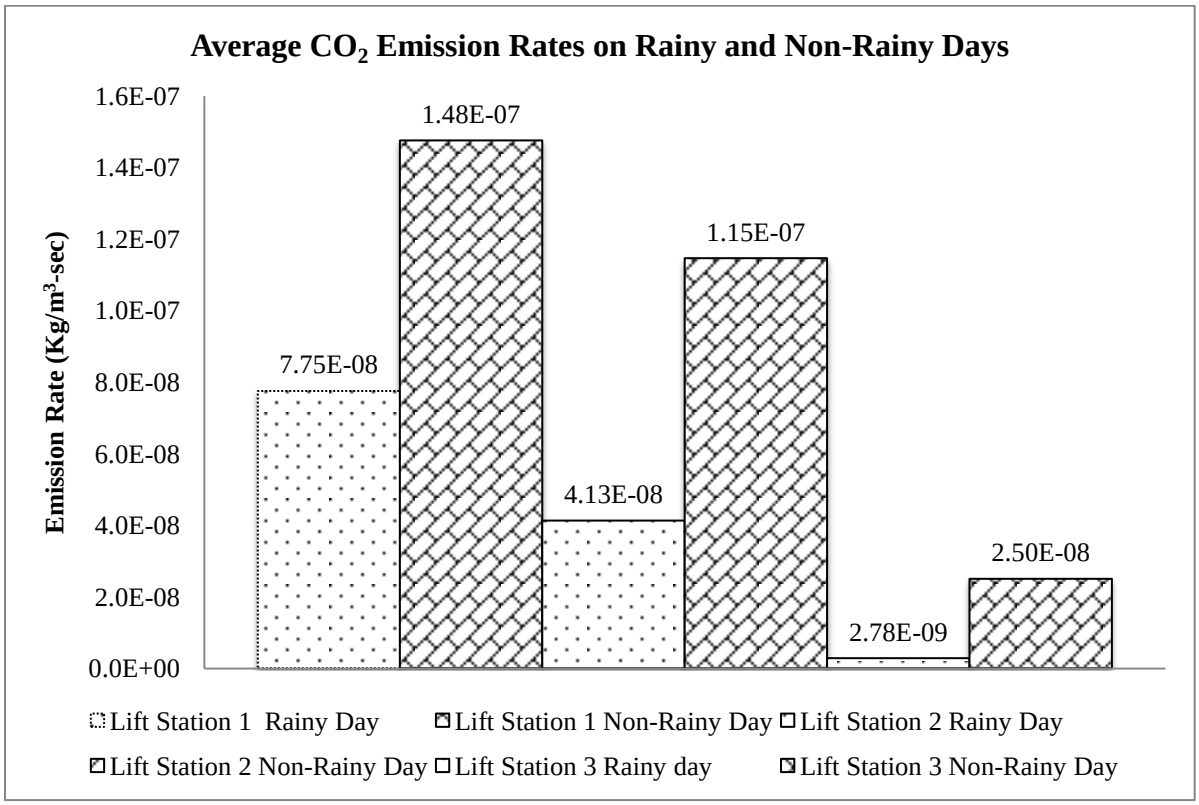
Note: Day 3 CO_2 result for Lift Station 2 is considered as an outlier may be omitted.

LIFT STATION	Lift Station 1	Lift Station 2	Lift Station 3
Total volume of the well(m^3)	390.2	29.2	57.7
Average volume of wastewater present in the well on Day 1 (m^3)	88.3	6.8	7.1
Average volume of wastewater present in the well on Day 2 (m^3)	119.5	6.9	6.3
Average volume of wastewater present in the well on Day 3 (m^3)	98.1	7.7	7.6
Average volume of wastewater present in the well on Day 4 (m^3)	105.4	6.9	6.5
Average volume of wastewater present in the well on Day 5 (m^3)	85.0	7.4	6.6
5 Day Average volume of wastewater present in the well (m^3)	99.2	7.1	6.8
Percent of wastewater present in the well (%)	25.4	24.5	11.8

TABLE 37: PERCENT OF WASTEWATER PRESENT IN THE WELL TO THE TOTAL VOLUME OF THE WELL

The average percentage of wastewater present in the well compared to the total volume of the well for all three lift stations is given in TABLE 37.

