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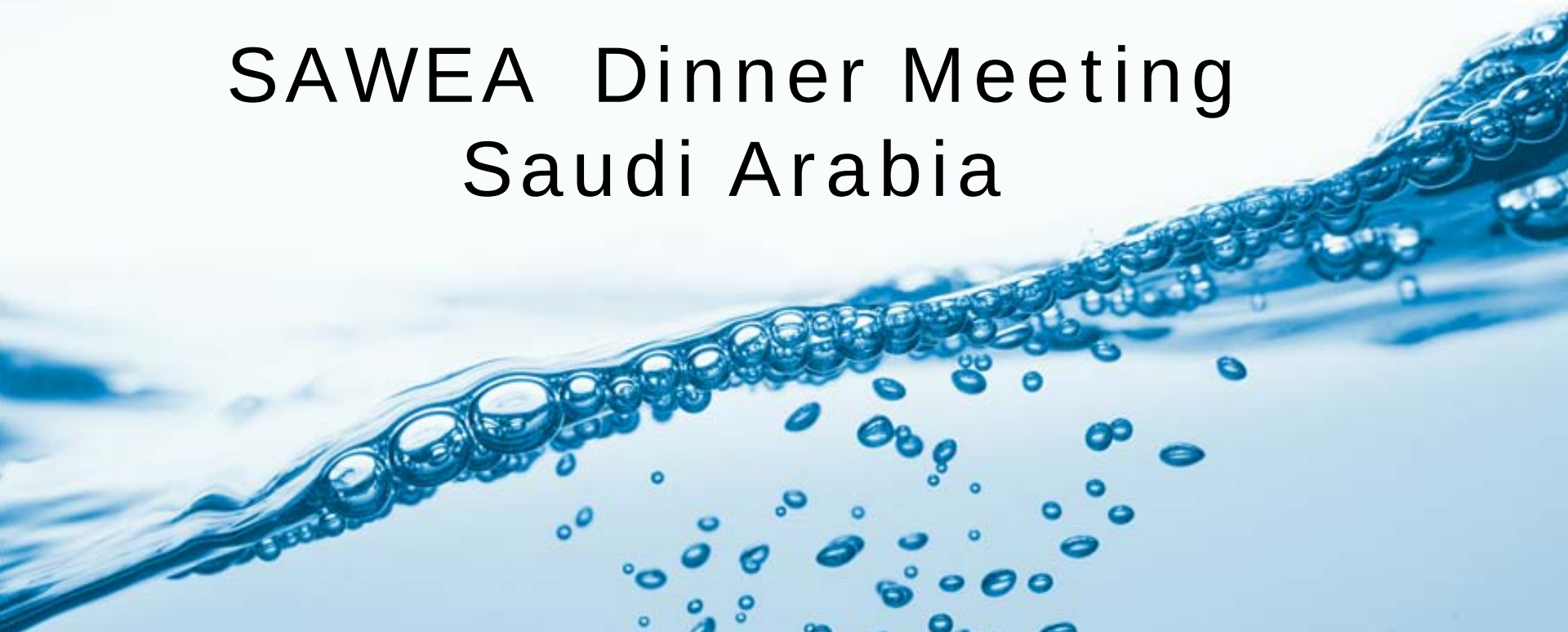
Odor Control Products

SAWEA Dinner Meeting
Saudi Arabia



RJE ODOR CONTROL PRODUCTS

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Why Have Odor Control?

- 20 years ago there was little talk of odor control. WWTP's were located out of town (away from receptors), and consequently odor was not a problem.

- Today odor control is generally considered an essential process in sewage treatment plant design, and in many other industries.

Why? Because:

1) Odor is a nuisance (complaints)
2) In some cases odors may be a health hazard (risk to employees)
3) Odorous compounds can cause corrosion (damage to equipment)

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Nuisance vs. Hazardous Odors

- Typically odors are a nuisance (smell bad) but the chemical compounds are present at concentrations well below hazardous levels

- But not always. H2S can exist in sewers well above the IDLH value of 100 ppm.

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Hydrogen Sulfide

SULFIDE (ppm)	PHYSICAL EFFECT	WARNING
0 I 0.1	Odor threshold	
I 10	Offensive odor	Gas monitor alarm should be at 10 ppm
I 50	Headaches, nausea, throat and eye irritation	
I 100	Eye injury	
I 300	Attack of eye, mucous membranes, and respiratory tract with possible life threat	Loss of sense of smell
I 1,000	Imminent life threat or death	

Most sewage odors are nuisance before they are hazardous

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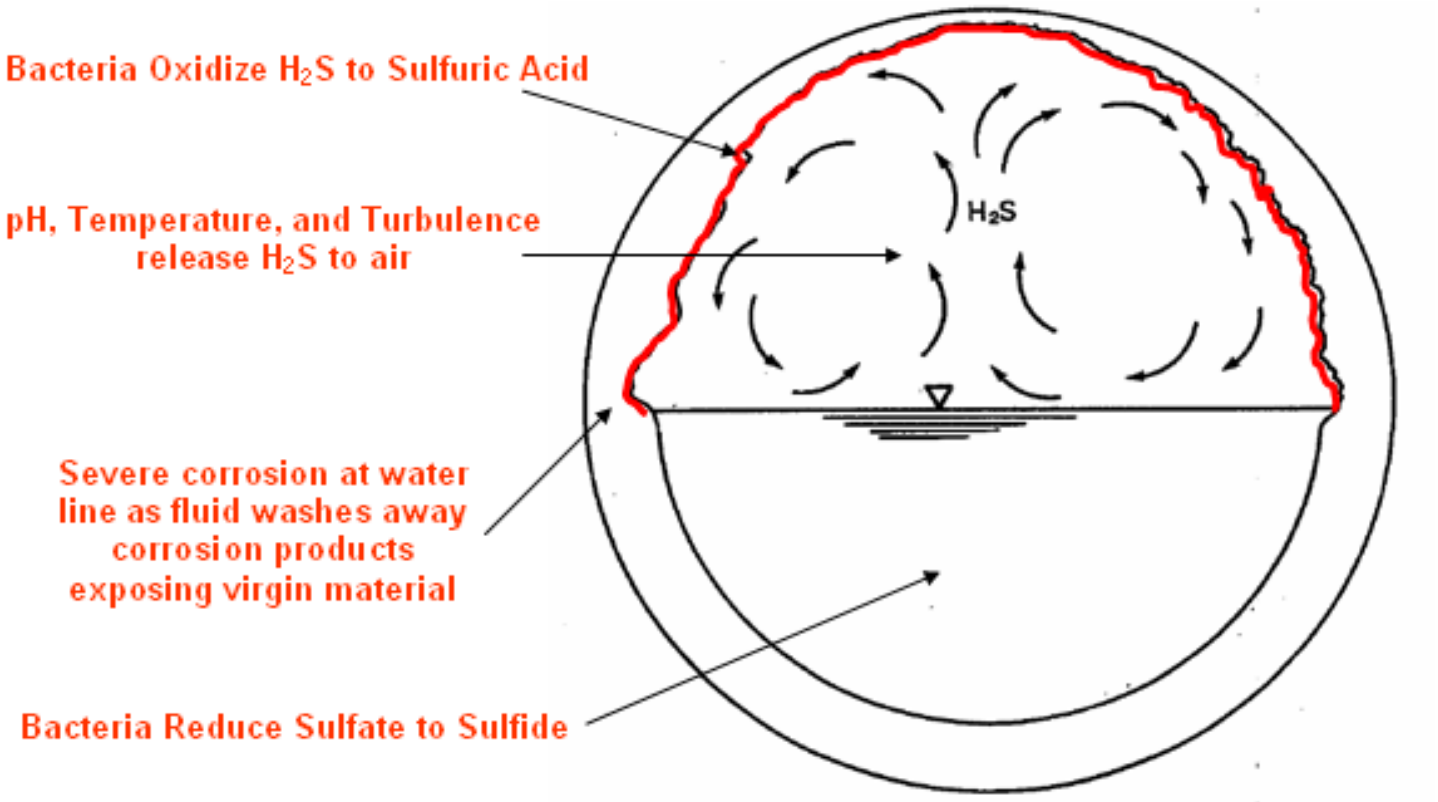
Compound	Typical Concentration in Sewage Treatment, ppm	Odour Threshold, ppm (smells bad)	OSHA PEL/IDLH, ppm (health hazard)	LEL, ppm (explosive)
Hydrogen Sulphide	0.1 to >500	0.001	20/100	40,000
Ammonia	0 to 200	17	50/300	15,000
Methyl Mercaptan	0.01 to 2	0.001	10/150	39,000
Carbon Disulphide	0.01 to 10	0.03	20/500	13,000

Schematic of Corrosion in Wastewater Line



Hydrogen Sulfide and Corrosion

Conditions Promoting Sulphide Generation

Level of B.O.D.

- High levels increase sulphide production and generate anaerobic conditions sooner

Sulphate Concentration

- Bacteria reduce sulphate to sulphide under anaerobic conditions

Temperature

- Higher temperatures promote biological activity

Stream Velocity

- Higher linear velocities lead to reduced thickness of slime layer

Surface Area

- Large surface areas support larger bacterial populations

Detention Time

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Conditions Promoting Hydrogen Sulfide Release

Temperature

- Solubility of H_2S is temperature dependent per Henry's Law.

pH

- Three species of Sulfides exist: H_2S, HS^-, $S^=$.
- Only H_2S is volatile.
- The proportion of H_2S to HS^- is pH dependent
- Low pH favors H_2S

Turbulence

- High velocities induce turbulence, which in turn increase the liquid/vapor mass transfer area.

Odor Control
Background Information

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- What is odor?
- **Types of odors from municipal sewage**
- Sources of odors at WWTP
- Ventilation and air flow rates
- Measurement of odors
- Treatment options: liquid phase vs. vapor phase

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Types of Odors

- **Hydrogen Sulfide (H2S)**
  - Typically 100x higher concentration than other odorous compounds
  - Masks other odors, which then become noticeable after H_2S is removed
  - Relatively easy to remove from air
- Organic Sulfur Compounds (DMS, DMDS, Mercaptans, COS, CS_2)
- Nitrogen Compounds: Ammonia and amines
- Other Volatile Organic Compounds (VOCs)
  - Aldehydes
  - Ketones
- Fatty Acids

Odorous Compounds found in Sewage Treatment Processes

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Sulphur Compounds	Formula	Odour description	Odour Threshold ppb	Typical Ranges ppb
Hydrogen Sulphide	H2S	Rotten eggs	0.5	50-500000
Dimethyl Sulphide	CH3-S-CH3	Decayed vegetables	0.1-2	10-1000
Dimethyl Disulphide	CH3-S-S-CH3	Decayed vegetables	0.1-2	1-100
Methyl Mercaptan	CH3-SH	Decayed cabbage	0.7	10-1000
Ethyl mercaptan	CH3-CH2-SH	Decayed cabbage	0.2	1-100
Carbon disulphide	CS2	Sweet, ether-like	25-160	1-100
Carbonyl sulphide	COS		100	1-100

*** There are no "typical sewage odours" for design purposes. Compounds and concentrations vary widely from source to source, site to site, hour to hour, and day to day.**

Odorous Compounds found in Sewage Treatment Processes

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Nitrogen Compounds	Formula	Odour description	Odour Threshold ppb	Typical Ranges ppb
Ammonia	NH3	Pungent	17	1000-200000
Methylamine	CH3NH2	Rotten fish	53	20-200
Dimethylamine	(CH3)2NH	Fishy, ammonia	49	20-200
Trimethylamine	(CH3)3N	Fishy, ammonia	40	20-200
Skatole	C9H9N	Fecal, repulsive	0.06	1-100
Indole	C2H6NH	Fecal, repulsive	1.4	1-100

Other Odorous Compounds	Formula	Odour description	Odour Threshold ppb	Typical Ranges ppb
Fatty acids		rancid, vinegar	0.1 to 1	
Aldehydes		rancid, acrid	2 to 400	10-1000
Ketones		sweet, fruity	200 to 4000	10-1000

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Some Comments About VOC's

- Volatile Organic Compounds (VOCs) are a large group of carbon-based chemicals that easily evaporate at room temperature. While some VOCs are odorous, many other VOCs are not. There are thousands of different VOCs produced and used in our daily lives.

- In sewage treatment the odorous VOC's are primarily amines, organic sulfides, mercaptans and some organic acids.

- Hydrocarbons are VOC's that are regulated because they contribute to photochemical smog. Although many are odorous, they are not generally a major contributor to municipal odors.

- Control of hydrocarbons requires very different technology from control of sewage odors.

Odor Control
Background Information

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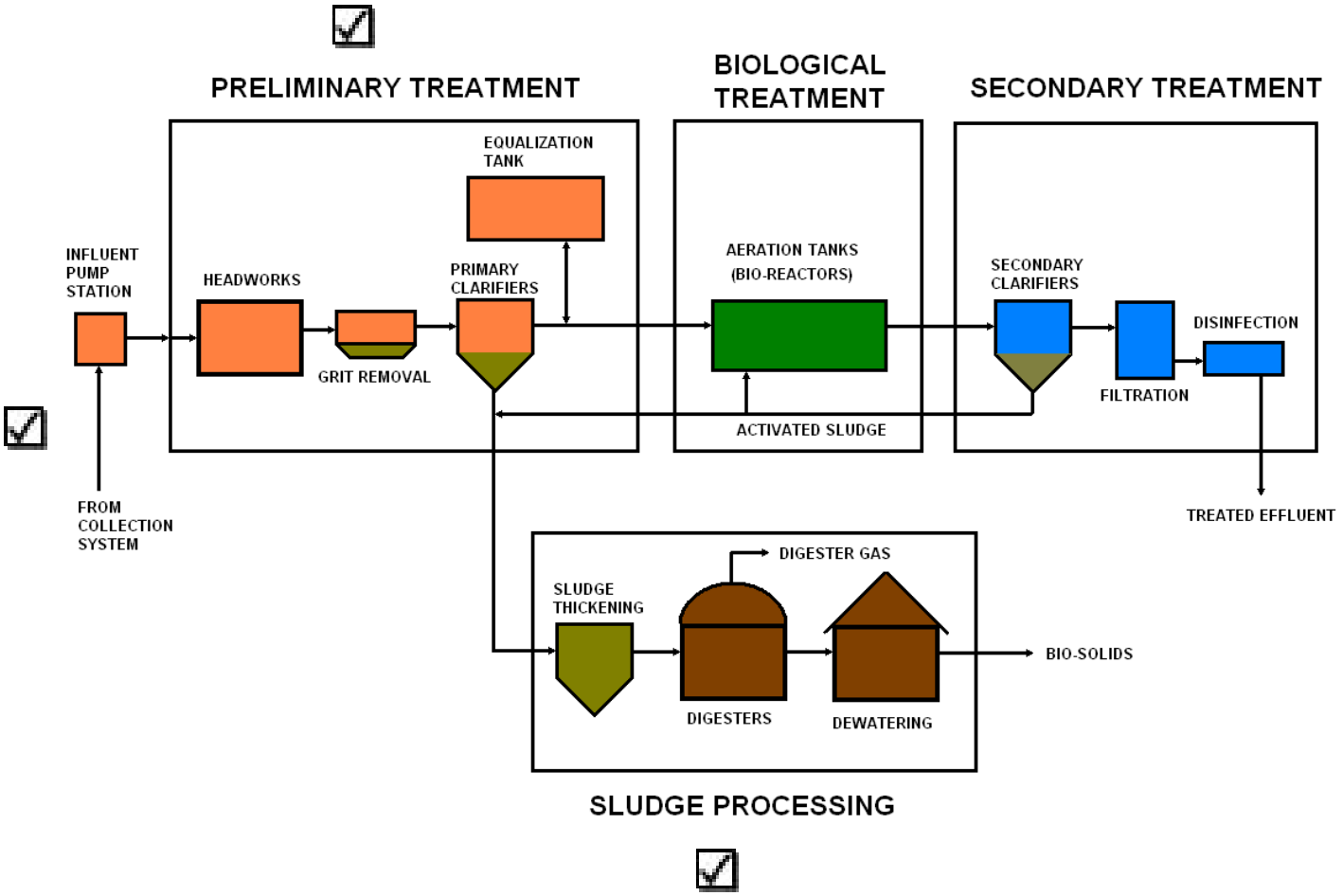
- **What is odor?**
- Types of odors from municipal sewage
- **Sources of odors at WWTP**
- Ventilation and air flow rates
- Measurement of odors
- Treatment options: liquid phase vs. vapor phase

