Wastewater Collection System Odor Control Design Guidelines:

Odor Impact and Vapor-Phase Control and Sulfide Generation and Liquid-phase Control

Odor Impact and Vapor-Phase Control

Objective

These guidelines are intended to provide a step-by-step method for estimating pressurization at siphons and wet wells, off-site odor potential, and any vapor-phase control which may be necessary. The calculations herin shall be followed to establish the maximum off-site hydrogen sulfide concentration and to determine if treatment of gasses is necessary. Once the calculations are complete, they shall be submitted to the City of San Marcos Engineering Director for review.

Overview

The steps presented herein provide a screening approach to estimate the potential for out-gassing, off-site odor impacts, and vapor-phase control. Step-by-step instructions are provided followed by an example illustrating the process. A form is provided to guide calculations.

Data Needs

Table 1 lists the data that will be needed for the calculations.

TABLE 1
Data needs

Data Needs	Symbol	value	Units
Average wastewater flow rate	Q		MGD
Wastewater pH	pH		-
Incoming sulfide concentration	S_{out}		mg/L
Wastewater temperature	T		ºC
Upstream pipe diameter	D_{up}		in
Upstream pipe slope	SL_{up}		ft/ft
Downstream pipe diameter	D_{down}		in
Downstream pipe slope	SL_{down}		ft/ft
Out-gassing structure volume	V		ft^3
Sensitive receptor distance from odor source	F		ft

Estimate H_2S_g Concentration

Step 1: Henry's law constant

Calculate Henry's law constant based on temperature as shown in Equation 1.

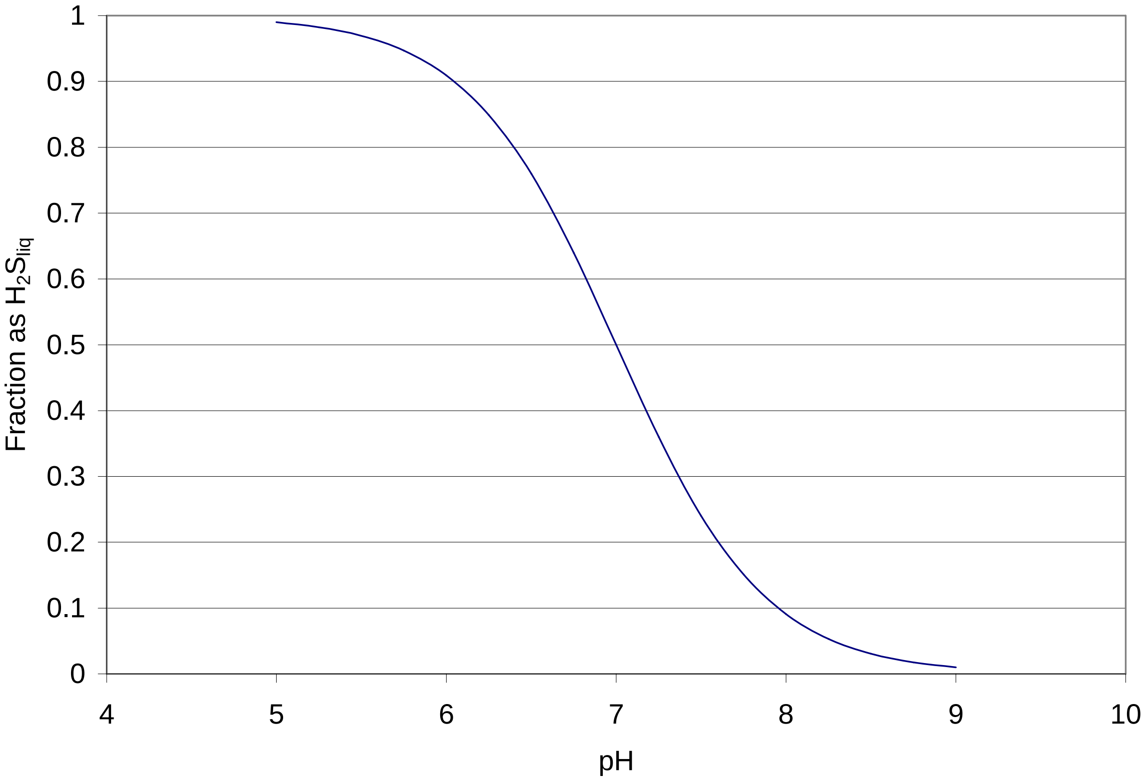
$$H = 0.0084T + 0.2043 \tag{1}$$

- H = Henry's Law constant for H_2S, (unitless)
- T = Wastewater temperature (°C)

Step 2: Liquid H_2S concentration

Use Figure 1 to estimate the FractionH_2S_{liq} based on pH.

FIGURE 1
Fraction, based on pH, of incoming sulfide that is in the form of H_2S_{liq}



Calculate the equilibrium liquid H_2S concentration based on FractionH_2S_{liq} and the incoming sulfide concentration, S_{out} (mg/L), as shown in Equation 2.

$$H_2S_{liq} = S_{out} \times FractionH_2S_{liq} \tag{2}$$

- FractionH_2S_{liq} = portion of dissolved sulfide in the form of H_2S at equilibrium (mg/L)
- S_{out} = incoming sulfide concentration (mg/L)
- H_2S_{liq} = incoming liquid H_2S concentration (mg/L)

Step 3: H_2S gas concentration

Calculate equilibrium hydrogen sulfide gas concentration based on Henry's Law as shown in Equation 3.

$$H_2S_{gas} = H \times H_2S_{liq} \tag{3}$$

- H_2S_{gas} = equilibrium hydrogen sulfide gas concentration (mg/L)
- H = Henry's Law constant for hydrogen sulfide (unitless)

Step 4: H_2S gas in ppmv

Convert H_2S_{gas} from units of mg/L to ppmv as shown in Equation 4. H_2S_{gas} is the concentration that would be at equilibrium with the in-coming liquid sulfide concentration and should be considered a conservative (high) estimate for the incoming hydrogen sulfide gas concentration.

$$H_2S_g = H_2S_{gas} \times (T + 273) \times 2.41 \tag{4}$$

- H_2S_g = the equilibrium hydrogen sulfide concentration (ppmv)

Calculate Upstream and Downstream Natural Ventilation

Ventilation in the upstream and downstream pipe due to liquid drag (natural ventilation) can be estimated based on hydraulic conditions in the pipes.

Step 5: Upstream natural ventilation

Use Figures 2, 3, 4, and 5 for 36, 24, 12, and 8-inch diameter pipes, respectively, to estimate the natural ventilation, Q_{airup} (cfm) in the pipe discharging into the structure where out-gassing is expected. If the upstream pipe slope and diameter is not represented by one of the curves, interpolate between the two nearest curves.