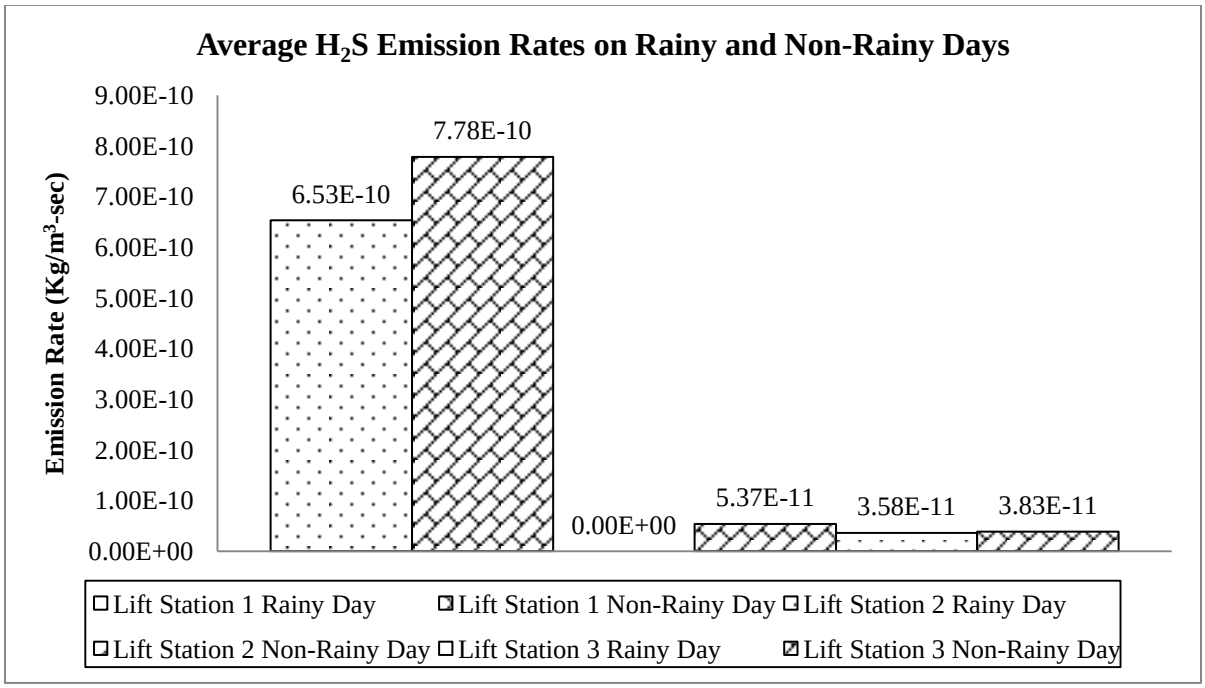
The graphs plotted below are based on the results obtained from TABLE 36, separating rainy and non-rainy days.



GRAPH 1: CO_2 Emission Rates on Rainy and Non-Rainy Days

Third reading for lift station 2 from TABLE 36 is omitted. Due to some reason the CO_2 emission rate is very high on Day 3 for lift station 2.

Note: The total volumes of the wet wells for lift station 1, lift station 2, and lift station 3 are 390.2 m^3, 29.2 m^3 and 57.7 m^3 respectively.



GRAPH 2: H_2S Emission Rates on Rainy and Non-Rainy Days

TABLE 38 shows the emission factors in the units of mg/m^3-hr for the three lift stations.

Day	LIFT STATION 1		LIFT STATION 2		LIFT STATION 3	
	CO_2 Emitted per Unit Volume of WW (mg/m^3-hr)	H_2S Emitted per Unit Volume of WW (mg/m^3-hr)	CO_2 Emitted per Unit Volume of WW (mg/m^3-hr)	H_2S Emitted per Unit Volume of WW (mg/m^3-hr)	CO_2 Emitted per Unit Volume of WW (mg/m^3-hr)	H_2S Emitted per Unit Volume of WW (mg/m^3-hr)
Day 1	620.00	10.70	130.00	0.00	6.36	0.01
Day 2	279.00	2.35	167.00	0.00	10.00	0.13
Day 3	268.00	0.09	2260.00	0.11	24.30	0.02
Day 4	368.00	0.05	457.00	0.10	200.00	0.31
Day 5	868.00	0.37	368.00	0.37	129.00	0.21
Average	480.60	2.71	676.40	0.12	73.93	0.14
Standard Deviation	258.86	4.57	895.69	0.15	86.66	0.13

TABLE 38: CO_2 AND H_2S EMISSION RATES IN mg/m^3-hr

Conversion Factor: $1Kg/m^3\text{-sec} = 3.6x10^9\ mg/m^3\text{-hr}$

Note: Day 3 CO_2 result for Lift Station 2 is considered as an outlier may be omitted.