Municipal Sewage Treatment Process



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Localized OC vs. Centralized OC

- **LOCALIZED** odor control uses several smaller odor control systems located near each odor source. Sizes and technology may vary from one location to another.
  - Eliminates complex ductwork and air flow balancing
  - Can use smaller and more focused technology for each source
  - Easy to install

- **CENTRALIZED** odor control uses ductwork to convey odors from odor sources to common central odor control system.
  - Allows easier redundancy
  - Common parts
  - Simpler maintenance

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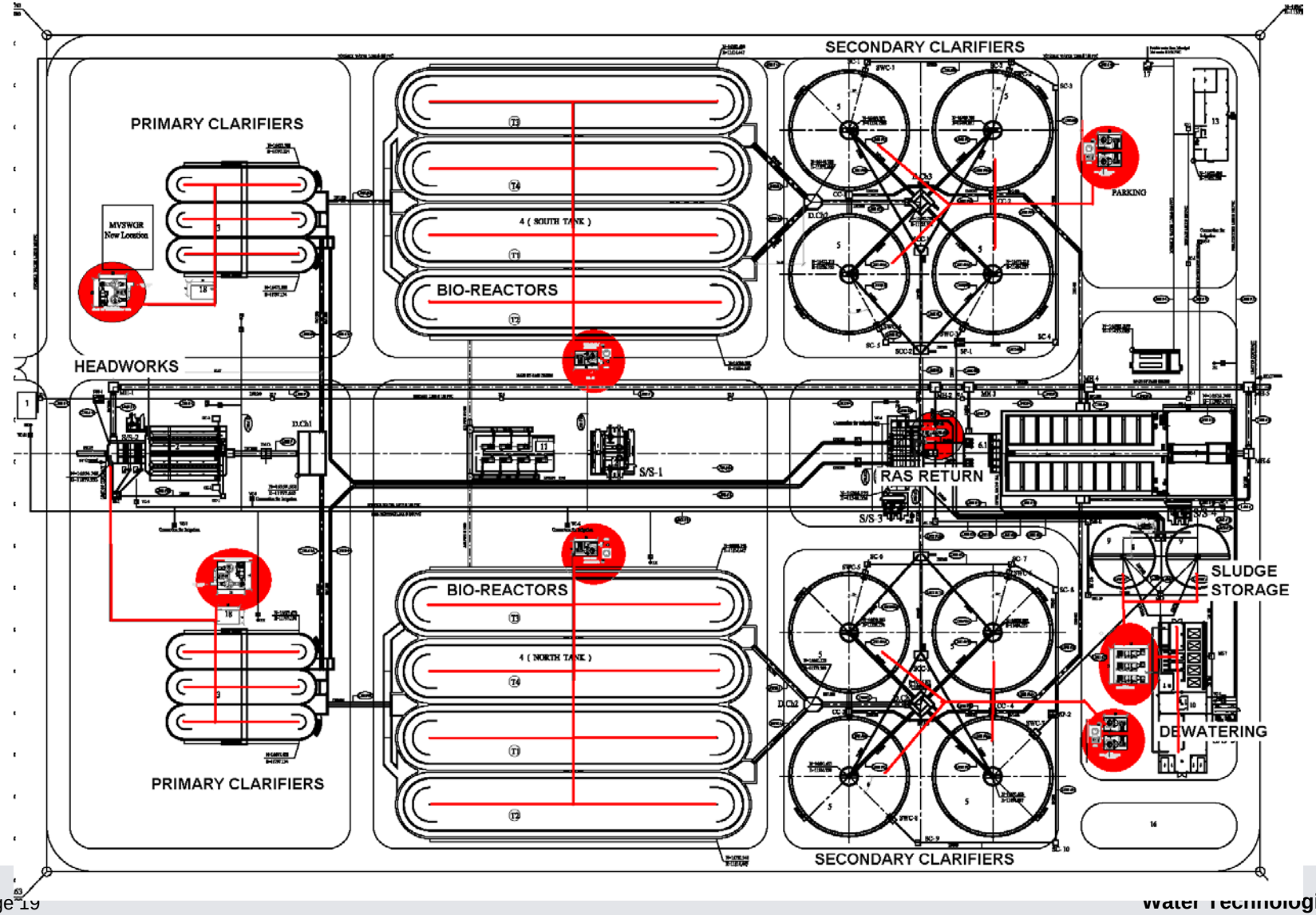
Municipal Odor Control: Localized OCS



Collection System

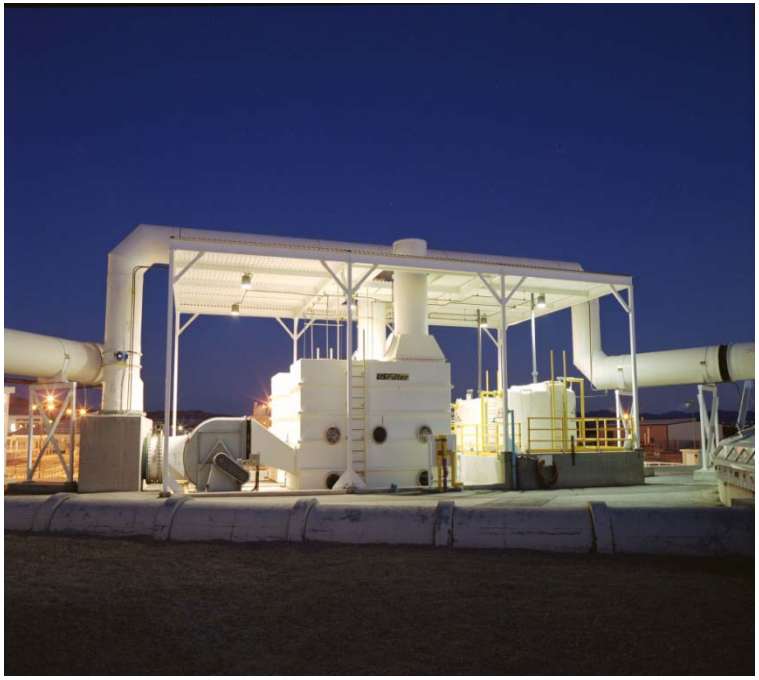
- Characterized by:
  - 99% H2S odours, 1% organic sulphides, low ammonia & amines
  - H2S can range from < 1ppm to > 500 ppm, with wide daily and seasonal variations
  - Smaller air flow requirements: 100 to 2000 m3/h typical. Unoccupied with 3-6 ACH typical
  - Residential locations, aesthetics and noise equally important
  - Remote, un-manned locations
    - **Low maintenance**
    - **Reliable operation**
    - **Simple process**
    - **Safety/vandal resistant**

Influent Pump Station & Headworks

- Characterized by:
  - 99% H2S odours, 1% organic sulphides, low ammonia and amines
  - Large air flow requirements: 5,000 to 50,000 m3/h typical. Occupied buildings require more ventilation (12+ ACH)
  - Located at WWTP, footprint can be important, tall towers okay
  - High H2S possible, 10 to 50 ppm is typical, with 300+ ppm not uncommon
  - Highly variable concentration with spikes to 10x the average

Primary Clarifiers

- Characterized by:
  - Low H2S odours, may be some organic sulphides, no ammonia and amines
  - Large air flow requirements: 20,000 to 50,000 m3/h typical. Unoccupied requiring 3-6 ACH
  - Located at WWTP, footprint can be important, tall towers okay
  - Lower H2S, 1 to 10 ppm is typical, with 50+ ppm not uncommon
  - Can have variable concentration with spikes to 10x the average



Bioreactors & Secondary Clarifiers

- Characterized by:
  - 99% H2S odours, 1% organic sulphides, low ammonia and amines
  - Very large air flow requirements: 50,000 to 100,000 m3/h typical. Unoccupied requiring 3-6 ACH
  - Located at WWTP, footprint can be important, tall towers okay
  - Lower H2S, < 1 ppm is typical
  - Often not controlled because of high cost per odour reduction

Biosolids Processing and Handling

- Characterized by:
  - low H2S odours, higher organic sulphides, may be high ammonia and amines
  - Medium air flow requirements: 5,000 to 10,000 m3/h typical. Occupied buildings requiring 12+ ACH
  - Located at WWTP, footprint can be important, tall towers okay
  - Lower H2S, < 10 ppm is typical
  - May be 0.1 to 1 ppm of DMS, MM, DMDS, and other organic sulphides
  - May be 100+ ppm of NH3, and 1-10 ppm of amines

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Digesters (bio-gas)

- Characterized by:
  - High H2S odours, with 50% methane and 30% CO2 typical
  - Medium to low air flow requirements: 2,000 to 5,000 m3/h typical.
  - Explosive gas.
  - High H2S, 500 to 2000 ppm is typical
  - High pressure gas (positive or vacuum)

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Types of Odours

- Hydrogen Sulphide (H2S)
  - Typically 100x higher concentration than other odours
  - Masks other odours, which then become noticeable after H2S is removed
  - Relatively easy to remove
- Organic Sulphides (DMS, DMDS, Mercaptans, COS, CS2)
- Nitrogen Compounds: Ammonia and amines, skatole, indole
- VOC's
  - Aldehydes
  - Ketones
- Fatty Acids

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Aldehydes		rancid, acrid	2 to 400	10-1000
Ketones		sweet, fruity	200 to 4000	10-1000

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Odour Measurement

- Hydrogen Sulphide (H2S) typically used as indicator of odour level

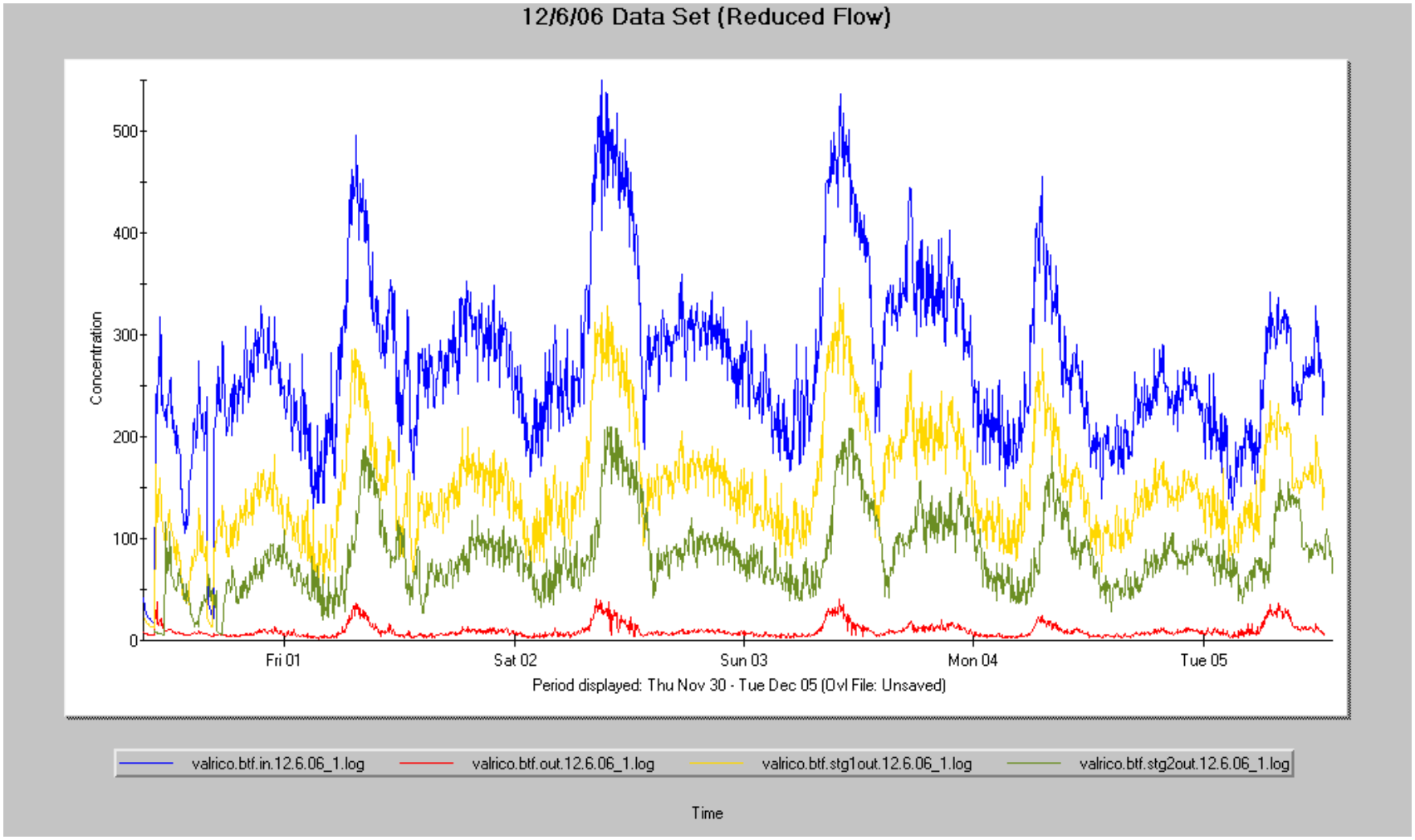
Grab Samples

Jerome Analyzer (gold film technology)	0.001 to 50 ppm
Wet chemical sensors (Interscan)	0.1 to 100 ppm
Odalog – data logger	0.01 to 200 ppm
Indicator tubes	0.1 to 10%

Continuous Monitors

Wet chemical sensors (Scott)	0.1 to 100 ppm
Odalog – CEM	0.01 to 200 ppm
Paper tape	0.1 to 10%
Converter SO2	0.001 to 100+ (w/dilution)

Odour Measurement



Odour Measurement

Other compounds –

- Tedlar bag followed by GC Analysis (grab sample only)
- On-site in-situ GC or FTIR (expensive)
- Indicator Tubes (limited accuracy, limited to few compounds)
- Ammonia analyzers (wet chemical cells)

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Gas Phase Options

- Wet Chemical Scrubbers
- Dry Chemical Scrubbers
- Activated Carbon (adsorption)
- Biofilters (organic media)
- Biotrickling Filters (inorganic media)

- Others: UV oxidation, Ozone, Chlorine dioxide, Spray or misting systems, Thermal oxidation

Biological Processes in Biofiltration

Under proper conditions certain bacteria will biologically oxidize H_2S and other sulfur compounds to soluble sulfates, releasing energy used to sustain the bacteria growth.

Biological odour control systems are designed to promote the growth of these sulfur-oxidizing bacteria.

Biological Processes in Biofiltration

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Requirements of Sulfur-oxidizing bacteria

- Energy source:
  H_2S and other sulfur compounds
- Carbon source:
  organic matter (heterotrophic bacteria)
  carbon dioxide (autotrophic bacteria)
- Nutrients: nitrate, phosphate, potassium
- Water
- Oxygen ($H_2S + O_2 \rightarrow H_2SO_4$)
- Temperature (10 to 50^oC)
- Time (for absorption and reaction)

Biological Processes in Biofiltration

Examples of sulfur-oxidizing bacteria: note some live at neutral pH, and some prefer acidic pH.