FIGURE 2:
Air flow as a function of water flow in a 36 inch pipe

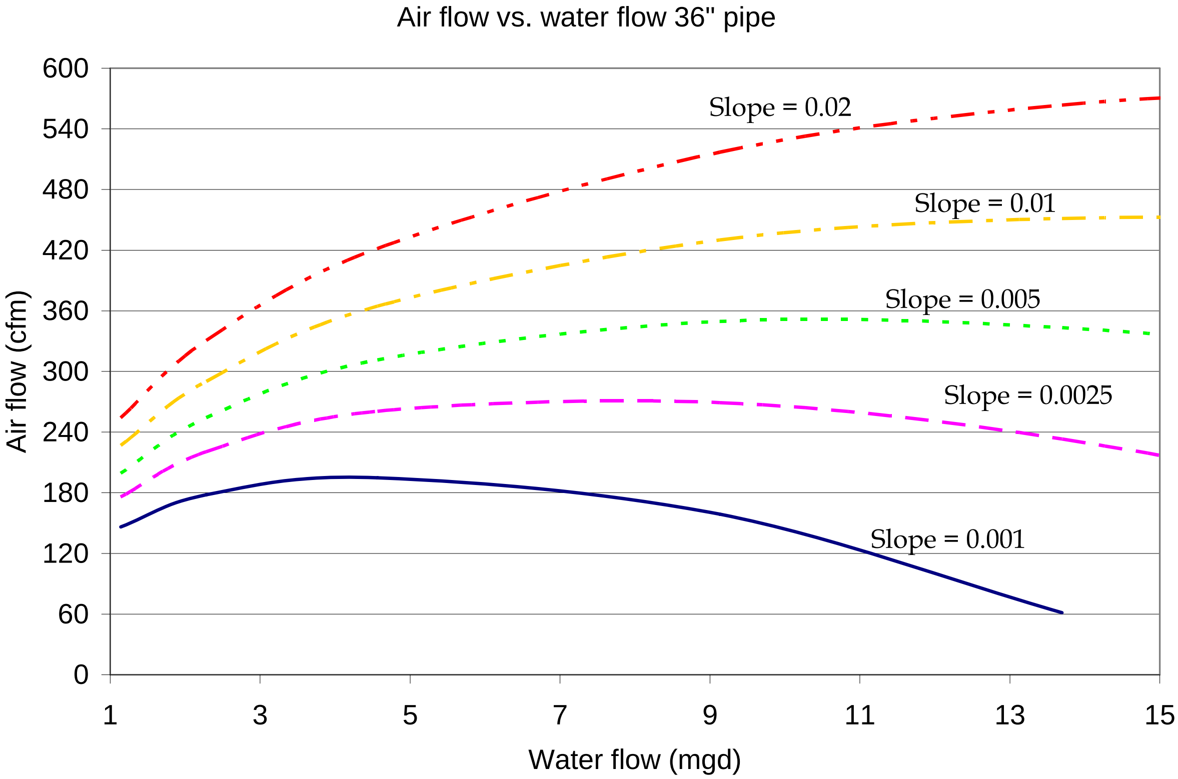


FIGURE 3:

Air flow as a function of water flow in a 24 inch pipe

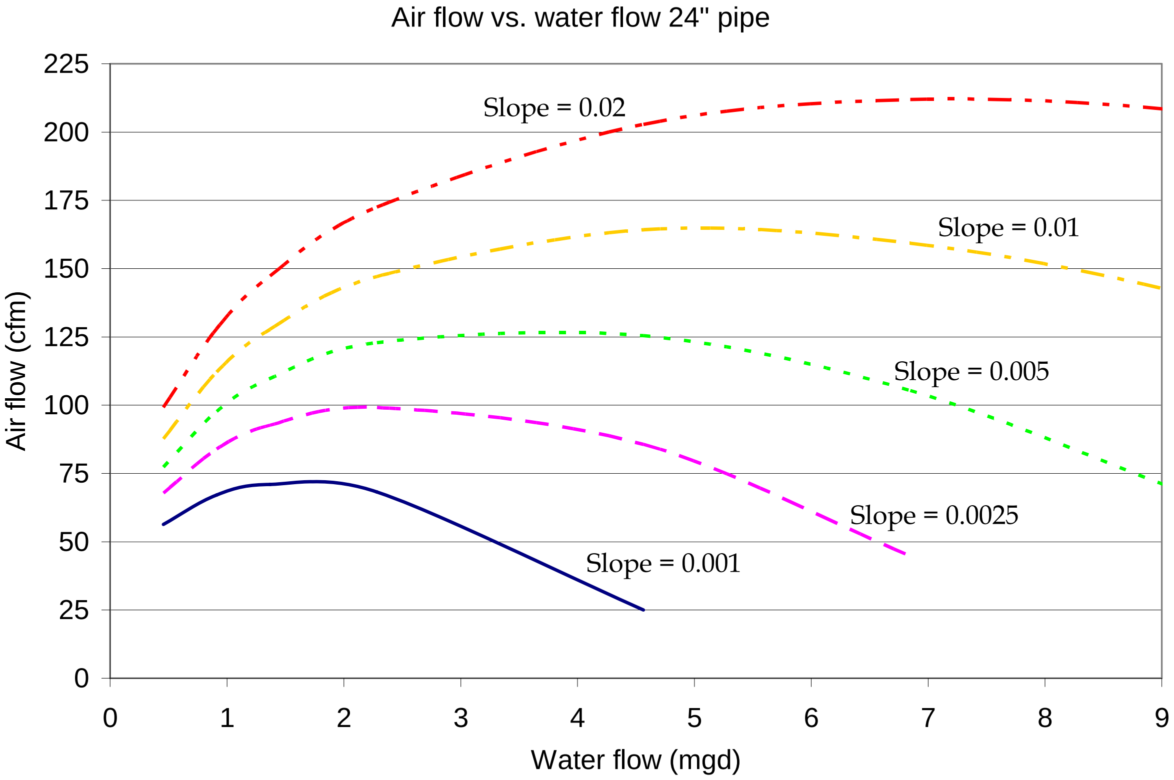


FIGURE 4:
Air flow as a function of water flow in a 12 inch pipe

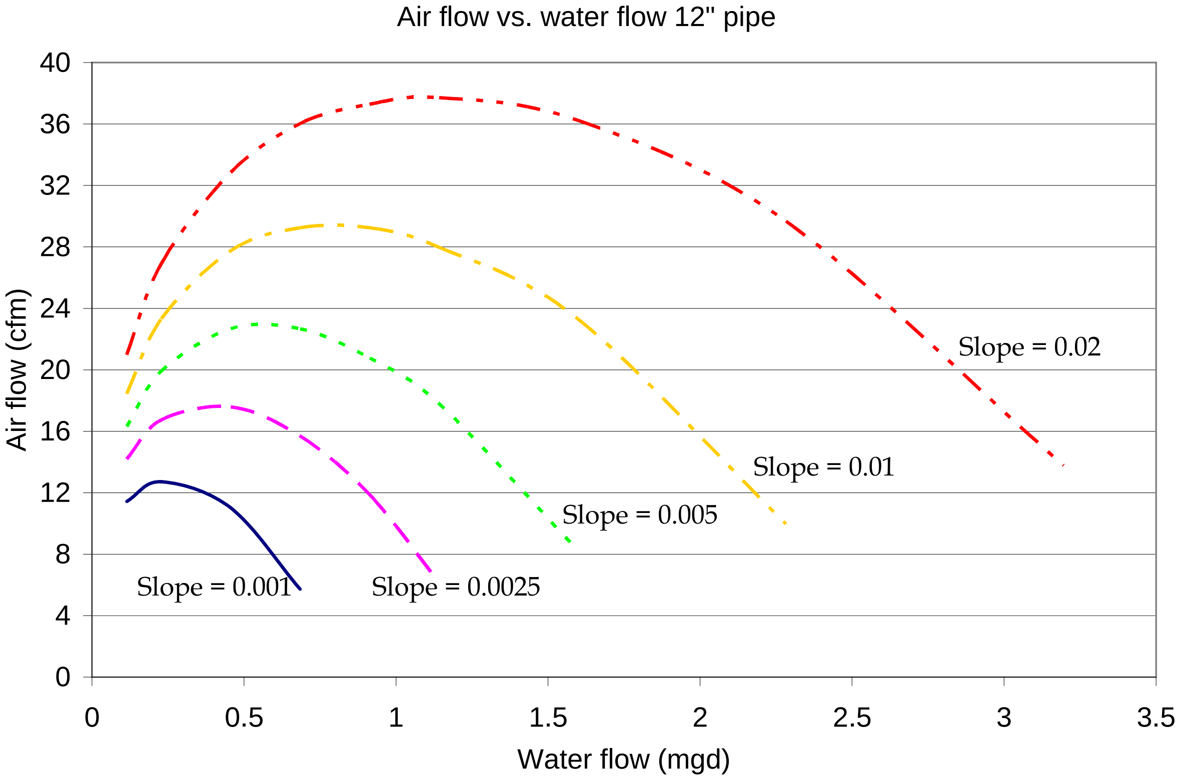
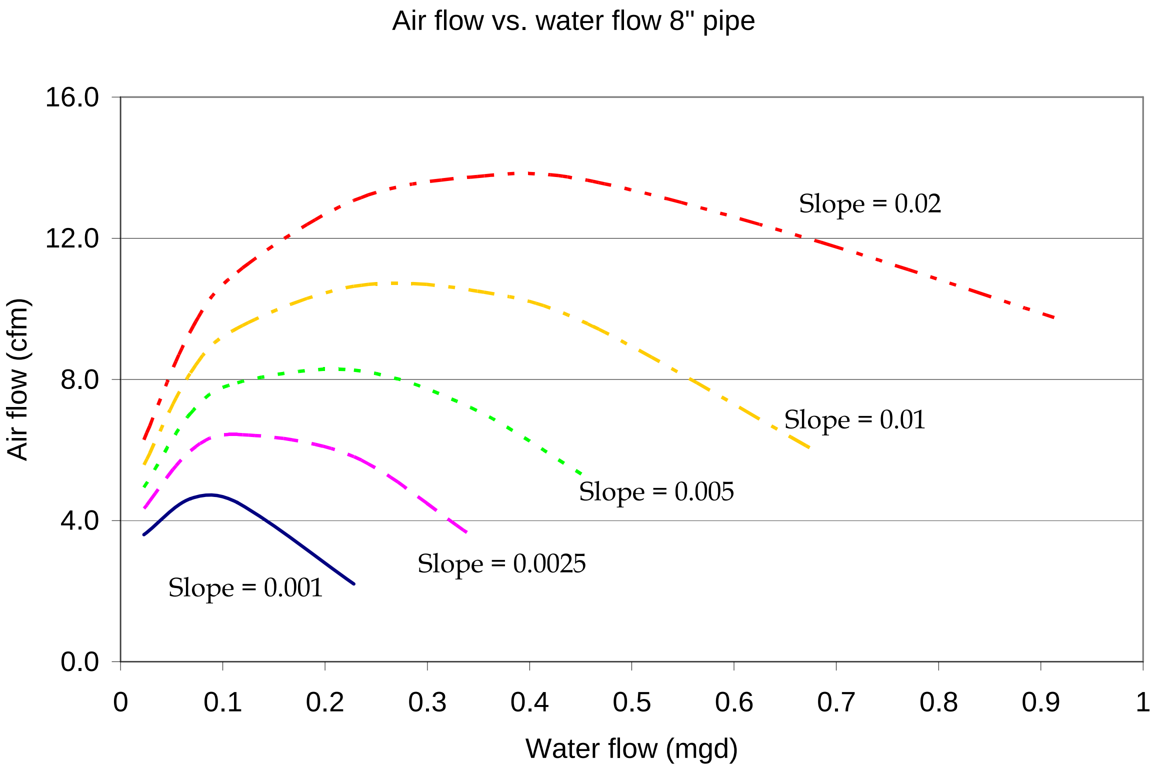