4.2 Analyses and Discussion

For Lift Station 2 on Day 3, the CO_2 emission rate observed compared to the other three lift station emissions and the lift station 2 emissions on other days is very large. This may be due to the high-strength wastewater present in the well on that day. About 1,000 ppm methane concentrations were observed on that particular day. Emissions are temperature variant.

From the obtained results, it is evident that the wastewater collection system is undergoing corrosion. Also, the lift station 1 emits H_2S greater than the WHO guidelines.

As with any method, this method does have some limitations. The method used in this research does not account to the leaks associated with the wet well as practically no wet well is completely closed. There may be some leakages from the well which are not considered in this approach of quantifying emissions.

Time interval used in this attempt was one-hour for monitoring concentrations of CO_2 and H_2S as well as the wastewater level in the wet well, so the values reported may not be accurate. However, by reducing the time-interval for field observations, the methodology should produce more accurate results of CO_2 and H_2S emissions. Temperatures in this research were taken from Internet rather than field observations.

The emissions may change depending upon the composition of the wastewater on any particular day. The concentrations may change depending upon the strength and p^H of the wastewater.

This methodology does not distinguish variations in emissions and emission factors based on wastewater characteristics, temperature, and residence time of the wastewater within wet wells as the final results are all lumped because the method measures actual emissions. It is important to note that the emission factors calculated in this study will vary as wastewater characteristics, temperature, and residence times change.

The temperature of the water and the surrounding temperature is a very important parameter because of its effect on chemical reactions and reaction rates, aquatic life and stability of the water. Optimum temperatures for bacterial activity are in the range from 25 to 35^o C In addition,

oxygen is less soluble in warm water than cold water, hence causing depletions in dissolved oxygen concentrations in the summer months.

The emission rates depend on solid and hydraulic retention times within the wet wells. An increase or decrease in the retention time results in an increase or decrease in the extent of the chemical or biological reaction. There is a minimum retention time for each reaction. If the retention time is less than the minimum retention time, bacteria cannot grow rapidly enough and the digestion process will fail eventually. Hence, the retention time is directly proportional to the emission rate.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The conclusions, derived from the analyses of the experimental data of the lift station are summarized as follows:

1. The emissions from the well depend on the wastewater characteristics; strong wastewater with high BOD values will emit greater amounts of gases.
2. Temperature is a very significant component for the H_2S emissions, higher the temperature greater the gas emitted.
3. Rainfall minimizes the emission rates from wet wells and thus emission factors. The emission rates can be below detectable level when rain occurs. This can be observed in TABLE 36.
4. CO_2 emissions are less dependent on temperature compared to H_2S emissions.
5. Omitting the third reading from Table 36 for Lift Station 2; it is observed that the emission rate depends on the percentage of wastewater present in the wet well to the total volume of the wet well.
6. The leakages in the wet well are not considered in determing the emission factors, so there might be slight difference in the actual and the calculated emission factors.
7. According to ATSDR, the MRLs for acute and intermediate inhalation are 0.07 ppm and 0.02 ppm. Hence, all the three lift stations emit H_2S greater than MRLs.
8. According to EPA, even at very low concentration (< 1 ppm) of hydrogen sulfide in the atmosphere can corrode the electrical and mechanical devices and also the concrete

structures. All three wet wells exhibit higher hydrogen sulfide levels which pose corrosion risks to the Kenner City's Wastewater infrastructure.

9. In summer at high temperatures the H_2S emissions could be much greater than what is reported in this research and could be much higher than the W.H.O. and ATSDR health risk levels.

5.2 Recommendations

It is recommended that the following changes in the procedures used in this investigation can be considered for future research. They are as follows:

1. This study can be extended to consider the temperature effect of the wastewater on the emission factor.
2. Another thing is to consider, the residence time of the wastewater in the well. This can be done considering the time interval between two pump runs and decreasing the time interval between the wastewater level obsevations.
3. Wastewater characteristics play a very important role on the stoichiometric process of the waste, hence wastewater characteristics like p^H, temperature, and hydraulic retention time should also be considered.
4. Additional data such as flow rate is required to develop a mathematical model to estimate more accurate values.
5. If the time interval decreased from one hour to the residence time of the wastewater, more precise values can be achieved.

6. Usage of an instrument, which can read CO_2 concentration upto 1ppm, so that the results would be more reliable.
7. City of Kenner should take necessary measurements to control the rate of hydrogen sulfide corrosion to protect its concrete structure, electrical and mechanical devices in order to avoid millions of dollars for repair and rehabilitation of the sewer collection system.

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