Genera	Species	Primary Electron donor	pH Range
Thiobacillus - grow poorly in organic media			
	Thiobacillus thioparus	H2S, sulfides, sulfur, thiosulfate	6 to 8
	Thiobacillus denitrificans	H2S, sulfur, thiosulfate	6 to 8
	Thiobacillus neapolitanus	sulfur, thiosulfate	5 to 8
	Thiobacillus thiooxidans	H2S, sulfides, sulfur, thiosulfate	2 to 5
	Thiobacillus acidophilus	sulfur	2 to 4
	Thiobacillus ferroxidans	sulfides, sulfur, ferrous iron	1.5 to 4
Thiobacillus - grow well in organic media			
	Thiobacillus novellus	thiosulfates	6 to 8
	Thiobacillus intermedius	thiosulfates	3 to 7
Other Sulfur-oxidizing bacteria			
Beggiatoa		H2S, thiosulfate	6 to 8
Thiotrix		H2S	6 to 8
Thiomicrospira		H2S, thiosulfate	6 to 8
Thermothrix		H2S, sulfite, thiosulfate	6.5 to 7.5
Sulfolobus		H2S, sulfur	1 to 4

ZABOCS Biofilter

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FEATURES

- Two Stages of Biofiltration
  - Mineral media (H_2S removal)
  - Bio-formulated carbon media for polishing (H_2S + organics)
  - 99+% H_2S removal

Handles Loading Fluctuations

- Small Footprint (450 m^3/h per m^2)
- Capacities from 170 to 8,500 m^3/h
- Custom-engineered air flow distributor
- Pre-humidification chamber
- Skid-mounted, Factory assembled for easy installation
- Automatic operation, ideal for remote lift stations
- Inert media, long media life
- 100+ installations

ZABOCS MEDIA

ZABOCS Expanded Clay Media

ZABOCS Pelletized Carbon Media

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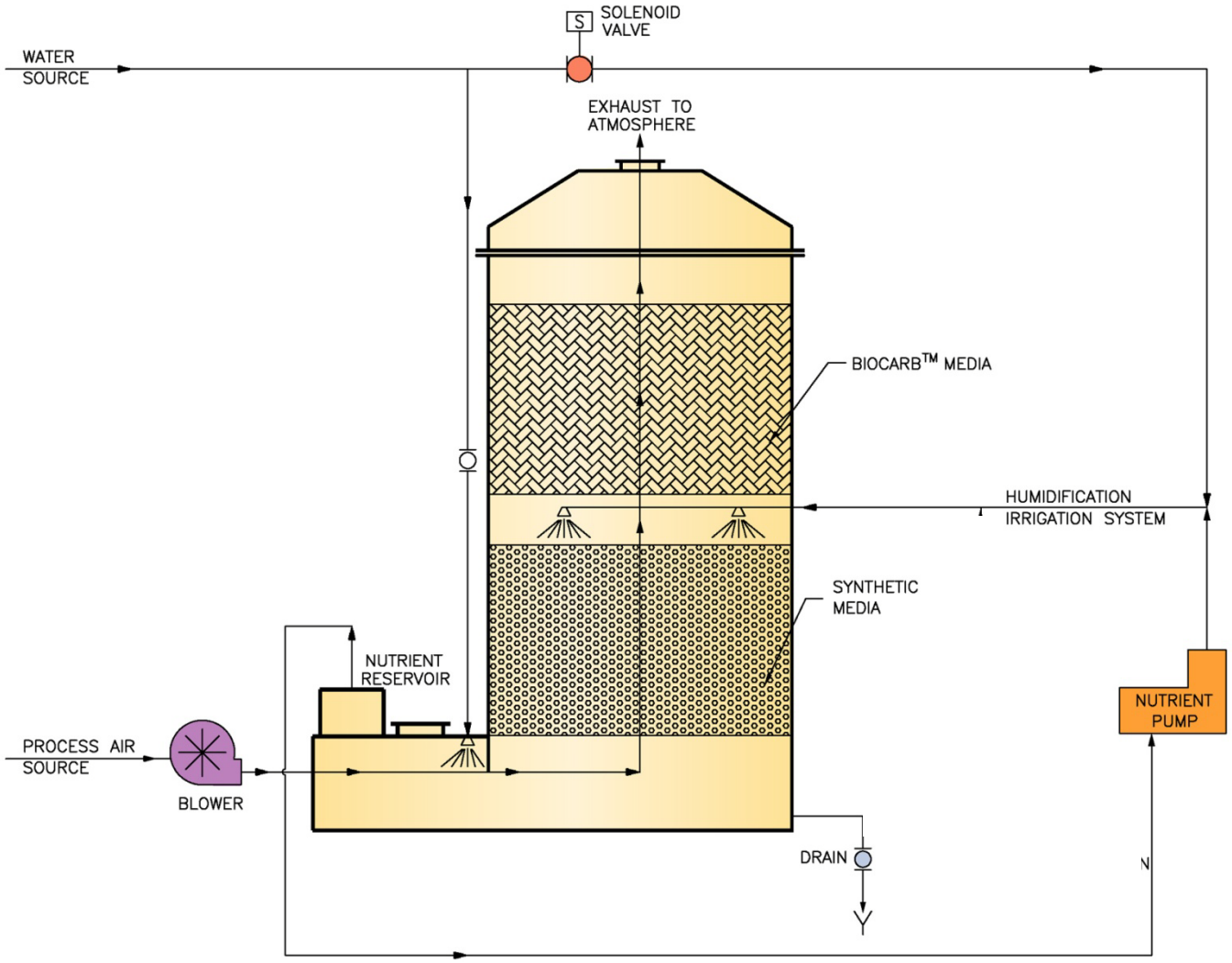
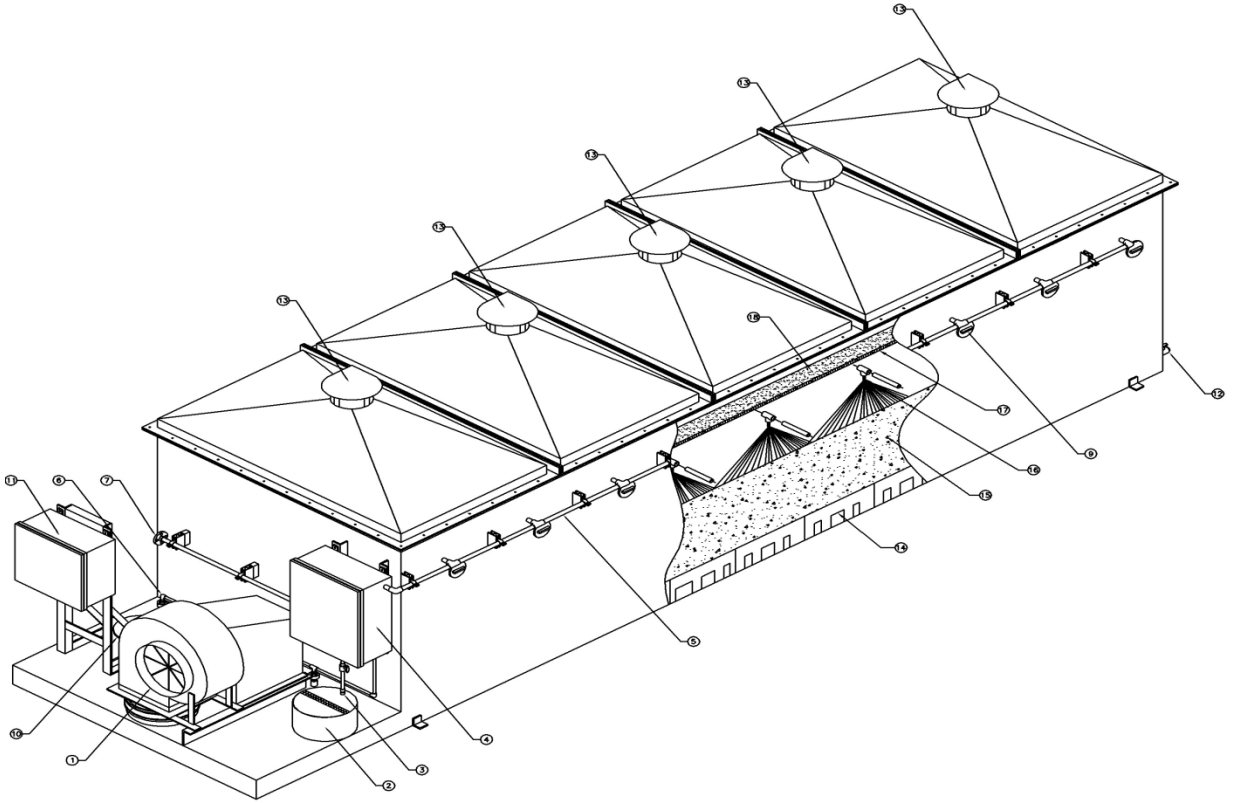
How does it work?



ZABOCS Biofilter



NOMENCLATURE

1. FAN (19" ID INLET)
2. NUTRIENT TANK
3. NUTRIENT FEED LINE
4. WATER PANEL
5. WATER FEED LINE
6. HUMIDIFIER WATER FEED LINE
7. WATER INLET CONNECTION (3/4" FLANGE)
8. MAIN ACCESS FLANGE (NOT SHOWN IN VIEW)
9. (9) ACCESS PORT – 6" DIA.
10. ACCESS PORT – 16" DIA.
11. ELECTRICAL CONTROL PANEL
12. SYSTEM DRAIN
13. (5) EXHAUST STACK – 12" DIA.
14. BACTEE SUPPORT SYSTEM
15. BIODAGENE BED
16. SPRAY NOZZLES
17. GRATING SUPPORT
18. BIOCARB BED

ZABOCS Biofilter – Sanibel Island, FL

Key Features

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- High air flow rate (~450 m3/h per m^2, compared to 100 m^3/h per m2 for conventional organic biofilters)
- Inorganic media biofilter → long media life, preferential development of autotrophic bacteria
- Quick acclimation → specialized media adsorbs odors during acclimation period, for immediate H_2S removal
- Targets inorganic (H_2S) and organic odors
- Compact Footprint
- Skid mounted for easy, low cost installation
- Low Operating Cost

ZABOCS BTF

Bio-trickling filter for high capacity odor control

Design Features:

- **High flow capacity** (2,000+ m^3/h per m^2)
- **High H_2S capacity** (300+ ppm)
- **2-stage design** to promote wider range of bacteria species to target organic sulfides and other odorous compounds
- **Polyurethane foam media** provides superior bacteria adhesion, high surface area and high H_2S capacity
- **Nutrient** to enhance bacteria growth
- **Recirculation in stage 1** with pH control for optimum H_2S removal
- **Low pressure drop** enables high velocity and small footprint

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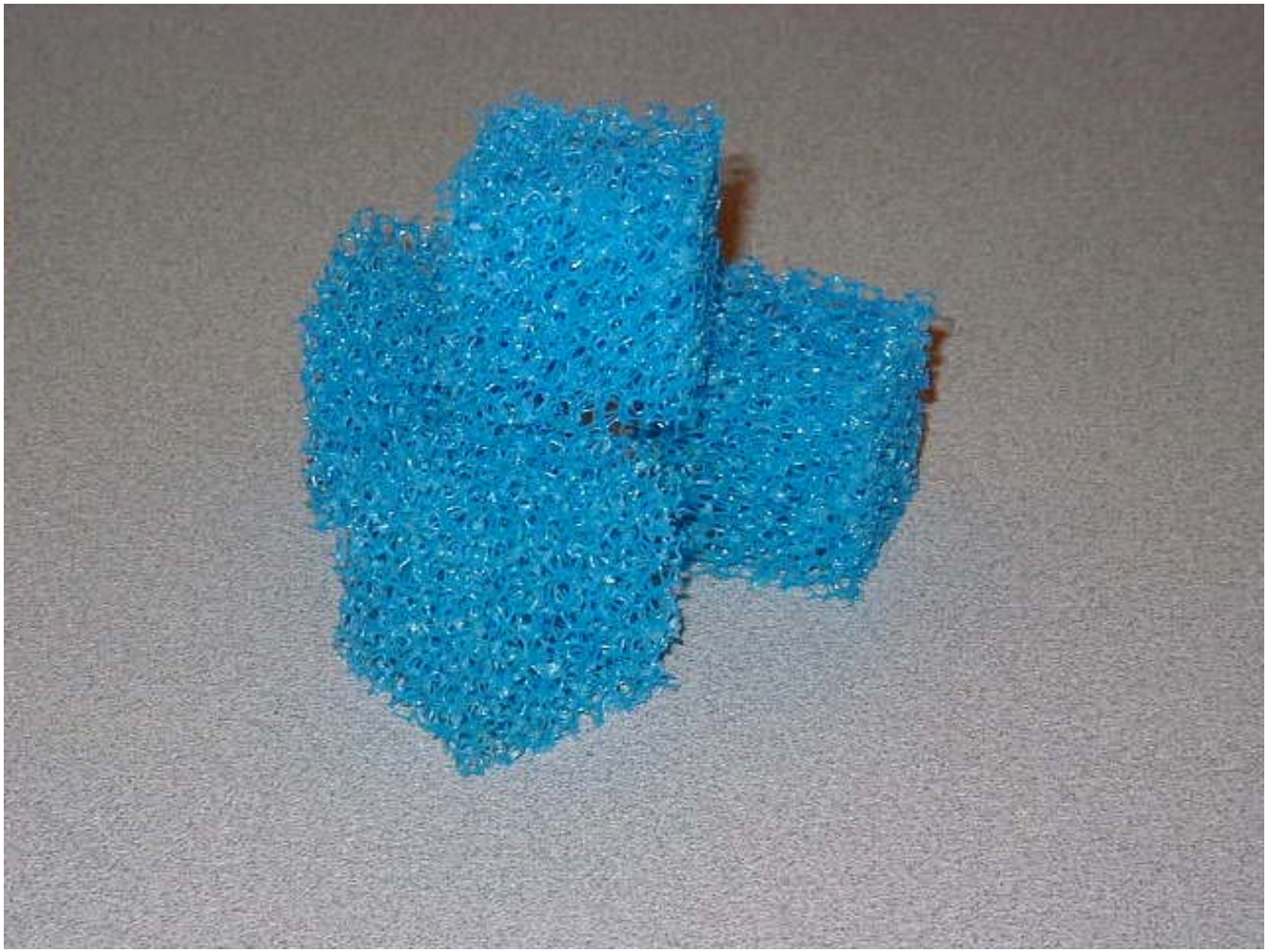
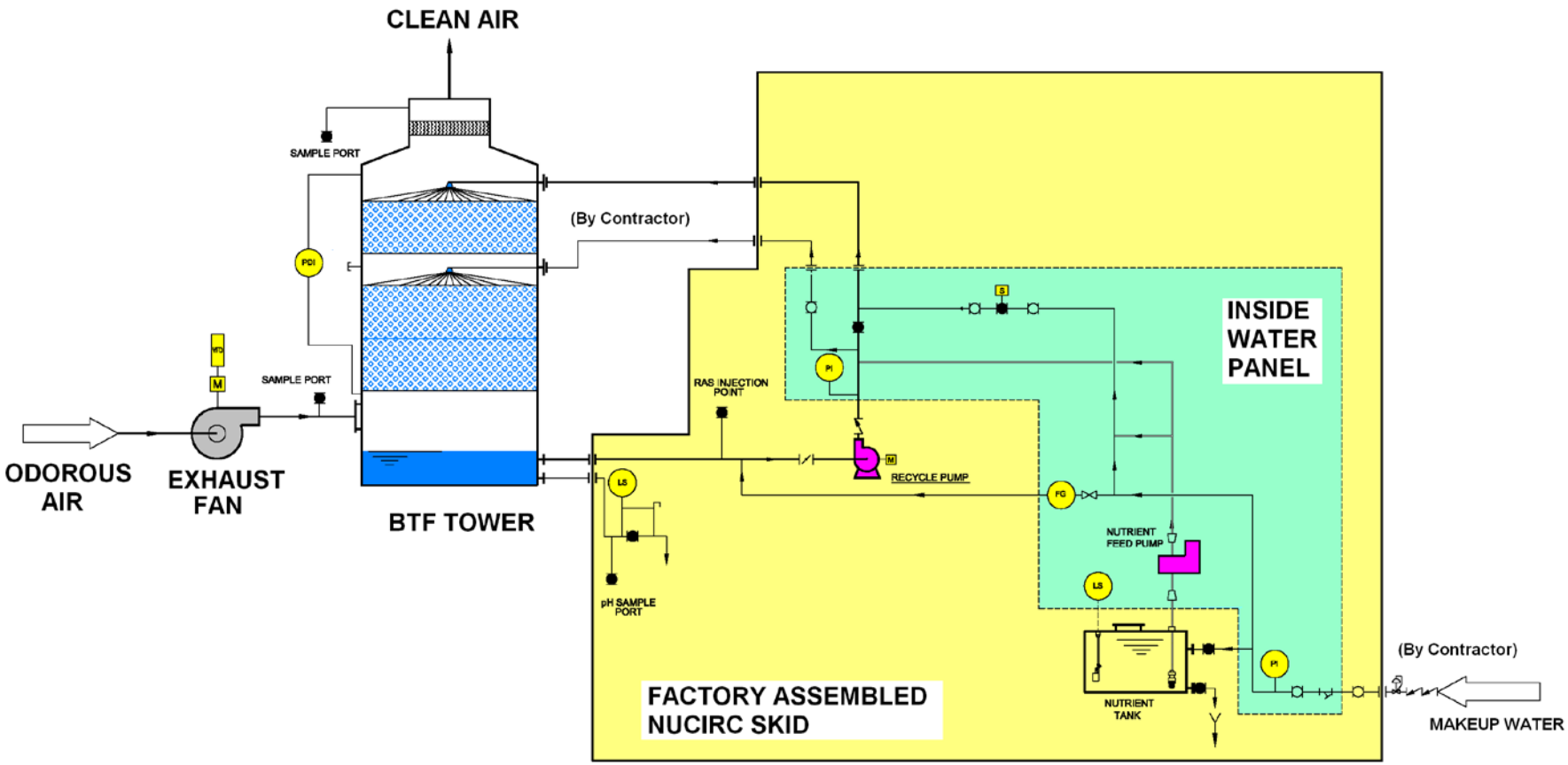
ZABOCS BTF - PUF Cube