Figure 5:

Air flow as a function of water flow in an 8 inch pipe



Step 6: Downstream natural ventilation

Use the approach in step five to estimate the downstream natural ventilation, $Q_{airdown}$ (cfm). For a siphon or other complete bottleneck, downstream natural ventilation will have no bearing on out-gassing and is zero for this purpose.

Step 7: Out-gas flow rate

Calculate the out-gassing flow rate, Q_{outgas} (cfm), as shown Equation 5.

$$Q_{outgas} = Q_{airup} - Q_{airdown} \tag{5}$$

- Q_{outgas} = The flow rate of air exiting a sewer structure due to pressurization (cfm)
- Q_{airup} = Natural ventilation in the upstream pipe (cfm)
- $Q_{airdown}$ = Natural ventilation in the downstream pipe (cfm)

Step 8: Hydrogen sulfide emission

Calculate the hydrogen sulfide emission rate as shown in Equation 6.

$$E_{H2S} = Q_{outgas} \times \frac{m^3/s}{2119cfm} \times H_2S_{gas} \tag{6}$$

- E_{H2S} = Hydrogen sulfide emission from the bottleneck (g/s)

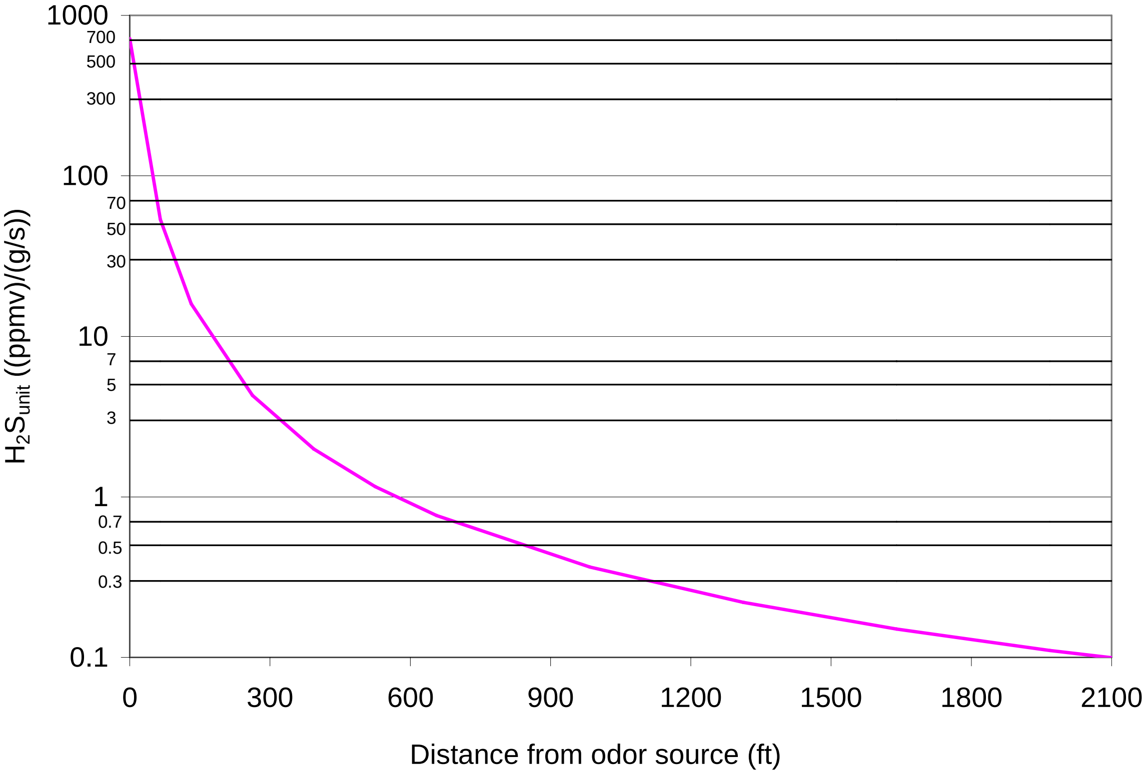
Estimate the Down-wind Odor Impact

EPA dispersion model Screen 3 was used to estimate down-wind hydrogen sulfide concentration per unit emission.

Step 9: Down-wind concentration per unit emission

Use Figure 6 to determine the worst-case H_2S_{unit} ((ppmv)/(g/s)) based on the distance from the out-gassing location to the nearest sensitive receptor, F (ft).

FIGURE 6
Worst-case hydrogen sulfide concentration per unit emission as a function of distance from the odor source.



Step 10: Down-wind worst-case concentration

Calculate down-wind worst-case H_2S concentration as shown in Equation 7.

$$H_2S_{receptor} = E_{H2S} \times H_2S_{unit} \tag{7}$$

- $H_2S_{receptor}$ = the worst-case projected hydrogen sulfide concentration at the receptor of concern due to the emission from the odor source, (ppmv)

Step 11: Offsite impact criteria

Compare $H_2S_{receptor}$ to the maximum acceptable off-site hydrogen sulfide concentration. If it is less, no treatment is needed. If it is more, go to step 12.

Determine the forced air flow rate needed for gas-phase treatment

Step 12: Air change criteria

Calculate the volumetric air flow rate, Q_{aer} (cfm), needed to provide 12 air changes per hour in the wet well or odor source structure as shown in Equation 8.

$$Q_{aer} = \frac{12}{hr} \times V \times \frac{hr}{60\,\text{min}} \tag{8}$$

- Q_{aer} = Structure ventilation rate needed to provide 12 air changes per hour (cfm)
- V = Volume of the wet well of odor source structure (ft^3)

Step 13: Forced air-flow rate selection

The wet well or odor source structure ventilation rate needed for gas-phase treatment is the greater of Q_{aer} and 2 x Q_{outgas}.

Example

Data Needs

Table 1 lists the data that will be needed for the calculations.