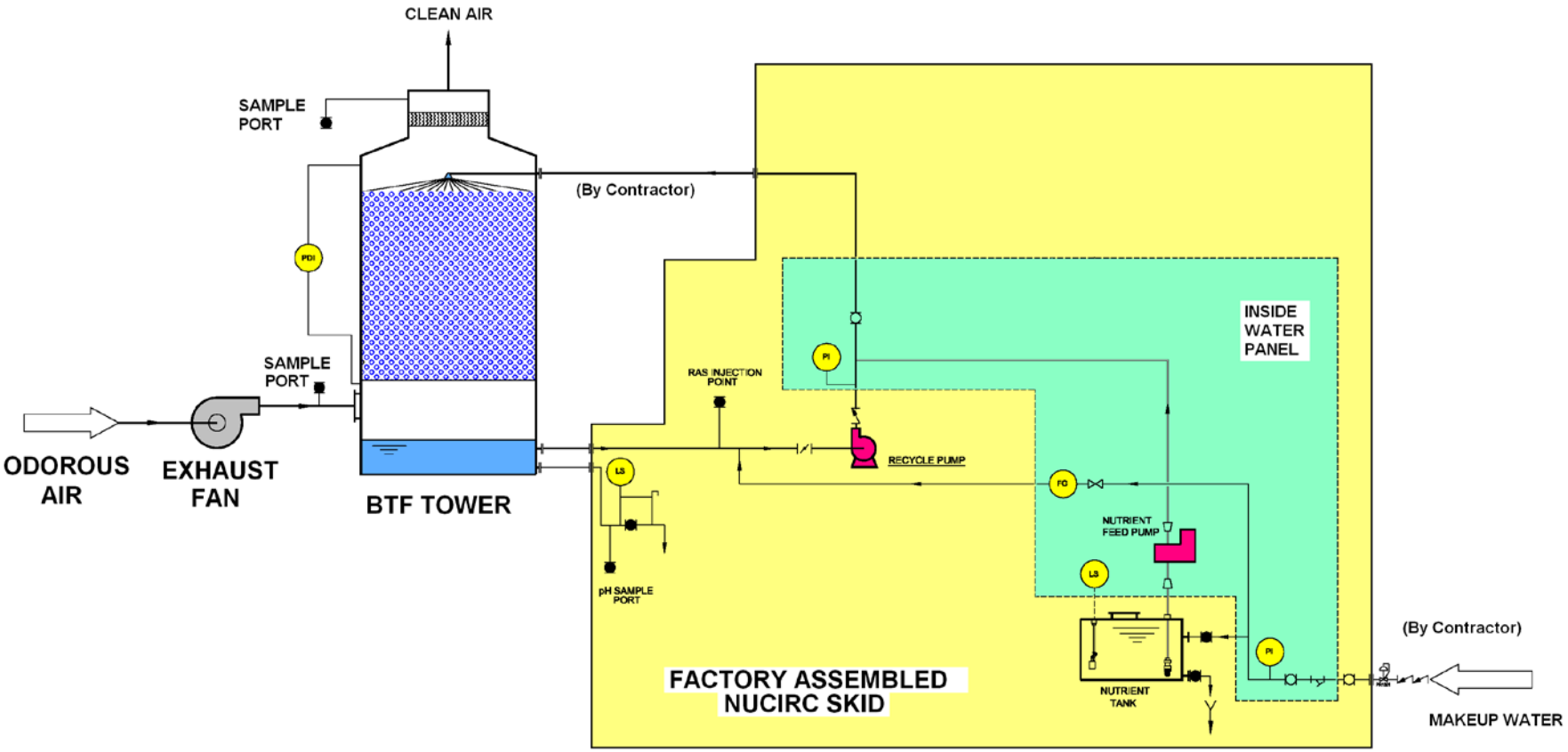
ZABOCS BTF

Padre Dam WWTP 3,400 m^3/h

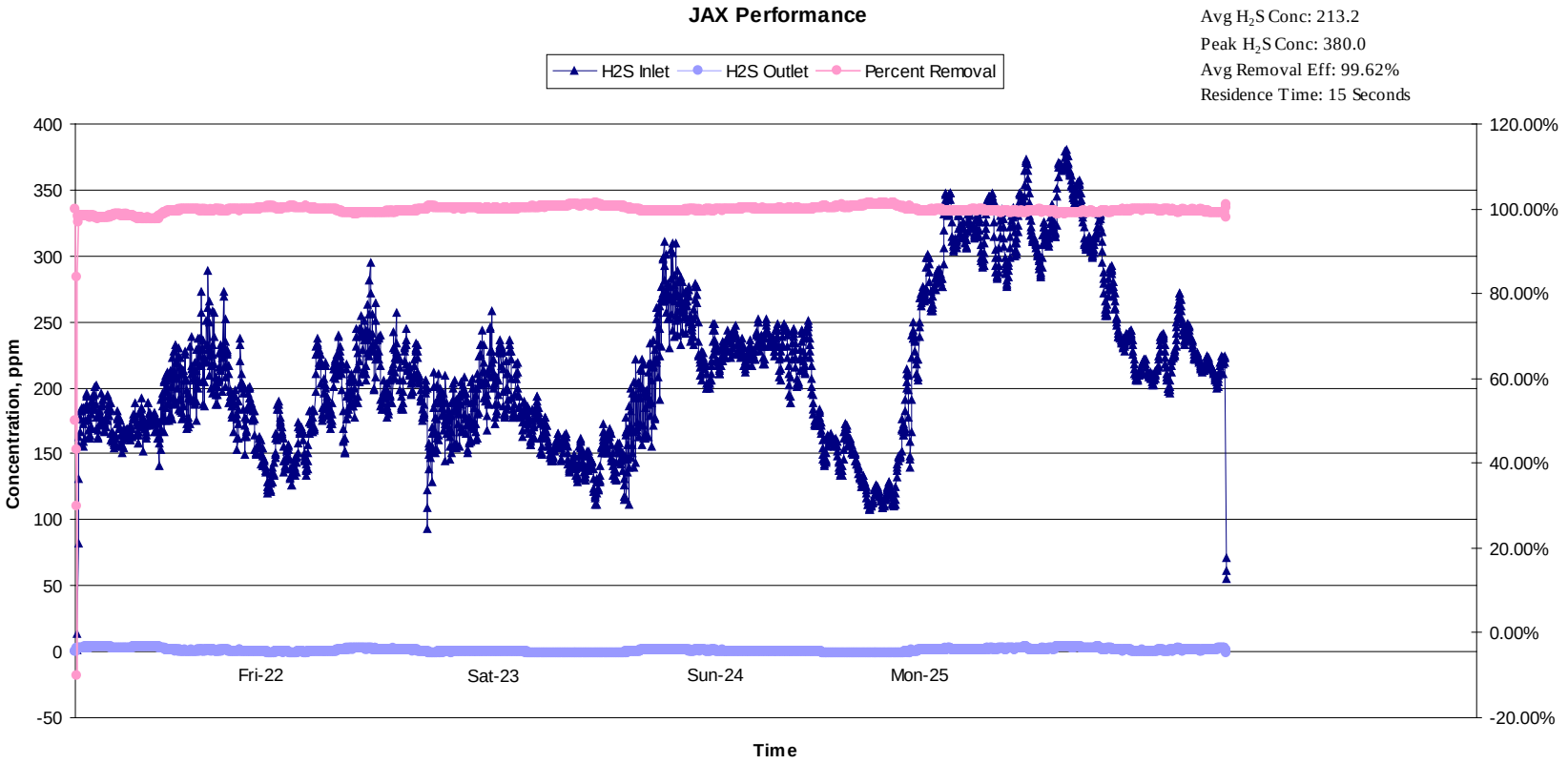
BTF PROCESS FLOW – TWO STAGE



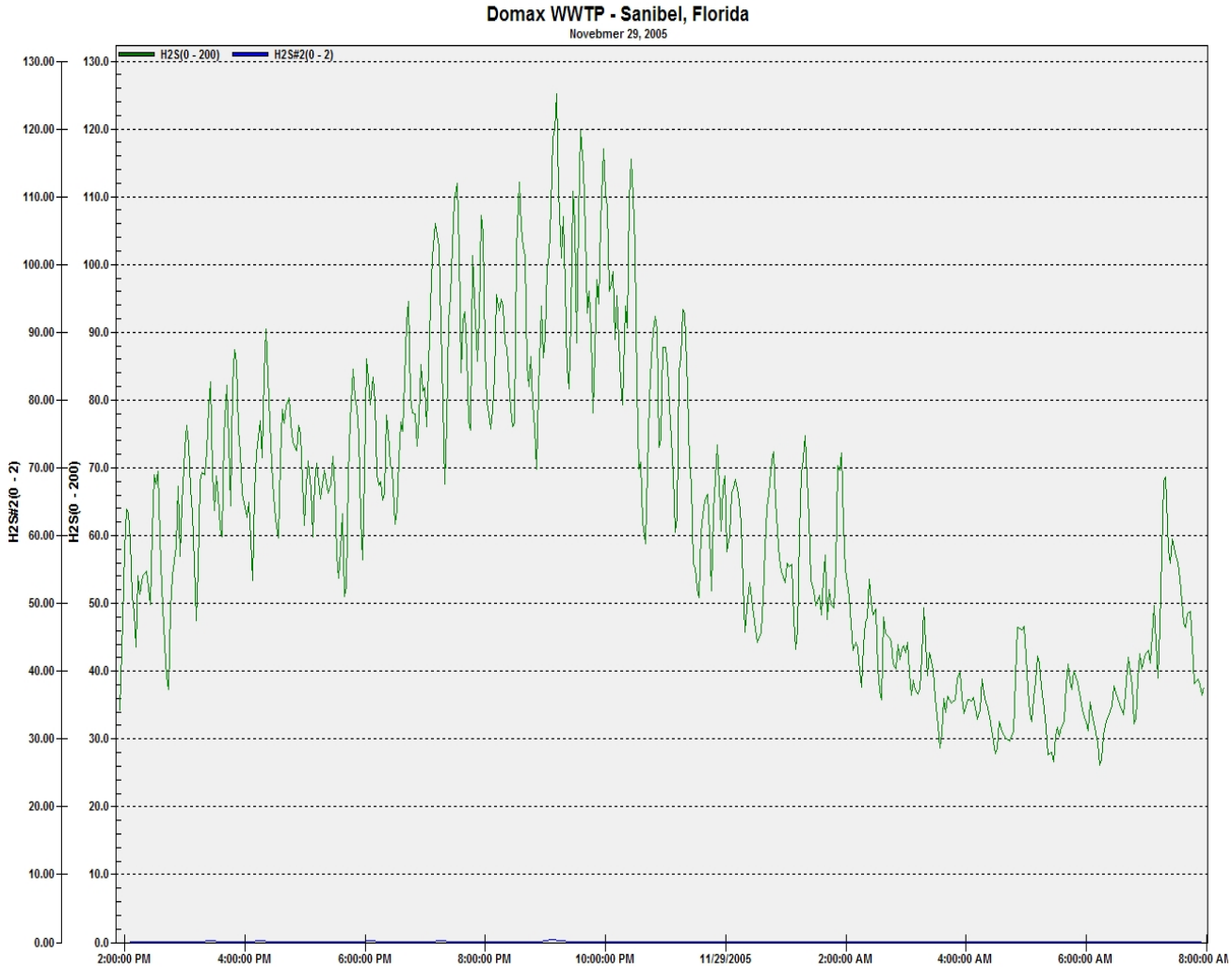
BTF PROCESS FLOW – SINGLE STAGE



ZABOCS BTF Field Data



ZABOCS Data from Sanibel Island, FL



Biological Odor Control Summary

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- Excellent in Collection system – remote lift stations, manholes
- Unattended, automatic operation
- Air flows from 170 to 8,500 m^3/h
- H_2S loadings of 300+ ppm
- 2-stages: biological followed by carbon
- Targets H_2S and VOC's

ZABOCS BTF

- Ideal for large Pump Stations & Treatment Plants
- Air flows to 30,000 m^3/h and higher per tower
- H_2S loadings of 300+ ppm
- 2-stage biological system, low pH and neutral pH
- H_2S, mercaptans and organic sulfides
- High velocity, small footprint

Chemical Scrubbing- Background

Two reactions required to effectively remove H_2S Hydrogen Sulfide is Solubilized by Caustic Soda (Sodium Hydroxide):

1. $H_2S + 2NaOH \longrightarrow Na_2S + 2H_2O$
2. $Na_2S + 4NaOCl \longrightarrow Na_2SO_4 + 4NaCl$
3. $H_2S + 2NaOH + 4NaOCl \longrightarrow$

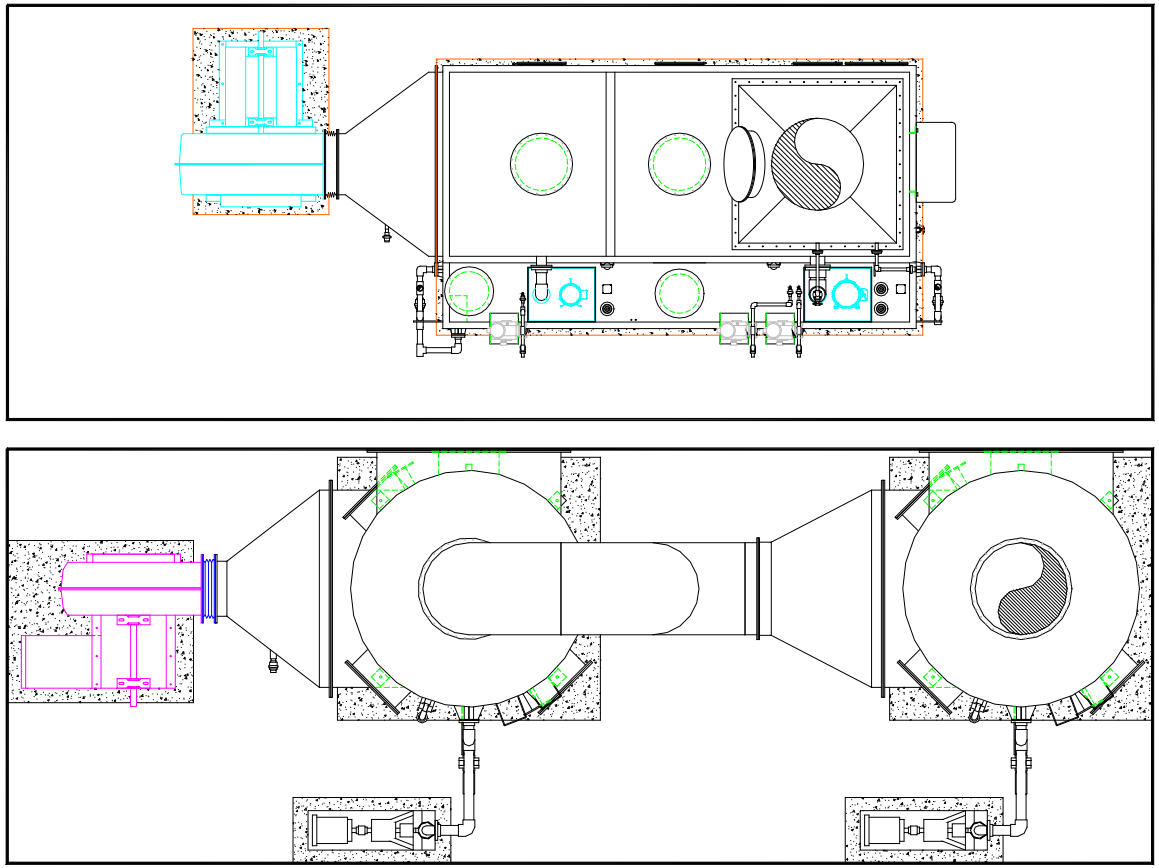
$$\longrightarrow Na_2SO4 + 4NaCl + 2H_2O$$

Robust Technology

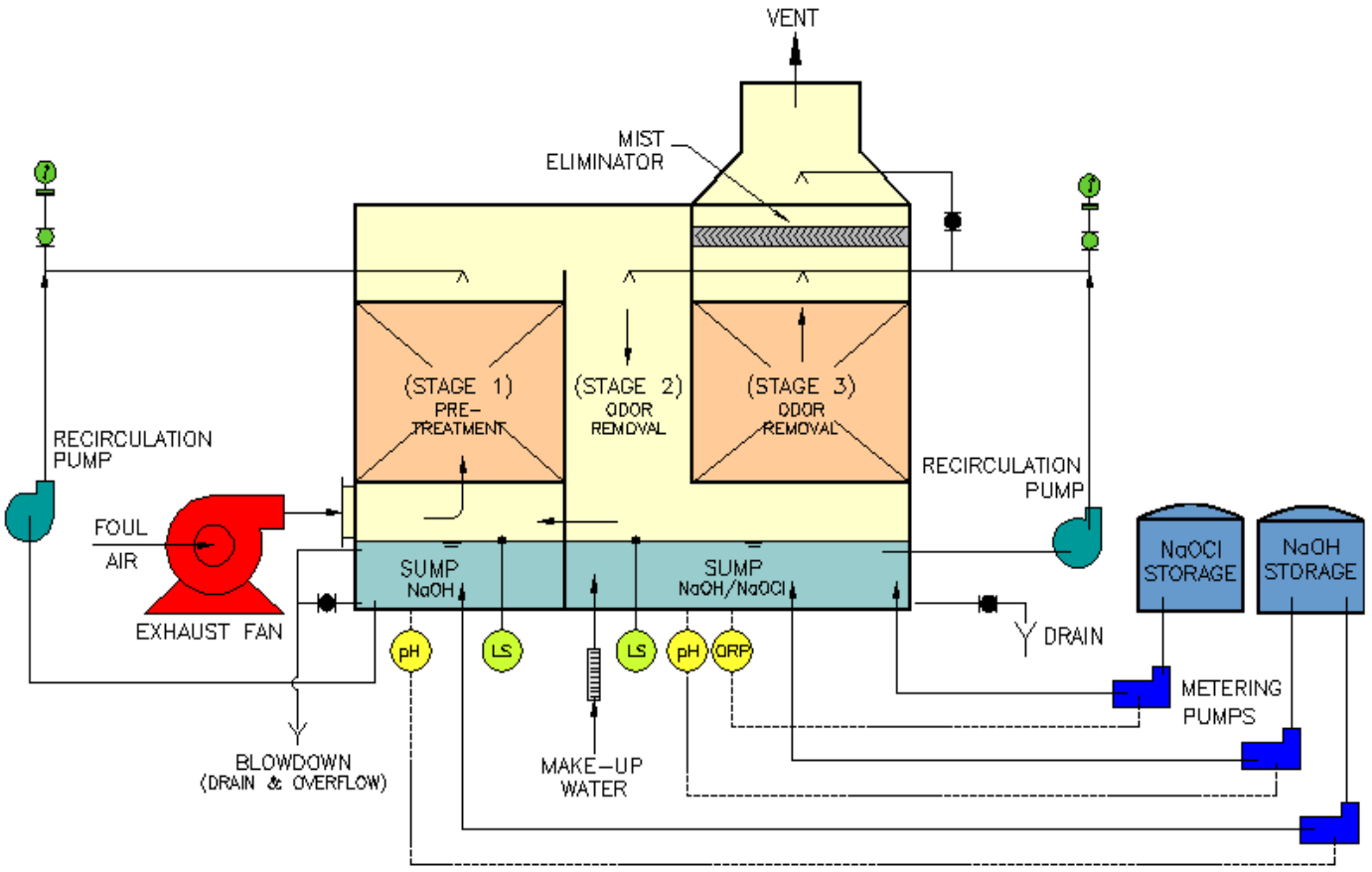
- High Inlet H_2S Concentrations Can Be Scrubbed
- Multiple Stages and Sumps Allow Removal of Different Odor Compounds such as Ammonia and Reduced Sulfides
- Odors that are Difficult to Scrub Can Be Eliminated in First Stage with the 2nd/3rd Stage as Polishers
- Use Different Chemical Solution in Each Stage to Target a Wide Range of Compounds
- 99.5%+ H_2S removal

Footprint Comparison:

Two-Stage Packed Tower Scrubber vs. Low-Profile Unit (40,000 m^3/hr)



LO/PRO® Process Flow Diagram



LO/PRO Process Configurations

The LO/PRO® Process Can Be Configured in Several Ways:

2-Stage or 3-Stage designs

- **Standard LO/PRO: for H2S removal up to 100 ppm**
  Stage 1 = NaOH,
  Stage 2 = NaOCl + NaOH
- **Hyperion LO/PRO: for high H2S (> 100 ppm)**
  Stage 1 & Stage 2 = NaOH
  Stage 2 = NaOH + NaOCl)
- **Hyperion Design: for NH3/amines and H2S/sulfides**
  Stage 1 = H2SO4
  Stage 2 = NaOH
  Stage 3 = NaOCl + NaOH
- **High Oxidation Design: for high mercaptans and organic sulfides**
  Stage 1 = NaOCl + NaOH
  Stage 2 = NaOH

LO/PRO® Odor Control Scrubbers
(LOw PROfile) Chemical Scrubbing

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Minimal Chemical Consumption

- **Counter-Current Chemistry**
- **Process Control - pH and ORP probes**
- **Pre-Treatment Stage Eliminates Approximately 70% of Odors Using a Cheaper Chemical**

LO/PRO® Benefits

- **Systems Pre-Assembled and Factory Tested, Delivered as a Single Unit**
- **Proven Operational Experience with Hundreds of Installations**
- **Small Footprint & Profile**
- **High Air Flow**
- **Minimal Installation and Start-up**
- **Minimal Chemical Consumption**
- **Low Maintenance**

Las Vegas, NV

Model LP-7000 (Qty. 7)

Design: 42,000 m^3/h each , 99.5%+ H_2S removal

Carbon Adsorption

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Contaminants “Adhere” to Surface of Adsorbent:

- **Activated Carbon**
- **Impregnated Carbon**

ODOR CONTROL CARBONS

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- Sewage odors (hydrogen sulfide, mercaptans, organic sulfides) are not adsorbed well by virgin activated carbons and as a result these carbons have relatively low capacity for sewage odors.

- To increase the capacity for these odorous compounds, various custom odor control carbon media have been developed, including:

  - Caustic impregnated carbon (NaOH, KOH, KI)
  - Sulfuric Acid Selective (Water regenerable) carbon
  - Sulfur selective carbon (Midas)

ODOR CONTROL CARBONS
WHAT'S AVAILABLE?

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Standard, Untreated Granular or Pelletized Activated Carbon

- Bituminous Coal Based
- Coconut Shell Based

Chemically Treated Activated Carbons

- Caustic Impregnated, KOH and NaOH
- KI Impregnated

"High Capacity" Carbons Based Adsorbents

- Water regenerable carbon (Calgon Centaur, others)
- Norit Darco, natural high mineral carbon media
- Midas™ odor control media (patented product)

How Odor Control Carbons Differ With Respect to H_2S Reaction Products

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	Products From H_2S Reaction	pH of Spent Carbon
Coconut Shell & Coal Carbons	Both Sulfur and Sulfuric Acid	Acidic pH <2
Impregnated (Caustic Treated) Carbons	Both Sulfur and Sulfuric Acid	Acidic pH <2
Water Regenerable Catalytic Carbon	>95% Sulfuric Acid	Acidic pH <1
Midas™ OCM	>95% Elemental Sulfur	Neutral or Slightly Acidic pH >5

Carbon Capacity Comparison

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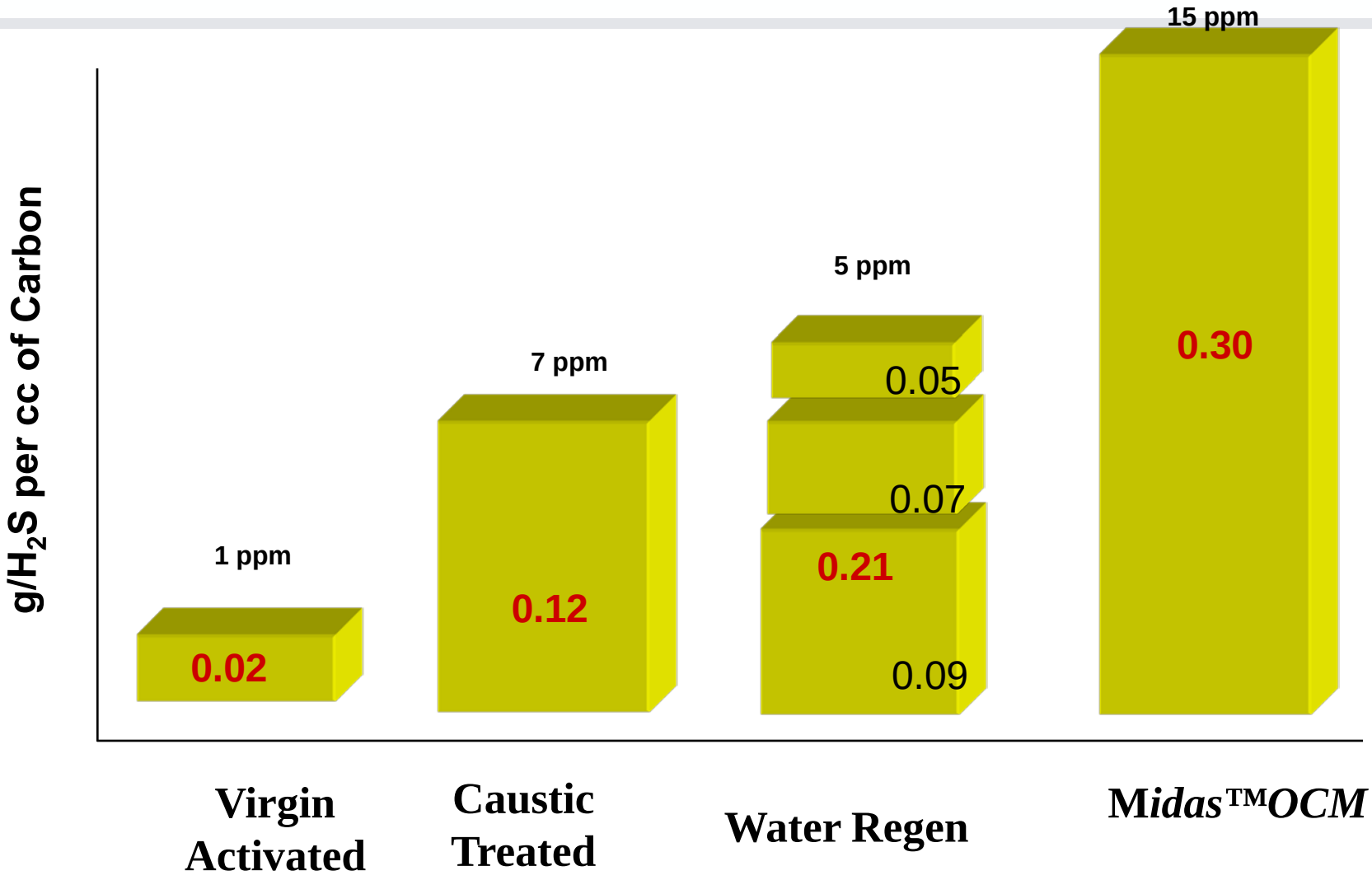

Carbon Capacity Comparison

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ESTIMATED CARBON LIFE	Coconut Shell	Centaur	Caustic Impregnated	Midas
Design Air Flow Rate, scfm	1,000	1,000	1,000	1,000
Inlet H2S Concentration, ppm	5	5	5	5
Vessel Diameter, ft	5.0	5.0	5.0	5.0
Carbon Bed Height, ft	3.0	3.0	3.0	3.0
Apparent Density, lbs/ft^3	31.0	35.0	34.4	30.0
Total Carbon Media, lbs	1,826	2,062	2,023	1,767
Carbon Capacity, g H2S/cc carbon:	**0.03**	**0.09**	**0.15**	**0.30**
Carbon Density, g carbon/cc	0.48	0.48	0.55	0.48
Carbon Capacity, g H2S/g carbon (or lbs H2S/lb carbon):	0.06	0.19	0.27	0.62
Usable Carbon @ Breakthrough (75% of Capacity):, lbs	1,370	1,546	1,518	1,325
Lbs of H2S Absorbed for Usuable Carbon in System	85	289	414	827
Lbs H2S/day	0.64	0.64	0.64	0.64
Carbon Life, days	134	455	651	1,300
No. yrs/change	0.4	1.2	1.8	3.6

Comparison of Odor Control Carbons

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Parameter	Coal	Coconut	Impregnated	Norit Darco	Calgon Centaur	Siemens Midas
Granular or Pelletized	Pelletized	Granular, Mesh 4-8	Pelletized	Granular, Mesh 4-10	Granular Mesh 4x6	Pelletized
Pressure drop at 60 fpm	0.6 "WC/ft	3"WC/ft	0.6 "WC/ft	2"WC/ft	3"WC/ft	0.6 "WC/ft
Chemical Impregnant	none	none	NaOH or KOH	none	none	none
Ignitition Temperature	720^{o}F	720^{o}F	300^{o}F	>720^{o}F	790^{o}F	842^{o}F
H2S Capacity, g-H2S/cc-C	0.02	0.03	0.12	0.20	0.09	0.30
Fate of H2S	S + H_2SO_4	S + H_2SO_4	S + H_2SO_4	S + H_2SO_4	H_2SO_4	S
pH of Spent Carbon	Acidic	Acidic	Acidic	Acidic	Acidic	Neutral
Water Regenerable?	NO	NO	NO	NO	YES	NO
Hazardous Fresh Media	NO	NO	YES	NO	NO	NO
Hazardous Spent Media	YES	YES	YES	YES	YES	NO

Common Design Configurations

- Small, skid-mounted systems
- Large single bed and dual bed systems
- Horizontal flow systems
- Small passive systems
- Other configurations in the market

Dry Media Odor Control

CAP – **Residential carbon adsorption system treating up to 20 ppm at 1000 cfm (2000 m3/h)**

RJMC – **Skid mounted carbon adsorption system treating up to 20 ppm at 1500 cfm (2500 m3/h)**

RJC – **Bulk single bed and dual bed carbon adsorption systems treating up to 20 ppm at 15,000 cfm (25,000 m3/h)**

V-Bank – **Bulk dual bed carbon adsorption systems treating up to 20 ppm at 65,000 cfm (100,000 m3/h)**

Carbon Adsorption

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Advantages

- Low operator attention
- Low maintenance
- Effective until breakthrough
- Carbon capacities handle 1 to 20 ppm
- Configurations for high flow rates
- Easy design for low flow rates

Disadvantages

- Limited carbon life
- Expensive to change out
- Some carbons are hazardous/flammable
- Limited capacity for some organic sulfides

Adsorption Summary

- **Reliable Odor Control**
- **Small Footprint**
- **Low Regular Maintenance**
- **Ideal for Low-Loading or “Polishing” Applications**

Technology Selection: Hybrid Systems

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Hybrid Systems, combining multiple technologies, can provide best overall odor removal.