TABLE 1
Data needs

Data Needs	Symbol	value	Units
Average wastewater flow rate	Q	6.85	mgd
Wastewater pH	pH	7.1	-
Incoming sulfide concentration	S_{out}	3.0	mg/L
Wastewater temperature	T	24	ºC
Upstream pipe diameter	D_{up}	30	in
Upstream pipe slope	SL_{up}	0.005	ft/ft
Downstream pipe diameter	D_{down}	30	in
Downstream pipe slope	SL_{down}	0.003	ft/ft
Out-gassing structure volume	V	800	ft^3
Sensitive receptor distance from odor source	F	150	ft

Estimate H_2S_g Concentration

Step 1: Henry's law constant

Calculate Henry's law constant based on temperature as shown in Equation 1.

T = 24 °C

$$H = (0.0084 \times 24) + 0.2043 \;= 0.4059 \tag{1}$$

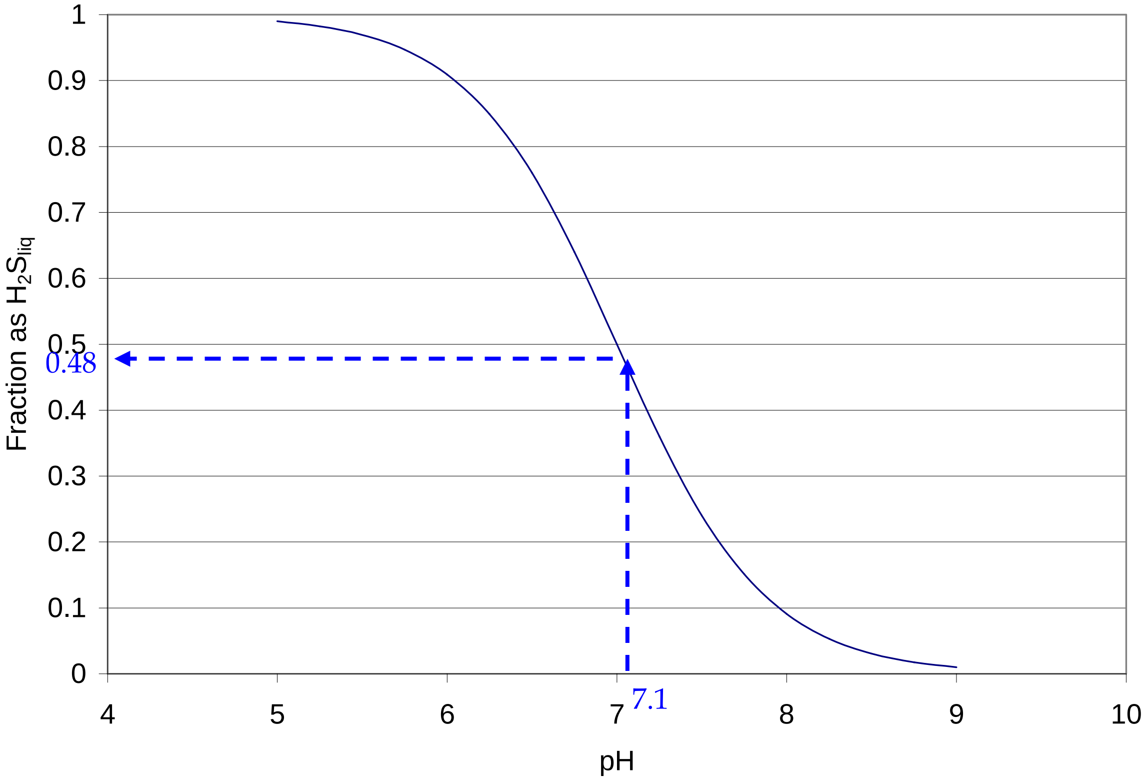
Step 2: Liquid H_2S concentration

Use Figure 1 to estimate the FractionH_2S_{liq} based on pH.

pH = 7.1

FIGURE 1

Fraction, based on pH, of incoming sulfide that is in the form of H_2S_{liq}



From Figure 1, H_2S_{liq} = 0.48

Calculate the equilibrium liquid H_2S concentration based on FractionH_2S_{liq} and the incoming sulfide concentration, S_{out} (mg/L), as shown in Equation 2.

H_2S_{liq} = 3.0 mg/L × 0.48 = 1.44 mg/L (2)

Step 3: H_2S gas concentration

Calculate equilibrium hydrogen sulfide gas concentration based on Henry's Law as shown in Equation 3.

H_2S_{gas} = 0.4059 × 1.44mg/L = 0.5845 mg/L (3)

Step 4: H_2S gas in ppmv

Convert H_2S_{gas} from units of mg/L to ppmv as shown in Equation 4.

H_2S_g = 0.5845mg/L × (24 + 273) × 2.41 = 418 ppmv (4)

Calculate Upstream and Downstream Natural Ventilation

Step 5: Upstream natural ventilation

Interpolate between Figures 2, and 3 for 30 inch diameter pipe to estimate the natural ventilation, Q_{airup} (cfm) in the pipe discharging into the structure where out-gassing is expected.

Q = 6.85 MGD

FIGURE 2:
Air flow as a function of water flow in a 36 inch pipe

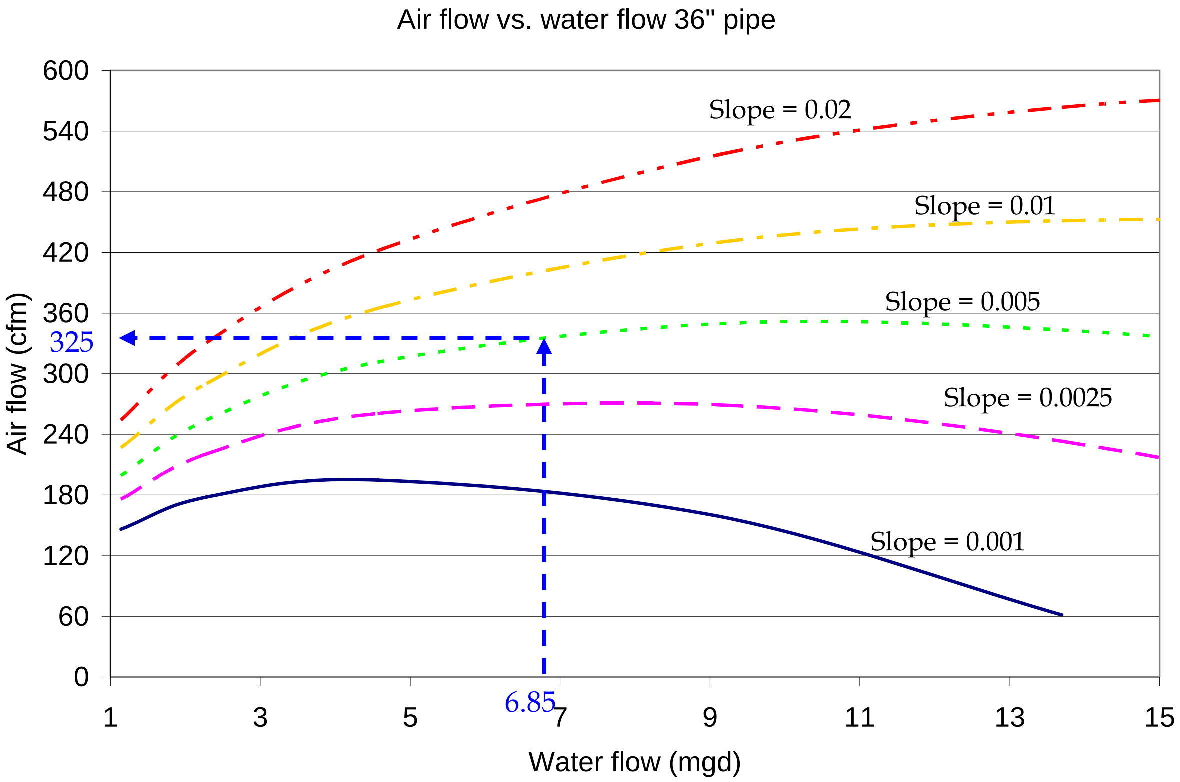
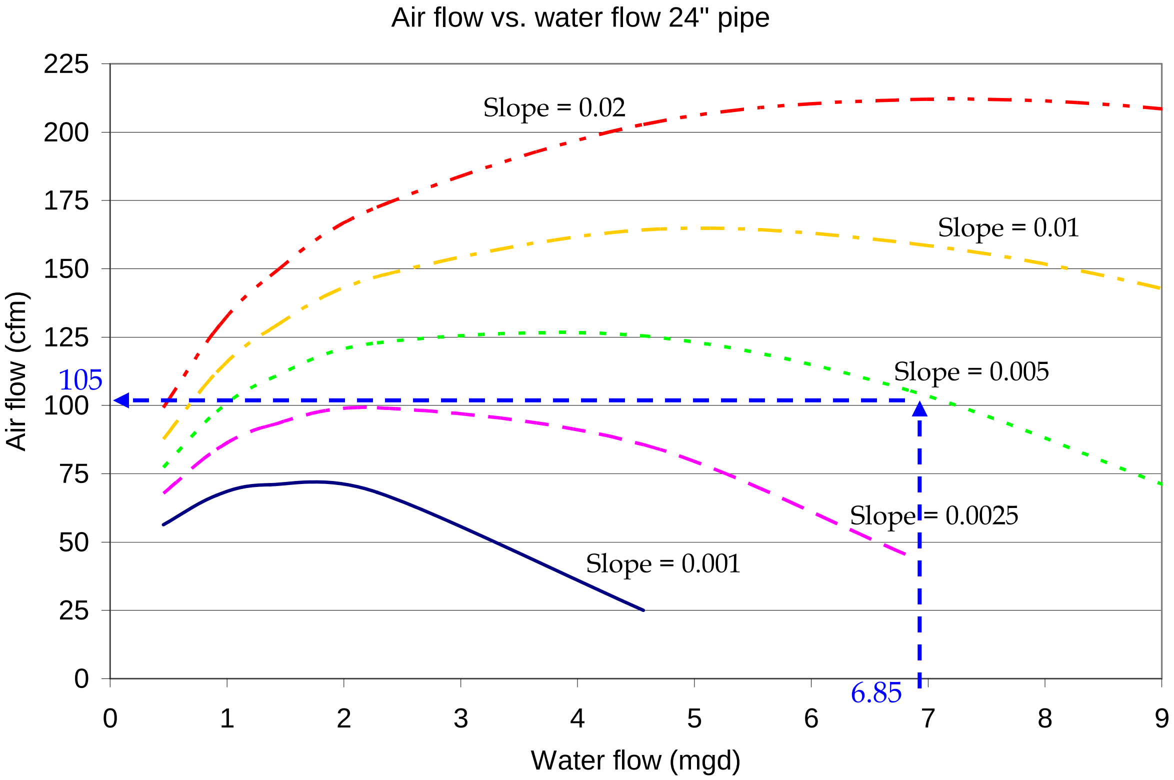