- **Chemical followed by carbon**
- **Biological followed by carbon**
- **Biological followed by chemical**
- **Biological followed by chemical followed by carbon**

Technology Selection: Hybrid Systems

SIEMENS

Multiple stage chemical scrubber followed by activated carbon polisher, using P60 pelletized virgin activated carbon.

Scrubber provides > 99% H2S removal, and > 90% odor removal. Activated carbon polisher provides overall 99.99% H2S removal, and > 99% odor removal.

Technology Selection: Hybrid Systems

SIEMENS

Bio-trickling scrubber followed by activated carbon polisher, using P60 pelletized virgin activated carbon.

BTF provides > 99% H2S removal, and > 75% odor removal. Activated carbon polisher provides overall >99.99% H2S removal, and > 95% odor removal.

Technology Selection: Hybrid Systems

SIEMENS

ZABOCS system provides biological stage followed by integral activated carbon polishing stage.

System typically provides > 99% H2S removal and > 95% odor removal in single compact package.

Technology Selection: Hybrid Systems

SIEMENS

- Project being installed in Dubai combines 12 bio-trickling scrubber towers followed by four single stage chemical scrubbers.
- System designed to treat up to 600 ppm of H2S, with > 99.9% H2S removal and > 90% odor removal.
- Bioscrubbers used as pre-treatment stage to reduce chemical cost.

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APPLICATIONS

Odor Control System	Odorous Compounds				Air Flow Range	H2S Concentration Range, ppm
	NH3	H2S	Sulphides	VOCs	m3/h	
Packed Tower Scrubber	good	good	good	poor	20,000 to 100,000	1 to 200
LO/PRO	good	good	good	poor	1500 to 40,000	1 to 500
Polystage	good	good	good	poor	500 to 10,000	1 to 500
ZABOCS	poor	good	good	good	100 to 8500	0 to 100
ZABOCS-BTF	fair	good	fair	poor	1000 to 25,000	1 to 500
ZABOCS P-Series	fair	good	good	good	300 to 1200	0 to 300
RJMC Series	(see specific media below)				200 to 2400	(see media)
RJC Bulk Series	(see specific media below)				2000 to 25,000	(see media)
CAP_Series	(see specific media below)				300 to 3000	(see media)
Midas OCM	poor	good	fair	fair	(see type above)	< 20
UOCH-KP	poor	good	fair	poor	(see type above)	< 10
P60 Carbon	poor	fair	fair	good	(see type above)	< 2
48C Carbon	poor	fair	fair	good	(see type above)	< 1

Technology Selection

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In summary:

- There is not one technology which is always best in all applications.
- Each technology has its advantages, and will be favored in certain applications.
- Cost is important, but not always the deciding factor.
- Hybrid solutions using multiple technologies is often the best choice when performance is most important.

APPLICATIONS

Information needed to select appropriate technology

- **Air Flow Rate or Ventilation Rate**
- **H2S Concentration (average and peak)**
- **Required level of odour removal (H2S and OU)**

- **Detailed performance and equipment specifications if available**
- **Testing requirements**
- **Concentration of other odorous compounds present**
- **Site location**
- **Temperatures (ambient air and odour stream)**
- **Need freeze protection?**
- **Indoor or Outdoor location?**
- **Hazardous area classification?**
- **Local 3-phase and 1-phase voltage and Hertz**

FACTORS TO CONSIDER

SIEMENS

For any given application, the selection of the best technology may be based on many factors, including:

- Capital cost for Equipment
- Installed cost
- Operating cost
- Source of funding and budget
- Maintenance requirements
- Reliability
- Safety
- Performance (% removal)
- Size (footprint, height)

EACH TECHNOLOGY HAS ITS NICHE

SIEMENS

There is no one technology that is best in every application. Each technology has it's niche.

- **<u>Wet Chemical Scrubbers:</u>**
  - can treat larger air flows in a single vessel
  - have more compact footprint
  - are less sensitive to variations in actual vs. design H2S loadings
  - and are effective for a wider range of odorous compounds (H_2S, NH_3, amines, organic sulfides).

EACH TECHNOLOGY HAS ITS NICHE

SIEMENS

- **Biological Systems:**
  - Have very low operating and maintenance costs
  - Do not require handling of hazardous chemicals.
  - Operating cost is not proportional to H2S concentration (hence they are well suited to high H2S applications)

EACH TECHNOLOGY HAS ITS NICHE

SIEMENS

- **Activated Carbon Systems:**
  - Are the simplest and lowest maintenance systems (until you need to change out the carbon)
  - Require only electrical power to operate (no water, no chemicals)
  - Are efficient for a wide range of compounds.

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TECHNOLOGY COMPARISON TABLE:

TYPE	CAPITAL COST	OPERATING COST	MAINTEN-ANCE	FOOT-PRINT	CFM/SF	ODOR REMOVAL	H2S PPM	H2S % REMOVAL	NH3 PPM	NH3 % REMOVAL
CHEMICAL SCRUBBERS	MEDIUM	HIGH	HIGH	SMALLER	500	> 95%	0 - 500 +	99.90%	0 - 1000 +	> 99%
BIO-TRICKLING SCRUBBERS	HIGHER	LOW	LOW	LARGER	150	75-90%	> 2 ppm	99%	<< H2S *	~95%
ORGANIC BIOFILTERS	LOW	LOW	LOW	VERY LARGE	5 - 10	75-90%	1- 50 PPM	99%	<< H2S *	~ 95%
HIGH CAPACITY CARBON	LOW	LOW	LOW	MEDIUM	60	> 90%	0-20 ppm	99.9	Poor	Poor
VIRGIN ACTIVATED CARBON	LOW	LOW	LOW	MEDIUM	75	> 90%	< 1 ppm	99.9	Poor	Poor

* Note that simultaneous H2S and NH3 removal in a biofilter is possible but tricky. High H2S concentration can suppress the oxidation of NH3, and high NH3 concentration can reduce the removal of H2S.

LIFE CYCLE COST

One way to compare cost of ownership is by estimating the life cycle cost.

Life cycle cost combines the capital cost, installation cost, operating cost and maintenance costs over the life of the equipment, or some other time period.

We will present several scenarios to show the relative cost of five odor control technologies:

- Single stage chemical scrubber
- Two-stage chemical scrubber (LO/PRO)
- Bio-trickling scrubber (ZABOCS BTF)
- High capacity carbon adsorber (Midas carbon)
- Virgin activated carbon adsorber (VoCarb P60 carbon)

LIFE CYCLE CALCULATION ASSUMPTIONS:

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- All capital costs based on List Price for equipment supplied by Siemens. There is no bias towards one technology.
- Based on requirement for 99% H2S removal only
- Installation cost estimated as fixed % of capital cost.
- Chemical costs based on ambient CO_2 concentrations, and:
  - NaOH (25 wt%) at $1.20/gallon
  - NaOCl (12.5 wt%) at $0.85/gallon
  - Nutrient at $2.00/lb
- Utilities: Electricity at $0.08/kW-hr, Water at $1.00/1000 gallons
- Maintenance Labor Rate at $50/hr
- Interest rate at 8.0%/year

LIFE CYCLE COST

SCENARIO #1:

- AIR FLOW RATE 25,000 CFM
- H_2S CONCENTRATIONS: 20, 10, 50 PPM
- LIFE CYCLE PERIOD: 20 YEARS
- OBJECTIVE: ABOVE 15-20 PPM, MULTIPLE BTF UNITS BETTER THAN SINGLE CHEMICAL SCRUBBER

25,000 CFM, 20 PPM, 20 YEARS

SIEMENS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	25,000	25,000	25,000	25,000	25,000
Average Inlet H2S Concentration, ppm	20.0	20.0	20.0	20.0	20.0
H2S Loading, lb/hr	2.64	2.64	2.64	2.64	2.64
Model	PT-0800	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	8.0	7.0	12.0	11.0	11.0
CFM/ft^2	497	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.3	1.4	1.4
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$227,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	1	2	2	2
Chemical Tanks	$72,500	$32,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$419,300**	**$374,725**	**$858,000**	**$410,400**	**$453,600**
OPERATING COST ($/Yr):					
Total System Horsepower	65	90	30	20	20
Total Power Cost $/yr)	$33,982	$47,052	$31,368	$20,912	$20,912
25% Sodium Hydroxide usage (gal/mo)	1,872	1,872			
Sodium Hydroxide cost ($/yr)	$26,957	$26,957	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	13,852	4,156			
12.5% Sodium Hypochlorite cost ($/yr)	$141,294	$42,388	$0	$0	$0
Media Life (years)	10	10	10	0.05	0.75
Media (cf)	503	490	4298	582	582
Media Cost, $/year	$402	$392	$12,893	$1,041,772	$115,752
Water usage, gal/year	926,020	926,020	1,736,287	0	0
Water cost ($/year)	$926	$926	$1,736	$0	$0
Nutrients ($/year)	$0	$0	$1,389	$0	$0
Manhours/Week	2.5	2.5	2.0	1.0	1.0
Maintenance	$8,770	$9,060	$12,050	$855	$6,145
ANNUAL OPERATING COST	**$212,331**	**$126,775**	**$59,436**	**$1,063,539**	**$142,809**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$2,503,993**	**$1,619,417**	**$1,441,554**	**$10,852,382**	**$1,855,723**

25,000 CFM, 10 PPM, 20 YEARS

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Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	25,000	25,000	25,000	25,000	25,000
Average Inlet H2S Concentration, ppm	10.0	10.0	10.0	10.0	10.0
H2S Loading, lb/hr	1.32	1.32	1.32	1.32	1.32
Model	PT-0800	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	8.0	7.0	12.0	11.0	11.0
CFM/ft^2	497	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.3	1.4	1.4
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$227,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	1	2	2	2
Chemical Tanks	$36,500	$17,500	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$368,900**	**$355,550**	**$858,000**	**$410,400**	**$453,600**
OPERATING COST ($/Yr):					
Total System Horsepower	65	90	30	20	20
Total Power Cost $/yr)	$33,982	$47,052	$31,368	$20,912	$20,912
25% Sodium Hydroxide usage (gal/mo)	936	936			
Sodium Hydroxide cost ($/yr)	$13,478	$13,478	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	6,926	2,078			
12.5% Sodium Hypochlorite cost ($/yr)	$70,647	$21,194	$0	$0	$0
Media Life (years)	10	10	10	0.10	1.51
Media (cf)	503	490	4298	582	582
Media Cost, $/year	$402	$392	$12,893	$520,886	$57,876
Water usage, gal/year	463,010	463,010	868,143	0	0
Water cost ($/year)	$463	$463	$868	$0	$0
Nutrients ($/year)	$0	$0	$695	$0	$0
Manhours/Week	2.5	2.5	2.0	1.0	1.0
Maintenance	$8,770	$9,060	$12,050	$855	$6,145
ANNUAL OPERATING COST	**$127,742**	**$91,639**	**$57,874**	**$542,653**	**$84,933**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$1,623,092**	**$1,255,277**	**$1,426,211**	**$5,738,246**	**$1,287,486**

25,000 CFM, 50 PPM, 20 YEARS

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Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	25,000	25,000	25,000	25,000	25,000
Average Inlet H2S Concentration, ppm	50.0	50.0	50.0	50.0	50.0
H2S Loading, lb/hr	6.61	6.61	6.61	6.61	6.61
Model	PT-0800	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	8.0	7.0	12.0	11.0	11.0
CFM/ft^2	497	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.3	1.4	1.4
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$227,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	1	2	2	2
Chemical Tanks	$86,000	$86,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$438,200**	**$444,600**	**$858,000**	**$410,400**	**$453,600**
OPERATING COST ($/Yr):					
Total System Horsepower	65	90	30	20	20
Total Power Cost $/yr)	$33,982	$47,052	$31,368	$20,912	$20,912
25% Sodium Hydroxide usage (gal/mo)	4,680	4,680			
Sodium Hydroxide cost ($/yr)	$67,392	$67,392	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	34,631	10,389			
12.5% Sodium Hypochlorite cost ($/yr)	$353,235	$105,970	$0	$0	$0
Media Life (years)	10	10	10	0.02	0.30
Media (cf)	503	490	4298	582	582
Media Cost, $/year	$402	$392	$12,893	$2,604,430	$289,381
Water usage, gal/year	2,315,049	2,315,049	4,340,717	0	0
Water cost ($/year)	$2,315	$2,315	$4,341	$0	$0
Nutrients ($/year)	$0	$0	$3,473	$0	$0
Manhours/Week	2.5	2.5	2.0	1.0	1.0
Maintenance	$8,770	$9,060	$12,050	$855	$6,145
ANNUAL OPERATING COST	**$466,096**	**$232,181**	**$64,124**	**$2,626,197**	**$316,438**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$5,014,395**	**$2,724,188**	**$1,487,581**	**$26,194,789**	**$3,560,435**

LIFE CYCLE COST

SCENARIO #2:

- AIR FLOW RATE 10,000 CFM
- H_2S CONCENTRATIONS: 10, 5 PPM
- LIFE CYCLE PERIOD: 20 YEARS
- OBJECTIVE: WHEN USING SINGLE BTF, TIPPING POINT IS LOWER THAN FOR MULTIPLE VESSELS, BUT CAPITAL IS HIGH

10,000 CFM, 10 PPM, 20 YEARS

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Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	10,000	10,000	10,000	10,000	10,000
Average Inlet H2S Concentration, ppm	10.0	10.0	10.0	10.0	10.0
H2S Loading, lb/hr	0.53	0.53	0.53	0.53	0.53
Model	PT-0500	LP-4500	BTF-1235	RJC-1000D	RJC-1000D
Packed bed width/diameter, ft	5.0	4.5	12.0	10.0	10.0
CFM/ft^2	509	494	88	64	64
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	15.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.2	2.8	2.8
Vessel Height, ft	22.0	13.0	27.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$163,000	$174,000	$290,000	$154,000	$168,000
Number of Systems	1	1	1	1	1
Chemical Tanks	$16,500	$11,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$251,300**	**$240,500**	**$377,000**	**$184,800**	**$201,600**
OPERATING COST ($/Yr):		$2			
Total System Horsepower	25	45	21	16	16
Total Power Cost $/yr)	$13,070	$23,526	$10,979	$8,365	$8,365
25% Sodium Hydroxide usage (gal/mo)	374	374			
Sodium Hydroxide cost ($/yr)	$5,391	$5,391	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	2,770	831			
12.5% Sodium Hypochlorite cost ($/yr)	$28,259	$8,478	$0	$0	$0
Media Life (years)	10	10	10	0.10	1.56
Media (cf)	196	203	1696	481	481
Media Cost, $/year	$157	$162	$5,089	$416,709	$46,301
Water usage, gal/year	185,204	185,204	347,257	0	0
Water cost ($/year)	$185	$185	$347	$0	$0
Nutrients ($/year)	$0	$0	$278	$0	$0
Manhours/Week	2.5	2.5	1.0	0.5	0.5
Maintenance	$8,130	$8,240	$4,050	$770	$2,140
ANNUAL OPERATING COST	**$55,192**	**$45,982**	**$20,743**	**$425,844**	**$56,806**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$793,186**	**$691,959**	**$580,660**	**$4,365,795**	**$759,327**

10,000 CFM, 5 PPM, 20 YEARS

SIEMENS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	10,000	10,000	10,000	10,000	10,000
Average Inlet H2S Concentration, ppm	5.0	5.0	5.0	5.0	5.0
H2S Loading, lb/hr	0.26	0.26	0.26	0.26	0.26
Model	PT-0500	LP-4500	BTF-1235	RJC-1000D	RJC-1000D
Packed bed width/diameter, ft	5.0	4.5	12.0	10.0	10.0
CFM/ft^2	509	494	88	64	64
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	15.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.2	2.8	2.8
Vessel Height, ft	22.0	13.0	27.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$163,000	$174,000	$290,000	$154,000	$168,000
Number of Systems	1	1	1	1	1
Chemical Tanks	$13,000	$10,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$246,400**	**$239,200**	**$377,000**	**$184,800**	**$201,600**
OPERATING COST ($/Yr):		$2			
Total System Horsepower	25	45	21	16	16
Total Power Cost $/yr)	$13,070	$23,526	$10,979	$8,365	$8,365
25% Sodium Hydroxide usage (gal/mo)	187	187			
Sodium Hydroxide cost ($/yr)	$2,696	$2,696	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	1,385	416			
12.5% Sodium Hypochlorite cost ($/yr)	$14,129	$4,239	$0	$0	$0
Media Life (years)	10	10	10	0.21	3.11
Media (cf)	196	203	1696	481	481
Media Cost, $/year	$157	$162	$5,089	$208,354	$23,150
Water usage, gal/year	92,602	92,602	173,629	0	0
Water cost ($/year)	$93	$93	$174	$0	$0
Nutrients ($/year)	$0	$0	$139	$0	$0
Manhours/Week	2.5	2.5	1.0	0.5	0.5
Maintenance	$8,130	$8,240	$4,050	$770	$2,140
ANNUAL OPERATING COST	**$38,275**	**$38,955**	**$20,431**	**$217,489**	**$33,655**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$622,186**	**$621,665**	**$577,591**	**$2,320,141**	**$532,032**

LIFE CYCLE COST

SCENARIO #3:

- AIR FLOW RATE 50,000 CFM
- H_2S CONCENTRATIONS: 20, 10, 1, 50, 100 PPM
- LIFE CYCLE PERIOD: 20 YEARS
- OBJECTIVE: MULTPLE BTFS EXPENSIVE TO INSTALL, BUT POTENTIAL SAVINGS HUGE; NEED DESIGN CONCENTRATION TO REALIZE SAVINGS

SIEMENS

50,000 CFM, 20 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	20.0	20.0	20.0	20.0	20.0
H2S Loading, lb/hr	5.29	5.29	5.29	5.29	5.29
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$81,750	$51,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$744,450**	**$732,225**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	3,744	3,744			
Sodium Hydroxide cost ($/yr)	$53,914	$53,914	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	27,705	8,311			
12.5% Sodium Hypochlorite cost ($/yr)	$282,588	$84,776	$0	$0	$0
Media Life (years)	10	10	10	0.05	0.75
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	$905	$784	$25,786	$1,041,772	$115,752
Water usage, gal/year	1,852,039	3,704,078	3,472,574	0	0
Water cost ($/year)	$1,852	$3,704	$3,473	$0	$0
Nutrients ($/year)	$0	$0	$2,778	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$454,817**	**$265,841**	**$138,023**	**$1,084,451**	**$179,321**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$5,209,915**	**$3,342,295**	**$3,071,125**	**$11,468,098**	**$2,667,802**

SIEMENS

50,000 CFM, 10 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	10.0	10.0	10.0	10.0	10.0
H2S Loading, lb/hr	2.64	2.64	2.64	2.64	2.64
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$72,500	$32,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$731,500**	**$707,525**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	1,872	1,872			
Sodium Hydroxide cost ($/yr)	$26,957	$26,957	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	13,852	4,156			
12.5% Sodium Hypochlorite cost ($/yr)	$141,294	$42,388	$0	$0	$0
Media Life (years)	10	10	10	0.10	1.51
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	$905	$784	$25,786	$520,886	$57,876
Water usage, gal/year	926,020	1,852,039	1,736,287	0	0
Water cost ($/year)	$926	$1,852	$1,736	$0	$0
Nutrients ($/year)	$0	$0	$1,389	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$285,641**	**$194,644**	**$134,897**	**$563,565**	**$121,445**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$3,535,964**	**$2,618,572**	**$3,040,440**	**$6,353,962**	**$2,099,565**

SIEMENS

50,000 CFM, 1 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	1.0	1.0	1.0	1.0	1.0
H2S Loading, lb/hr	0.26	0.26	0.26	0.26	0.26
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$21,000	$10,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$659,400**	**$678,600**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	187	187			
Sodium Hydroxide cost ($/yr)	$2,696	$2,696	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	1,385	416			
12.5% Sodium Hypochlorite cost ($/yr)	$14,129	$4,239	$0	$0	$0
Media Life (years)	10	10	10	1.00	15.07
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	$905	$784	$25,786	$52,089	$5,788
Water usage, gal/year	92,602	185,204	173,629	0	0
Water cost ($/year)	$93	$185	$174	$0	$0
Nutrients ($/year)	$0	$0	$139	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$133,382**	**$130,567**	**$132,084**	**$94,767**	**$69,356**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$1,968,962**	**$1,960,527**	**$3,012,824**	**$1,751,240**	**$1,588,151**

SIEMENS

50,000 CFM, 50 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	50.0	50.0	50.0	50.0	50.0
H2S Loading, lb/hr	13.21	13.21	13.21	13.21	13.21
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$91,500	$91,500	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$758,100**	**$784,550**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	9,360	9,360			
Sodium Hydroxide cost ($/yr)	$134,784	$134,784	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	69,262	20,779			
12.5% Sodium Hypochlorite cost ($/yr)	$706,469	$211,941	$0	$0	$0
Media Life (years)	10	10	10	0.02	0.30
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	$905	$784	$25,786	$2,604,430	$289,381
Water usage, gal/year	4,630,098	9,260,196	8,681,434	0	0
Water cost ($/year)	$4,630	$9,260	$8,681	$0	$0
Nutrients ($/year)	$0	$0	$6,945	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$962,348**	**$479,432**	**$147,398**	**$2,647,109**	**$352,950**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$10,206,570**	**$5,491,687**	**$3,163,180**	**$26,810,505**	**$4,372,514**

SIEMENS

50,000 CFM, 100 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	100.0	100.0	100.0	100.0	100.0
H2S Loading, lb/hr	26.43	26.43	26.43	26.43	26.43
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$91,500	$91,500	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$758,100**	**$784,550**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	18,720	18,720			
Sodium Hydroxide cost ($/yr)	$269,568	$269,568	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	138,523	41,557			
12.5% Sodium Hypochlorite cost ($/yr)	$1,412,939	$423,882	$0	$0	$0
Media Life (years)	10	10	10	0.01	0.15
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	$905	$784	$25,786	$5,208,860	$578,762
Water usage, gal/year	9,260,196	18,520,392	17,362,868	0	0
Water cost ($/year)	$9,260	$18,520	$17,363	$0	$0
Nutrients ($/year)	$0	$0	$13,890	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$1,808,231**	**$835,417**	**$163,025**	**$5,251,539**	**$642,331**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$18,511,578**	**$8,986,799**	**$3,316,604**	**$52,381,184**	**$7,213,700**

LIFE CYCLE COST

SCENARIO #4:

- AIR FLOW RATE 1,000 CFM
- H_2S CONCENTRATIONS: 10, 50 PPM
- LIFE CYCLE PERIOD: 20 YEARS
- OBJECTIVE: CARBON BENEFICIAL WHEN USING SINGLE SYSTEM AT LOW CONCENTRATION, BUT NO PROTECTION AGAINST HIGHER PPM

SIEMENS

1,000 CFM, 10 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	1,000	1,000	1,000	1,000	1,000
Average Inlet H2S Concentration, ppm	10.0	10.0	10.0	10.0	10.0
H2S Loading, lb/hr	0.05	0.05	0.05	0.05	0.05
Model	PT-0200	LP-1750	BTF-0427	RJC-0450S	RJC-0450S
Packed bed width/diameter, ft	2.0	1.75	4.0	4.5	4.5
CFM/ft^2	318	327	80	63	63
Single or dual bed (carbon only)				1.0	1.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	14.0	3.0	3.0
Media contact time, sec	1.9	1.8	10.6	2.9	2.9
Vessel Height, ft	22.0	13.0	26.0	9.0	9.0
CAPITAL EQUIPMENT					
Capital Cost per System	$119,000	$136,000	$85,000	$63,000	$65,000
Number of Systems	1	1	1	1	1
Chemical Tanks	$10,000	$10,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$180,600**	**$189,800**	**$110,500**	**$75,600**	**$78,000**
OPERATING COST ($/Yr):					
Total System Horsepower	5	10	4	3	3
Total Power Cost $/yr)	$2,614	$5,228	$2,091	$1,568	$1,568
25% Sodium Hydroxide usage (gal/mo)	37	37			
Sodium Hydroxide cost ($/yr)	$539	$539	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	277	83			
12.5% Sodium Hypochlorite cost ($/yr)	$2,826	$848	$0	$0	$0
Media Life (years)	10	10	10	0.11	1.58
Media (cf)	31	31	176	49	49
Media Cost, $/year	$25	$25	$528	$41,671	$4,630
Water usage, gal/year	18,520	18,520	34,726	0	0
Water cost ($/year)	$19	$19	$35	$0	$0
Nutrients ($/year)	$0	$0	$28	$0	$0
Manhours/Week	2.5	2.5	1.0	0.5	0.5
Maintenance	$7,690	$7,860	$3,025	$315	$1,625
ANNUAL OPERATING COST	**$13,713**	**$14,518**	**$5,706**	**$43,554**	**$7,823**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$315,233**	**$332,339**	**$166,527**	**$503,222**	**$154,812**

SIEMENS

1,000 CFM, 50 PPM, 20 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	1,000	1,000	1,000	1,000	1,000
Average Inlet H2S Concentration, ppm	50.0	50.0	50.0	50.0	50.0
H2S Loading, lb/hr	0.26	0.26	0.26	0.26	0.26
Model	PT-0200	LP-1750	BTF-0427	RJC-0450S	RJC-0450S
Packed bed width/diameter, ft	2.0	1.75	4.0	4.5	4.5
CFM/ft^2	318	327	80	63	63
Single or dual bed (carbon only)				1.0	1.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	14.0	3.0	3.0
Media contact time, sec	1.9	1.8	10.6	2.9	2.9
Vessel Height, ft	22.0	13.0	26.0	9.0	9.0
CAPITAL EQUIPMENT					
Capital Cost per System	$119,000	$136,000	$85,000	$63,000	$65,000
Number of Systems	1	1	1	1	1
Chemical Tanks	$13,000	$10,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$184,800**	**$189,800**	**$110,500**	**$75,600**	**$78,000**
OPERATING COST ($/Yr):					
Total System Horsepower	5	10	4	3	3
Total Power Cost $/yr)	$2,614	$5,228	$2,091	$1,568	$1,568
25% Sodium Hydroxide usage (gal/mo)	187	187			
Sodium Hydroxide cost ($/yr)	$2,696	$2,696	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	1,385	416			
12.5% Sodium Hypochlorite cost ($/yr)	$14,129	$4,239	$0	$0	$0
Media Life (years)	10	10	10	0.02	0.32
Media (cf)	31	31	176	49	49
Media Cost, $/year	$25	$25	$528	$208,354	$23,150
Water usage, gal/year	92,602	92,602	173,629	0	0
Water cost ($/year)	$93	$93	$174	$0	$0
Nutrients ($/year)	$0	$0	$139	$0	$0
Manhours/Week	2.5	2.5	1.0	0.5	0.5
Maintenance	$7,690	$7,860	$3,025	$315	$1,625
ANNUAL OPERATING COST	**$27,247**	**$20,140**	**$5,957**	**$210,238**	**$26,344**
EQUIPMENT LIFE CYCLE (yrs)	20	20	20	20	20
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$452,313**	**$387,533**	**$168,982**	**$2,139,746**	**$336,648**

LIFE CYCLE COST

REVISIT SCENARIO #1:

- AIR FLOW RATE 25,000 CFM
- H_2S CONCENTRATIONS: 20 PPM
- LIFE CYCLE PERIOD: 5 YEARS

- H2S CONCENTRATIONS: 20, 1 PPM
- LIFE CYCLE PERIOD: 1 YEARS
- OBJECTIVE: BTF NOT ECONOMICAL FOR IF USED FOR ONLY A FEW YEARS

SIEMENS

25,000 CFM, 20 PPM, 5 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	25,000	25,000	25,000	25,000	25,000
Average Inlet H2S Concentration, ppm	20.0	20.0	20.0	20.0	20.0
H2S Loading, lb/hr	2.64	2.64	2.64	2.64	2.64
Model	PT-0800	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	8.0	7.0	12.0	11.0	11.0
CFM/ft^2	497	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.3	1.4	1.4
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$227,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	1	2	2	2
Chemical Tanks	$72,500	$32,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$419,300**	**$374,725**	**$858,000**	**$410,400**	**$453,600**
OPERATING COST ($/Yr):					
Total System Horsepower	65	90	30	20	20
Total Power Cost $/yr)	$33,982	$47,052	$31,368	$20,912	$20,912
25% Sodium Hydroxide usage (gal/mo)	1,872	1,872			
Sodium Hydroxide cost ($/yr)	$26,957	$26,957	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	13,852	4,156			
12.5% Sodium Hypochlorite cost ($/yr)	$141,294	$42,388	$0	$0	$0
Media Life (years)	10	10	10	0.05	0.75
Media (cf)	503	490	4298	582	582
Media Cost, $/year	($804)	($784)	$12,893	$1,041,772	$115,752
Water usage, gal/year	926,020	926,020	1,736,287	0	0
Water cost ($/year)	$926	$926	$1,736	$0	$0
Nutrients ($/year)	$0	$0	$1,389	$0	$0
Manhours/Week	2.5	2.5	2.0	1.0	1.0
Maintenance	$8,770	$9,060	$12,050	$855	$6,145
ANNUAL OPERATING COST	**$211,124**	**$125,599**	**$59,436**	**$1,063,539**	**$142,809**
EQUIPMENT LIFE CYCLE (yrs)	5	5	5	5	5
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$1,262,258**	**$876,204**	**$1,095,312**	**$4,656,803**	**$1,023,796**