FIGURE 3:
Air flow as a function of water flow in a 24 inch pipe



$Q_{airup} = (325 + 105)/2 = 215$ cfm

Step 6: Downstream natural ventilation

Use the same approach as in Step 5 to estimate the downstream natural ventilation, $Q_{airdown}$ (cfm). Interpolate between Figures 2, and 3 for 30 inch diameter pipe to estimate the natural ventilation, $Q_{airdown}$ (cfm) in the pipe flowing out of the structure where out-gassing is expected. Interpolate between the 0.0025 slope curve and the 0.005 slope curve.

FIGURE 2:
Air flow as a function of water flow in a 36 inch pipe

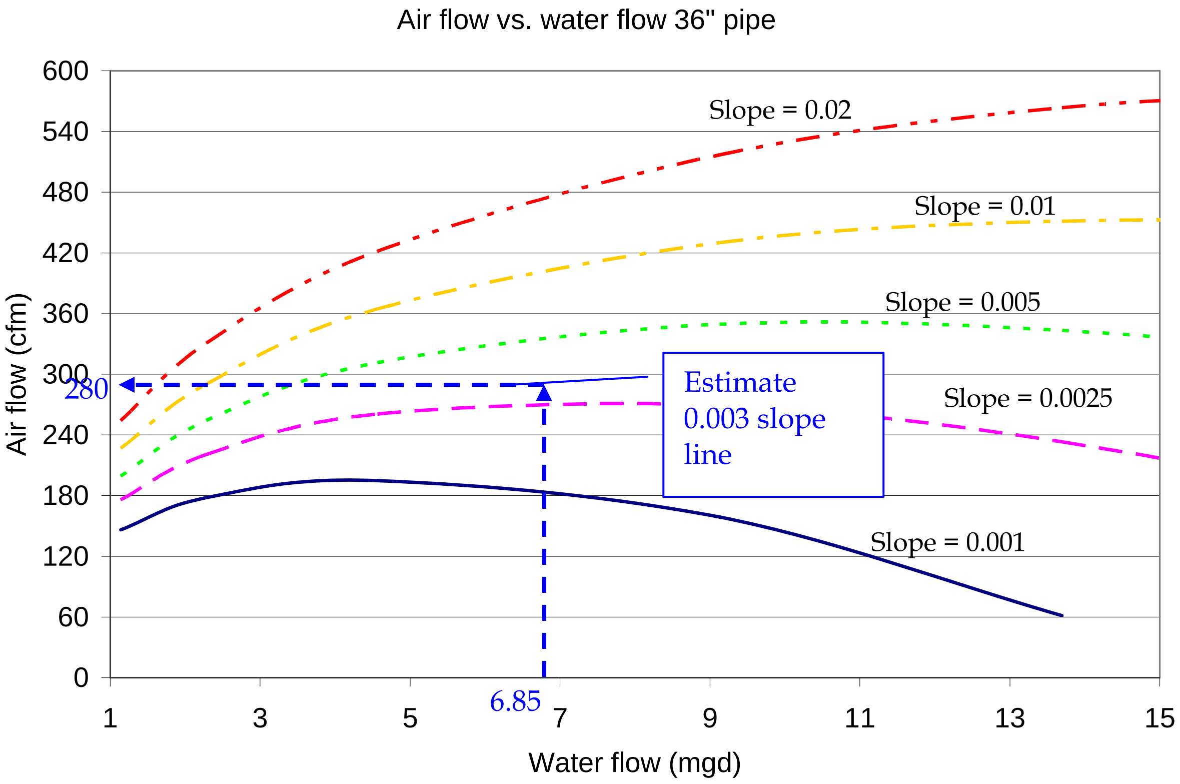
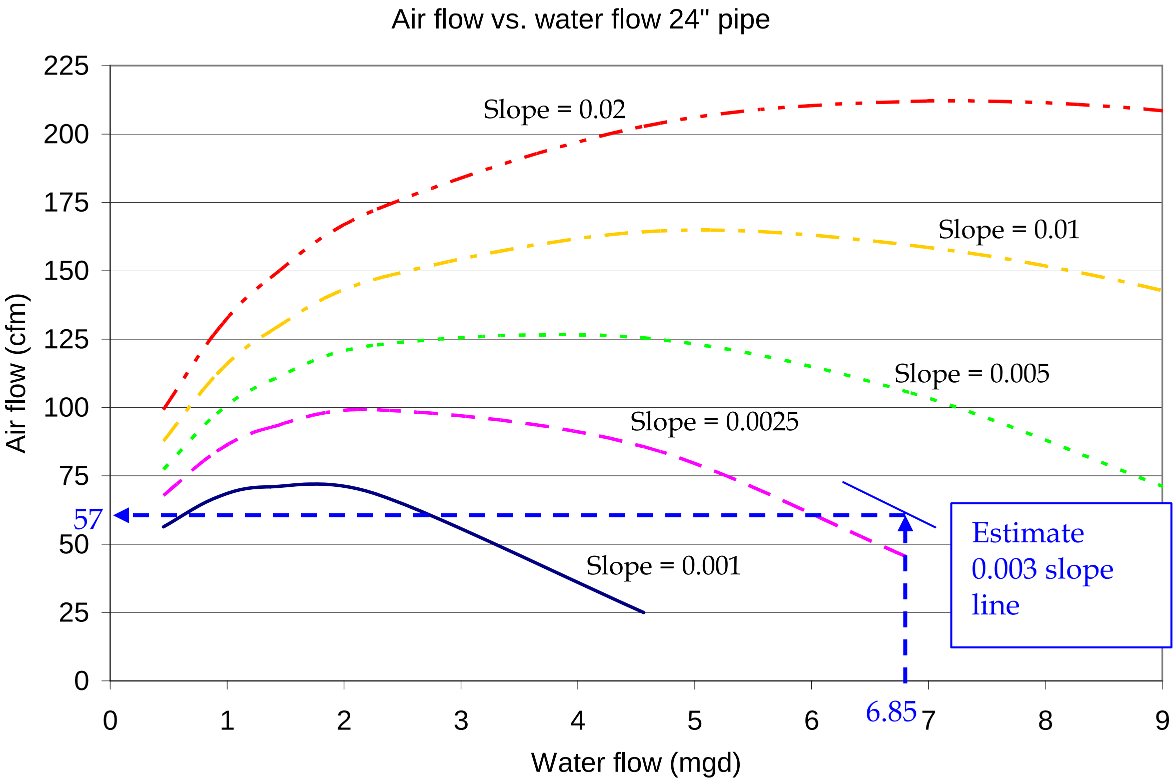


FIGURE 3:
Air flow as a function of water flow in a 24 inch pipe



$Q_{airdown}$ = (280 + 57)/2 = 169 cfm

Step 7: Out-gas flow rate

Calculate the out-gassing flow rate, Q_{outgas} (cfm), as shown Equation 5.

$$Q_{outgas} = 215 - 169 = 46\ \text{cfm} \tag{5}$$

Step 8: Hydrogen sulfide emission

Calculate the hydrogen sulfide emission rate as shown in Equation 6.

$$E_{H2S} = 46cfm \times \frac{m^3/s}{2119cfm} \times 0.5845mg/L = 0.013\ \text{g/s} \tag{6}$$

Estimate the Down-wind Odor Impact

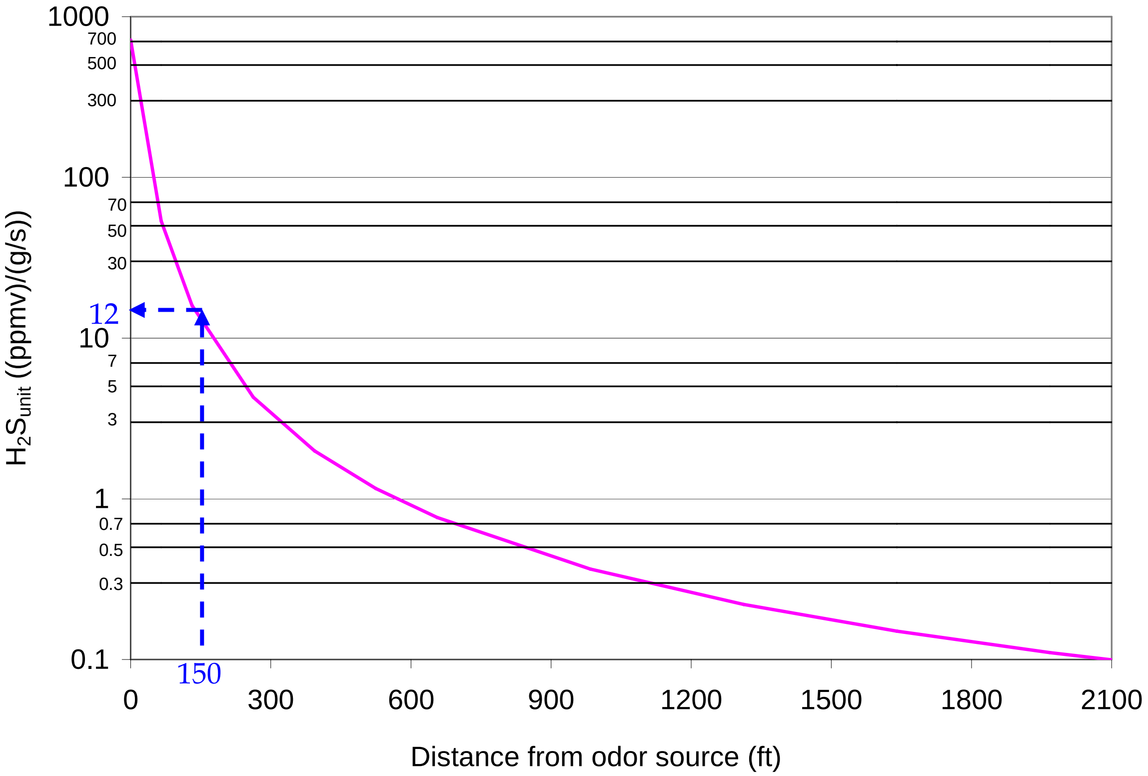
Step 9: Down-wind concentration per unit emission

Use Figure 6 to determine the worst-case H_2S_{unit} ((ppmv)/(g/s)) based on the distance from the out-gassing location to the nearest sensitive receptor, F (ft).

F = 150 ft

FIGURE 6

Worst-case hydrogen sulfide concentration per unit emission as a function of distance from the odor source.



From Figure 6, H_2S_{unit} = 12 (ppmv)/(g/s)

Step 10: Down-wind worst-case concentration

Calculate down-wind worst-case H_2S concentration as shown in Equation 7.

$$H_2S_{receptor} = 0.013 g/s \times 12 \frac{ppmv}{g/s} = 0.16 \text{ ppmv} \tag{7}$$

Step 11: Offsite impact criteria

Compare $H_2S_{receptor}$ to the maximum acceptable off-site hydrogen sulfide concentration. If it is less, no treatment is needed. If it is more, go to step 12.

0.16 ppmv is approximately 200 times the human detection threshold. Therefore, treatment may be needed.

Determine the forced air flow rate needed for gas-phase treatment

Step 12: Air change criteria

Calculate the volumetric air flow rate, Q_{aer} (cfm), needed to provide 12 air changes per hour in the wet well or odor source structure as shown in Equation 8.

$$Q_{aer} = \frac{12}{hr} \times 800\, ft^3 \times \frac{hr}{60 \min} = 160 \text{ cfm} \tag{8}$$

Step 13: Forced air-flow rate selection

The wet well or odor source structure ventilation rate needed for vapor-phase treatment is the greater of Q_{aer} and Q_{outgas}

2 x $Q_{outgass}$ = 2 x 46 cfm = 92 cfm < Q_{aer} = 160 cfm. Therefore, 160 cfm or greater would need to be treated.

Odor Impact Potential and Preliminary Vapor Phase Treatment Assessment

Project Name:____

Project Location:____

Data Needs	#	Formula	Value	units
Average wastewater flow rate (Q)	1	Given in Table 1		mgd
Wastewater pH (pH)	2	Given in Table 1		-
Incoming sulfide concentration (S_{out})	3	Given in Table 1		mg/L
Wastewater temperature (T)	4	Given in Table 1		ºC
Upstream pipe diameter (D_{up})	5	Given in Table 1		in
Upstream pipe slope (SL_{up})	6	Given in Table 1		ft/ft
Downstream pipe diameter (D_{down})	7	Given in Table 1		in
Downstream pipe slope (SL_{down})	8	Given in Table 1		ft/ft
Out-gassing structure volume (V)	9	Given in Table 1		ft^3
Sensitive receptor distance from odor source (F)	10	Given in Table 1		ft
Henry's Law constant (H)	11	$= 0.0084 \times \#4 + 0.2043 =$		-
Fraction of dissolved sulfide as H_2S_{liq} (FractionH_2S_{liq})	12	Use #2 and read from Figure 1		-
Liquid-phase H2S concentration (H_2S_{liq})	13	$= \#3 \times \#12 =$		mg/L
Equilibrium vapor-phase H2S concentration (H_2S_{gas})	14	$= \#11 \times \#13 =$		mg/L
Equilibrium vapor-phase H2S concentration (H_2S_g)	15	$= \#14 \times (\#4 + 273) \times 2.41 =$		ppmv

Calculation Form Con’t

Upstream natural Ventilation (Q_{airup})	16	Use #1, #5, and #6, and read value from Figures 2, 3 or 4. Interpolate, if necessary.		cfm
Downstream natural Ventilation ($Q_{airdown}$)	17	Use #1, #7, and #8, and read value from Figures 2, 3, 4, or 5. Interpolate, if necessary.		cfm
Out-gas flow rate (Q_{outgas})	18	$= \#16 - \#17 \; =$		cfm
Hydrogen sulfide emission rate (E_{H2S})	19	$= \#18 \times \frac{m^3 / s}{2119 \; cfm} \times \#14 \; =$		g/s
Worst case H2S concentration per unit emission at receptor ($H_2S_{uni}t$)	20	Use #10 to read value from Figure 6		ppmv/(g /s)
Worst case H2S concentration at receptor ($H_2S_{receptor}$)	21	$= \#19 \times \# 20 \; =$		ppmv
Is #21 acceptable?	If yes, then no treatment is necessary – Stop here			
	If no, then treatment is necessary - Continue			
Volumetric air flow rate required to ventilate structure with 12 air changes per hour (Q_{aer})	22	$= \frac{12}{hr} \times \#9 \times \frac{hr}{60 \; \min} =$		cfm
The required foul air treatment flow rate will be #22 or two times #18, which ever is larger.				