SIEMENS

25,000 CFM, 20 PPM, 1 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	25,000	25,000	25,000	25,000	25,000
Average Inlet H2S Concentration, ppm	20.0	20.0	20.0	20.0	20.0
H2S Loading, lb/hr	2.64	2.64	2.64	2.64	2.64
Model	PT-0800	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	8.0	7.0	12.0	11.0	11.0
CFM/ft^2	497	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.3	1.4	1.4
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$227,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	1	2	2	2
Chemical Tanks	$72,500	$32,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$419,300**	**$374,725**	**$858,000**	**$410,400**	**$453,600**
OPERATING COST ($/Yr):					
Total System Horsepower	65	90	30	20	20
Total Power Cost $/yr)	$33,982	$47,052	$31,368	$20,912	$20,912
25% Sodium Hydroxide usage (gal/mo)	1,872	1,872			
Sodium Hydroxide cost ($/yr)	$26,957	$26,957	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	13,852	4,156			
12.5% Sodium Hypochlorite cost ($/yr)	$141,294	$42,388	$0	$0	$0
Media Life (years)	10	10	10	0.05	0.75
Media (cf)	503	490	4298	582	582
Media Cost, $/year	($7,238)	($7,056)	$12,893	$1,041,772	$115,752
Water usage, gal/year	926,020	926,020	1,736,287	0	0
Water cost ($/year)	$926	$926	$1,736	$0	$0
Nutrients ($/year)	$0	$0	$1,389	$0	$0
Manhours/Week	2.5	2.5	2.0	1.0	1.0
Maintenance	$8,770	$9,060	$12,050	$855	$6,145
ANNUAL OPERATING COST	**$204,690**	**$119,327**	**$59,436**	**$1,063,539**	**$142,809**
EQUIPMENT LIFE CYCLE (yrs)	1	1	1	1	1
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$608,828**	**$485,213**	**$913,034**	**$1,395,158**	**$585,831**

SIEMENS

25,000 CFM, 1 PPM, 1 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	25,000	25,000	25,000	25,000	25,000
Average Inlet H2S Concentration, ppm	1.0	1.0	1.0	1.0	1.0
H2S Loading, lb/hr	0.13	0.13	0.13	0.13	0.13
Model	PT-0800	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	8.0	7.0	12.0	11.0	11.0
CFM/ft^2	497	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.2	1.2	10.3	1.4	1.4
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$227,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	1	2	2	2
Chemical Tanks	$24,250	$23,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$351,750**	**$362,700**	**$858,000**	**$410,400**	**$453,600**
OPERATING COST ($/Yr):					
Total System Horsepower	65	90	30	20	20
Total Power Cost $/yr)	$33,982	$47,052	$31,368	$20,912	$20,912
25% Sodium Hydroxide usage (gal/mo)	94	94			
Sodium Hydroxide cost ($/yr)	$1,348	$1,348	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	693	208			
12.5% Sodium Hypochlorite cost ($/yr)	$7,065	$2,119	$0	$0	$0
Media Life (years)	10	10	10	1.00	15.07
Media (cf)	503	490	4298	582	582
Media Cost, $/year	($7,238)	($7,056)	$12,893	$52,089	$5,788
Water usage, gal/year	46,301	46,301	86,814	0	0
Water cost ($/year)	$46	$46	$87	$0	$0
Nutrients ($/year)	$0	$0	$69	$0	$0
Manhours/Week	2.5	2.5	2.0	1.0	1.0
Maintenance	$8,770	$9,060	$12,050	$855	$6,145
ANNUAL OPERATING COST	**$43,972**	**$52,569**	**$56,467**	**$73,855**	**$32,844**
EQUIPMENT LIFE CYCLE (yrs)	1	1	1	1	1
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$392,465**	**$411,375**	**$910,284**	**$478,785**	**$484,012**

LIFE CYCLE COST

REVISIT SCENARIO #3:

- AIR FLOW RATE 50,000 CFM
- H_2S CONCENTRATIONS: 50, 5, 10, 20 PPM
- LIFE CYCLE PERIOD: 5 YEARS
- OBJECTIVE: BTF v LO/PRO TIPPING POINT NO LONGER 50 PPM

SIEMENS

50,000 CFM, 50 PPM, 5 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	50.0	50.0	50.0	50.0	50.0
H2S Loading, lb/hr	13.21	13.21	13.21	13.21	13.21
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$91,500	$91,500	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$758,100**	**$784,550**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	9,360	9,360			
Sodium Hydroxide cost ($/yr)	$134,784	$134,784	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	69,262	20,779			
12.5% Sodium Hypochlorite cost ($/yr)	$706,469	$211,941	$0	$0	$0
Media Life (years)	10	10	10	0.02	0.30
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	($1,810)	($1,568)	$25,786	$2,604,430	$289,381
Water usage, gal/year	4,630,098	9,260,196	8,681,434	0	0
Water cost ($/year)	$4,630	$9,260	$8,681	$0	$0
Nutrients ($/year)	$0	$0	$6,945	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$959,633**	**$477,080**	**$147,398**	**$2,647,109**	**$352,950**
EQUIPMENT LIFE CYCLE (yrs)	5	5	5	5	5
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$4,589,637**	**$2,689,393**	**$2,304,519**	**$11,389,938**	**$2,316,426**

SIEMENS

50,000 CFM, 5 PPM, 5 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	5.0	5.0	5.0	5.0	5.0
H2S Loading, lb/hr	1.32	1.32	1.32	1.32	1.32
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$91,500	$91,500	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$758,100**	**$784,550**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	936	936			
Sodium Hydroxide cost ($/yr)	$13,478	$13,478	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	6,926	2,078			
12.5% Sodium Hypochlorite cost ($/yr)	$70,647	$21,194	$0	$0	$0
Media Life (years)	10	10	10	0.20	3.01
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	($1,810)	($1,568)	$25,786	$260,443	$28,938
Water usage, gal/year	463,010	926,020	868,143	0	0
Water cost ($/year)	$463	$926	$868	$0	$0
Nutrients ($/year)	$0	$0	$695	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$198,338**	**$156,694**	**$133,335**	**$303,122**	**$92,507**
EQUIPMENT LIFE CYCLE (yrs)	5	5	5	5	5
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$1,550,007**	**$1,410,183**	**$2,248,366**	**$2,031,077**	**$1,276,553**

SIEMENS

50,000 CFM, 10 PPM, 5 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	10.0	10.0	10.0	10.0	10.0
H2S Loading, lb/hr	2.64	2.64	2.64	2.64	2.64
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$72,500	$32,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$731,500**	**$707,525**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	1,872	1,872			
Sodium Hydroxide cost ($/yr)	$26,957	$26,957	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	13,852	4,156			
12.5% Sodium Hypochlorite cost ($/yr)	$141,294	$42,388	$0	$0	$0
Media Life (years)	10	10	10	0.10	1.51
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	($1,810)	($1,568)	$25,786	$520,886	$57,876
Water usage, gal/year	926,020	1,852,039	1,736,287	0	0
Water cost ($/year)	$926	$1,852	$1,736	$0	$0
Nutrients ($/year)	$0	$0	$1,389	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$282,926**	**$192,292**	**$134,897**	**$563,565**	**$121,445**
EQUIPMENT LIFE CYCLE (yrs)	5	5	5	5	5
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$1,861,143**	**$1,475,293**	**$2,254,605**	**$3,070,951**	**$1,392,095**

SIEMENS

50,000 CFM, 20 PPM, 5 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	50,000	50,000	50,000	50,000	50,000
Average Inlet H2S Concentration, ppm	20.0	20.0	20.0	20.0	20.0
H2S Loading, lb/hr	5.29	5.29	5.29	5.29	5.29
Model	PT-1200	LP-7000	BTF-1236	RJC-1100D	RJC-1100D
Packed bed width/diameter, ft	12.0	7.0	12.0	11.0	11.0
CFM/ft^2	442	510	111	59	59
Single or dual bed (carbon only)				2.0	2.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	19.0	3.0	3.0
Media contact time, sec	1.4	0.6	10.3	0.7	0.7
Vessel Height, ft	22.0	13.0	31.0	13.0	13.0
CAPITAL EQUIPMENT					
Capital Cost per System	$450,000	$256,000	$330,000	$171,000	$189,000
Number of Systems	1	2	4	4	4
Chemical Tanks	$81,750	$51,250	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$744,450**	**$732,225**	**$1,716,000**	**$820,800**	**$907,200**
OPERATING COST ($/Yr):					
Total System Horsepower	200	90	30	20	20
Total Power Cost $/yr)	$104,559	$94,103	$62,736	$41,824	$41,824
25% Sodium Hydroxide usage (gal/mo)	3,744	3,744			
Sodium Hydroxide cost ($/yr)	$53,914	$53,914	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	27,705	8,311			
12.5% Sodium Hypochlorite cost ($/yr)	$282,588	$84,776	$0	$0	$0
Media Life (years)	10	10	10	0.05	0.75
Media (cf)	1131	980	8595	582	582
Media Cost, $/year	($1,810)	($1,568)	$25,786	$1,041,772	$115,752
Water usage, gal/year	1,852,039	3,704,078	3,472,574	0	0
Water cost ($/year)	$1,852	$3,704	$3,473	$0	$0
Nutrients ($/year)	$0	$0	$2,778	$0	$0
Manhours/Week	2.5	5.0	4.0	2.0	2.0
Maintenance	$11,000	$28,560	$43,250	$855	$21,745
ANNUAL OPERATING COST	**$452,103**	**$263,489**	**$138,023**	**$1,084,451**	**$179,321**
EQUIPMENT LIFE CYCLE (yrs)	5	5	5	5	5
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$2,549,567**	**$1,784,262**	**$2,267,084**	**$5,150,698**	**$1,623,178**

LIFE CYCLE COST

REVISIT SCENARIO #5:

- AIR FLOW RATE 1,000 CFM
- H_2S CONCENTRATIONS: 50 PPM
- LIFE CYCLE PERIOD: 1 YEARS

- H2S CONCENTRATIONS: 20 PPM
- LIFE CYCLE PERIOD: 5 YEARS
- OBJECTIVE: CARBON ATTRACTIVE FOR TEMPORARY

SIEMENS

1,000 CFM, 50 PPM, 1 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	1,000	1,000	1,000	1,000	1,000
Average Inlet H2S Concentration, ppm	50.0	50.0	50.0	50.0	50.0
H2S Loading, lb/hr	0.26	0.26	0.26	0.26	0.26
Model	PT-0200	LP-1750	BTF-0427	RJC-0450S	RJC-0450S
Packed bed width/diameter, ft	2.0	1.75	4.0	4.5	4.5
CFM/ft^2	318	327	80	63	63
Single or dual bed (carbon only)				1.0	1.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	14.0	3.0	3.0
Media contact time, sec	1.9	1.8	10.6	2.9	2.9
Vessel Height, ft	22.0	13.0	26.0	9.0	9.0
CAPITAL EQUIPMENT					
Capital Cost per System	$119,000	$136,000	$85,000	$63,000	$65,000
Number of Systems	1	1	1	1	1
Chemical Tanks	$13,000	$10,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$184,800**	**$189,800**	**$110,500**	**$75,600**	**$78,000**
OPERATING COST ($/Yr):					
Total System Horsepower	5	10	4	3	3
Total Power Cost $/yr)	$2,614	$5,228	$2,091	$1,568	$1,568
25% Sodium Hydroxide usage (gal/mo)	187	187			
Sodium Hydroxide cost ($/yr)	$2,696	$2,696	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	1,385	416			
12.5% Sodium Hypochlorite cost ($/yr)	$14,129	$4,239	$0	$0	$0
Media Life (years)	10	10	10	0.02	0.32
Media (cf)	31	31	176	49	49
Media Cost, $/year	($452)	($441)	$528	$208,354	$23,150
Water usage, gal/year	92,602	92,602	173,629	0	0
Water cost ($/year)	$93	$93	$174	$0	$0
Nutrients ($/year)	$0	$0	$139	$0	$0
Manhours/Week	2.5	2.5	1.0	0.5	0.5
Maintenance	$7,690	$7,860	$3,025	$315	$1,625
ANNUAL OPERATING COST	**$26,769**	**$19,674**	**$5,957**	**$210,238**	**$26,344**
EQUIPMENT LIFE CYCLE (yrs)	1	1	1	1	1
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$209,586**	**$208,017**	**$116,015**	**$270,265**	**$102,392**

SIEMENS

1,000 CFM, 20 PPM, 5 YEARS

Present Value Analysis	SINGLE STAGE CHEMICAL SCRUBBER	MULTIPLE STAGE CHEMICAL SCRUBBER	BIO-TRICKLING SCRUBBER	CARBON ADSORBER WITH P60 VIRGIN CARBON	CARBON ADSORBER WITH MIDAS CARBON
DESIGN SPECIFICATIONS:					
Design Air Flow Rate, scfm	1,000	1,000	1,000	1,000	1,000
Average Inlet H2S Concentration, ppm	20.0	20.0	20.0	20.0	20.0
H2S Loading, lb/hr	0.11	0.11	0.11	0.11	0.11
Model	PT-0200	LP-1750	BTF-0427	RJC-0450S	RJC-0450S
Packed bed width/diameter, ft	2.0	1.75	4.0	4.5	4.5
CFM/ft^2	318	327	80	63	63
Single or dual bed (carbon only)				1.0	1.0
Media Type	Lantec 3.5	Lantec 3.5	PUF cubes	P60 Virgin Carbon	Midas OCM
Media height	10.0	10.0	14.0	3.0	3.0
Media contact time, sec	1.9	1.8	10.6	2.9	2.9
Vessel Height, ft	22.0	13.0	26.0	9.0	9.0
CAPITAL EQUIPMENT					
Capital Cost per System	$119,000	$136,000	$85,000	$63,000	$65,000
Number of Systems	1	1	1	1	1
Chemical Tanks	$10,000	$10,000	$0	$0	$0
Installation Factor (Capital cost x IF = installed cost)	1.40	1.30	1.30	1.20	1.20
INSTALLED CAPITAL COST	**$180,600**	**$189,800**	**$110,500**	**$75,600**	**$78,000**
OPERATING COST ($/Yr):					
Total System Horsepower	5	10	4	3	3
Total Power Cost $/yr)	$2,614	$5,228	$2,091	$1,568	$1,568
25% Sodium Hydroxide usage (gal/mo)	75	75			
Sodium Hydroxide cost ($/yr)	$1,078	$1,078	$0	$0	$0
Sodium Hypochlorite usage (gal/mo)	554	166			
12.5% Sodium Hypochlorite cost ($/yr)	$5,652	$1,696	$0	$0	$0
Media Life (years)	10	10	10	0.05	0.79
Media (cf)	31	31	176	49	49
Media Cost, $/year	($50)	($49)	$528	$83,342	$9,260
Water usage, gal/year	37,041	37,041	69,451	0	0
Water cost ($/year)	$37	$37	$69	$0	$0
Nutrients ($/year)	$0	$0	$56	$0	$0
Manhours/Week	2.5	2.5	1.0	0.5	0.5
Maintenance	$7,690	$7,860	$3,025	$315	$1,625
ANNUAL OPERATING COST	**$17,021**	**$15,850**	**$5,769**	**$85,225**	**$12,454**
EQUIPMENT LIFE CYCLE (yrs)	5	5	5	5	5
COST OF MONEY (Annual %)	8%	8%	8%	8%	8%
PRESENT VALUE COST	**$248,559**	**$253,084**	**$133,534**	**$415,879**	**$127,724**

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