Sulfide Generation and Liquid-phase Control

Objective

These guidelines are intended to provide a step-by-step method for estimating sulfide generation in force mains and siphons, liquid-phase chemical dose requirements, oxygen injection, and costs for controlling sulfide. The calculations shall be followed to establish the maximum sulfide generation and to determine if treatment of sulfide is necessary, as well as determine the approximate cost of treatment. Once the calculations are complete, they shall be submitted to the City of San Marcos Engineering Director for review.

Overview

The steps presented herein provide a screening approach to estimate sulfide generation in force mains and siphons, approximate chemical dosing required to control sulfide, oxygen injection required to control sulfide, and associated planning level costs. Step-by-step instructions are provided followed by an example illustrating the process. A form is provided to guide calculations.

Data Needs

Table 1 lists the data that will be needed for the calculations.

TABLE 1
Data needs

Data Needs	Symbol	value	Units
Summer wastewater temperature	T_{sum}		ºC
Winter wastewater temperature	T_{win}		ºC
Five-day biochemical chemical oxygen demand	BOD_5		mg/L
Average wastewater flow rate	Q		mgd
Pipe diameter	D		in
Pipe length	L		ft
Dissolved sulfide at the upstream end of the pipe	S_{in}		mg/L
Threshold sulfide concentration	S_{Thresh}		mg/L

Calculate Sulfide Generation

Step 1: Force main/Siphon retention time

Calculate retention time, R (min), according to Equation 1.

$$R = \frac{L}{Q} \times \frac{\pi D^2}{4} \times \frac{7.48 \times 10^{-5}\, mgal \cdot \min}{in^2 \cdot ft \cdot day} \qquad (1)$$

- R = Pipe retention time (min)
- L = Pipe length (ft)

- Q = average wastewater flow rate (mgd)
- D = Pipe diameter (in)

Step 2: Effective BOD

Calculate the temperature adjusted effective biochemical oxygen demand, BOD_{eff} (mg/L), as shown in Equation 2. Calculate BOD_{eff} for summer and winter wastewater temperatures.

$$BOD_{eff} = BOD_5 \times 1.07^{(T-20^o C)} \qquad (2)$$

- BOD_{eff} = BOD adjusted for temperature (mg/L)
- BOD_5 = Five day BOD at 20 °C (mg/L)
- T = Wastewater temperature (°C)

Step 3: Downstream sulfide concentration

Calculate liquid sulfide at the downstream end of the pipe for summer and winter BOD_{eff} as shown in Equation 3. This calculation conservatively assumes zero initial upstream dissolved oxygen (DO_{in}).

$$S_{out} = \left[\frac{100in + D}{100{,}000D \cdot \min} \right] \times BOD_{eff} \times R + S_{in} \qquad (3)$$

- S_{out} = Sulfide concentration at the downstream end of the pipe (mg/L)
- S_{in} = Sulfide measured entering the pipe (mg/L)

Step 4: Threshold comparison

If S_{out} is less than the target threshold concentration, S_{thresh} (mg/L) for summer conditions, then no chemicals are needed to control sulfide. Two typical target threshold concentrations are 0.5 and 1 mg/L. The lower the value, the lower the risk of having odor complaints. However, as the threshold value is decreased, annual operating costs associated with chemical consumption increase.

Step 5: Chemical selection

If S_{out} is greater than S_{thresh}, select a chemical and dose from Table 2.

TABLE 2

Liquid phase chemical dose and cost for controlling sulfide

Chemical	Dose[1] (gal / lb sulfide)	Cost[2] ($/gal)
Hydrogen Peroxide (50% solution)	0.6	3.4
Iron Salts (30% $FeCl_2$ solution)	2.7	0.7
Bioxide	1.3	2
Pure Oxygen (supplied to tank)	N/A	From Vendor

1. Doses shown are typical for municipal wastewater. Actual doses could be larger or smaller than the values shown.

TABLE 2

Liquid phase chemical dose and cost for controlling sulfide

Chemical	**Dose[1] (gal / lb sulfide)**	**Cost[2] ($/gal)**
Hydrogen Peroxide (50% solution)	0.6	3.4
Iron Salts (30% $FeCl_2$ solution)	2.7	0.7

2. Costs shown in Table 2 are provided for screening purposes. Actual current costs and availability should be verified with vendors.

Calculate Chemical Cost

Step 6: Daily sulfide load

Calculate the daily sulfide load (lb sulfide/day) for summer and winter S_{out} as shown in Equation 4.

$$Load = Q \times S_{out} \times \frac{8.35 L \cdot lb}{mgal \cdot mg} \tag{4}$$

- Load = Daily sulfide load exiting the pipe (lb/day)

Q = Average wastewater flow rate (mgd)

Step 7: Yearly chemical cost

Use the dose and cost of the selected chemical to calculate chemical cost per year by using the average of the summer and winter sulfide loads as shown in Equation 5. This step conservatively assumes that the entire load will be treated to a target of zero sulfide rather than the threshold target.

$$ChemicalCost / year = \frac{Load_{winter} + Load_{summer}}{2} \times \frac{365 days}{yr} \times Dose \times Cost \tag{5}$$

Calculate the oxygen needed to control sulfide

Sulfide can be prevented from forming in a siphon or forcemain by injecting air or oxygen at the upstream end of the force main. The DO_{in} needed to keep the entire force main aerobic will depend on R and BOD_{eff}. An oxygen concentration of 1.0 mg/L or greater is sufficient to prevent sulfide generation.

Step 8: Upstream oxygen concentration needed

Use Equation 6 to calculate DO_{in} needed to maintain a DO greater than 1.0 mg/L at the downstream end of the pipe. Use BOD_{eff} for the summer temperature.

$$DO_{in}^{needed} = \frac{2.8 mg / L}{hr} \times \frac{BOD_{eff}}{200 mg / L} \times R \times \frac{hr}{60 \min} + \frac{1.0 mg}{L} \tag{6}$$

DO_{in}^{needed} = Dissolved oxygen concentration needed in the upstream end to maintain aerobic conditions throughout the pipe (mg/L)

Step 9: Oxygen injection rate

Calculate the oxygen injection rate, G (g/min) needed to provide the DO_{in}^{needed} as shown in Equation 7.

$$G = \frac{Q \times DO_{in}^{needed}}{\eta_{diff}} \times \frac{2.63 L \cdot day \cdot g}{mg \cdot mgal \cdot \min} \tag{7}$$

- G = the pure oxygen injection rate (g/min)
- η_{diff} = Diffuser efficiency (gas dissolved/gas injected)

Use a default value of 0.8 for η_{diff} until information on the diffuser equipment is available.

Step 10: Yearly oxygen cost

Calculate yearly oxygen cost as shown in Equation 8.

$$OxygenCost / year = G \times \frac{526 kg \cdot \min}{g \cdot yr} \times Cost_{O_2} \tag{8}$$

- $Cost_{O2}$ = Delivered oxygen unit cost ($/kg)

Compare Options

Compare costs for O_2 injection and chemical treatment to estimate the lowest cost option.

Example

Data Needs

TABLE 1
Data needs

Data Needs	Symbol	Value	Units
Summer wastewater temperature	T_{sum}	27	ºC
Winter wastewater temperature	T_{win}	18	ºC
Five-day biochemical chemical oxygen demand	BOD_5	260	mg/L
Average wastewater flow rate	Q	0.144	mgd
Pipe diameter	D	12	in
Pipe length	L	2000	ft
Dissolved sulfide at the upstream end of the pipe	S_{in}	0.6	mg/L
Threshold sulfide concentration	S_{Thresh}	1.0	mg/L

Calculate Sulfide Generation

Step 1: Force main/Siphon retention time

L = 2,000 ft

Q = 0.144 mgd

D = 12 in

$$R = \frac{2{,}000}{0.144} \times \frac{\pi(12)^2}{4} \times \frac{7.48 \times 10^{-5}\, mgal \cdot \min}{in^2 \cdot ft \cdot day} = 118 \min$$

Step 2: Effective BOD

T_{sum} = 27 ºC

T_{win} = 18 ºC

$$SummerBOD_{eff} = 260 mg/L \times 1.07^{(27-20^o C)} = 418 mg/L$$

$$W\,\text{int}\,erBOD_{eff} = 260 mg/L \times 1.07^{(18-20^o C)} = 227 mg/L$$

Step 3: Downstream sulfide concentration

Summer BOD_{eff} = 418 mg/L

Winter BOD_{eff} = 227 mg/L

S_{in} = 0.6 mg/L

R = 117.5 mg/L

D = 12 in

$$SummerS_{out} = \left[\frac{100in + 12in}{100{,}000 \times 12in \cdot \min}\right] \times 418mg / L \times 117.5\min + 0.6mg / L = 5.2mg / L$$

$$W\,\mathrm{int}\,erS_{out} = \left[\frac{100in + 12in}{100{,}000 \times 12in \cdot \min}\right] \times 227mg / L \times 117.5\min + 0.6mg / L = 3.1mg / L$$

Step 4: Threshold comparison

Summer S_{out} = 5.2 mg/L > 1.0 mg/L = S_{thresh}. Therefore treatment needed.

Step 5: Chemical selection

Try iron salts

TABLE 2
Liquid phase chemical dose and cost for controlling sulfide

Chemical	Dose (gal / lb sulfide)	Cost ($/gal)
Hydrogen Peroxide (50% solution)	0.6	3.4
Iron Salts (30% $FeCl_2$ solution)	2.7	0.7
Sodium Hypochlorite (12% solution)	10	1.0
Bioxide	1.3	2
Pure Oxygen (supplied to tank)	N/A	From Vendor

Calculate Chemical Cost

Step 6: Daily sulfide load

Q = 0.144 mgd

Summer S_{out} = 5.2 mg/L

Winter S_{out} = 3.1 mg/L

$$Load = 0.144mgd \times 5.2mg / L \times \frac{8.35L \cdot lb}{mgal \cdot mg} = 6.25lb / day$$

$$Load = 0.144mgd \times 3.1mg / L \times \frac{8.35L \cdot lb}{mgal \cdot mg} = 3.73lb / day$$

Step 7: Yearly chemical cost

Dose = 2.7 gal/lb

Cost = $0.7/gal

Summer Load = 6.25 lb/day

Winter Load = 3.73 lb/day

$$ChemicalCost/year = \frac{(6.25+3.73)lb/day}{2} \times \frac{365days}{yr} \times \frac{2.7gal}{lb} \times \frac{\$0.7}{gal} = \$3442/yr$$

Calculate the oxygen needed to control sulfide

Step 8: Upstream oxygen concentration needed

Summer BOD_{eff} = 418 mg/L

R = 117.5 min

$$DO_{in}^{needed} = \frac{2.8mg/L}{hr} \times \frac{418mg/L}{200mg/L} \times 117.5\min \times \frac{hr}{60\min} + \frac{1.0mg}{L} = 12.5mg/L$$

Step 9: Oxygen injection rate

DO_{in}^{needed} = 12.5 mg/L

Q = 0.144 mgd

η_{diff} = 0.8

$$G = \frac{0.144 \times 12.5mg/L}{0.8} \times \frac{2.63L \cdot day \cdot g}{mg \cdot mgal \cdot \min} = 5.92g/\min$$

Step 10: Yearly oxygen cost

Oxygen cost = $1.00/kg (this is a guess)

G = 5.92 g/min

$$OxygenCost/year = 5.92g/\min \times \frac{526kg \cdot \min}{g \cdot yr} \times \$1.00/kg = \$3114/yr$$

Compare Options

$3,114 < $3,442. Therefore oxygen may be less expensive depending on capital costs.

Liquid Phase Sulfide Generation Potential and Preliminary Control Assessment

Project Name:____

Project Location:____

Data Needs	#	Formula	Value	Units
Summer wastewater temperature (T_{sum})	1	Data provided		ºC
Winter wastewater temperature (T_{win})	2	Data provided		ºC
Five-day biochemical chemical oxygen demand (BOD_5)	3	Data Provided		mg/L
Average wastewater flow rate (Q)	4	Data Provided		mgd
Pipe diameter (D)	5	Data Provided		in
Pipe length (L)	6	Data Provided		ft
Dissolved sulfide at the upstream end of the pipe (S_{in})	7	Data Provided		mg/L
Threshold sulfide concentration (S_{Thresh})	8	As Provided by COSM		mg/L
Pipe Retention Time (R)	9	$= \frac{\#6}{\#4} \times \frac{\pi(\#5)^2}{4} \times \frac{7.48 \times 10^{-5}\ mgal \cdot \min}{in^2 \cdot ft \cdot day} =$		min
Temperature adjusted Summer BOD (Summer BOD_{eff})	10	$= \#3 \times 1.07^{(\#1 - 20^{o}C)} =$		mg/L
Temperature adjusted Winter BOD (Winter BOD_{eff})	11	$= \#3 \times 1.07^{(\#2 - 20^{o}C)} =$		mg/L
Summer sulfide concentration exiting the downstream end of the pipe (Summer S_{out})	12	$S = \left[\frac{100\ in + \#5}{100,000 \times \#5 \cdot \min}\right] \times \#10 \times \#9 + \#7$		mg/L
Winter sulfide concentration exiting the downstream end of the pipe (Winter S_{out})	13	$= \left[\frac{100\ in + \#5}{100,000 \times \#5 \cdot \min}\right] \times \#11 \times \#9 + \#7 =$		mg/L
Summer sulfide load exiting the downstream end of the pipe (Summer Load)	14	$= \#4 \times \#12 \times \frac{8.35\ L \cdot lb}{mgal \cdot mg} =$		lb/day

Data Needs	#	Formula	Value	Units
Winter sulfide load exiting the downstream end of the pipe (Winter Load)	15	$= \#4 \times \#13 \times \frac{8.35\ L \cdot lb}{mgal \cdot mg} =$		lb/day
Is Summer #12 > #8?	If no, then no treatment is necessary – Stop here			
	If yes, then treatment is necessary - Continue			
Select a chemical from Table 2	Peroxide, Iron, Sodium Hypochlorite, or Bioxide			
Chemical Dose	16	From Table 2 or Vendor		gal / lb sulfide
Chemical Cost	17	From Table 2 or Vendor		$/gal
Chemical Cost per year to control sulfide (Chemical Cost/yr)	18	$= \frac{\#15+\#14}{2} \times \frac{365\,days}{yr} \times \#16 \times \#17 =$		$/yr
Dissolved oxygen concentration needed at upstream end of pipe to control sulfide (DO_{in}^{needed})	19	$= \frac{2.8 mg/L}{hr} \times \frac{\#10}{200 mg/L} \times R \times \frac{hr}{60 \min} + \frac{1.0 mg}{L} =$		mg/L
Pure oxygen injection rate needed to provide assuming 0.8 diffuser efficiency (G)	20	$= \frac{\#4 \times \#19}{0.8} \times \frac{2.63\ L \cdot day \cdot g}{mg \cdot mgal \cdot \min} =$		g/min
Oxygen cost ($Cost_{O2}$)	21	Obtain price from Vendor		$/kg
Yearly cost to provide pure oxygen (O_2 Cost/yr)	22	$= \#20 \times \frac{526\ kg \cdot \min}{g \cdot yr} \times \#21 =$		$/yr
Compare #22 to #18				