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# ODOR CONTROL



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# Why Odor Control?

- 20 years ago there was little talk of odor control.  WWTP’s and PS were located out of town, and 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)

# Nuisance vs. Hazardous Odors

| Compound | Typical Concentration Range*, ppm | Nuisance odor, ppm | Health Hazard, ppm | Explosion hazard, ppm |
|---|---|---|---|---|
| Hydrogen Sulphide | 0.05 to 500 | 0.001 | 20/100 | 40,000 |
| Ammonia | 0 to 200 | 17 | 50/300 | 15,000 |
| Methyl Mercaptan | 0.001 to 1 | 0.001 | 10/150 | 39,000 |
| Carbon Disulphide | 0.01 to 10 | 0.03 | 20/500 | 13,000 |

# Hydrogen Sulfide Concerns

**$H_2S$ is primary odour, typically 10 to 100 times more concentrated than other odors**

- *Rotten Egg Odor,*
- *Low Odor Threshold (~1 ppb)*
- *Typical concentrations from 10 to 500 ppm or more*

**Safety - Exposure Effects:**

- *Nuisance Odor (below 10 ppm)*
- *Headache and Nausea (10 - 50 ppm)*
- *Eye/Lung Damage (50 - 500 ppm)*
- *Collapse and Death (500+ ppm)*

**Corrosion:**

- *Forms Sulfuric Acid in Condensate*

# Hydrogen Sulfide Odor and Toxicity

Rotten Egg Odor Alarm

Serious Eye Injury

Loss of Sense of Smell

Imminent Life Threat

Immediate Collapse

| |
|---|
| Odor Threshold |
| Offensive Odor |
| Headache, Nausea<br>Throat and Eye Irritation |
| Eye Injury |
| Conjunctivitis, Respiratory Tract Irritation, Olfactory Paralysis |
| Pulmonary Edema |
| Strong Nervous System Stimulation<br>Apnea |
| Death |

0.1

3

10

50

100

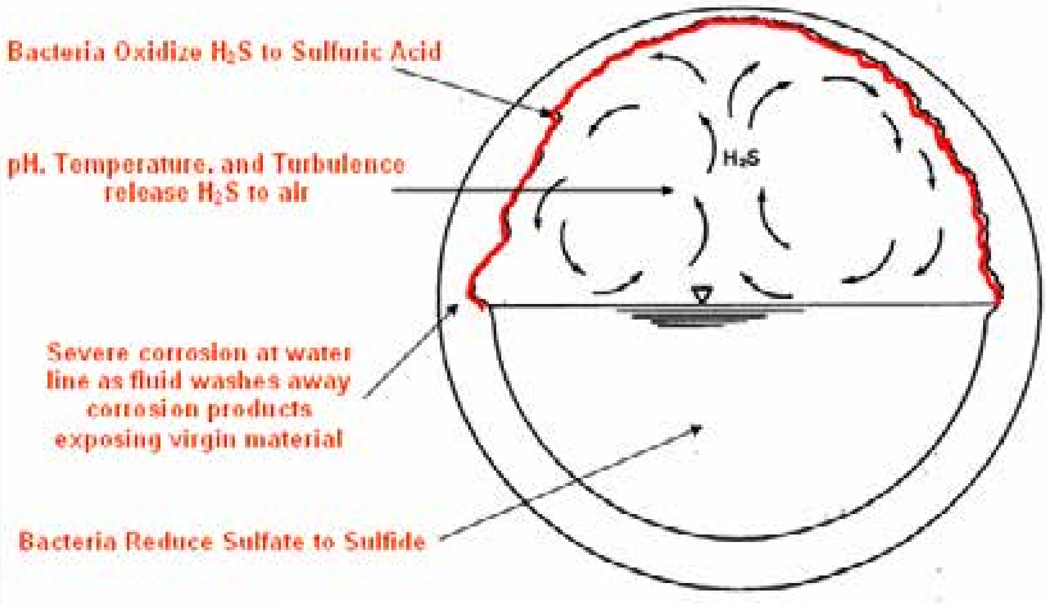
300

500

1,000

2,000 ppm

# Hydrogen Sulfide and Corrosion



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# 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**

- *Long detention times allow for longer anaerobic zones*

# Conditions Promoting Hydrogen Sulphide Release

**Temperature**

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

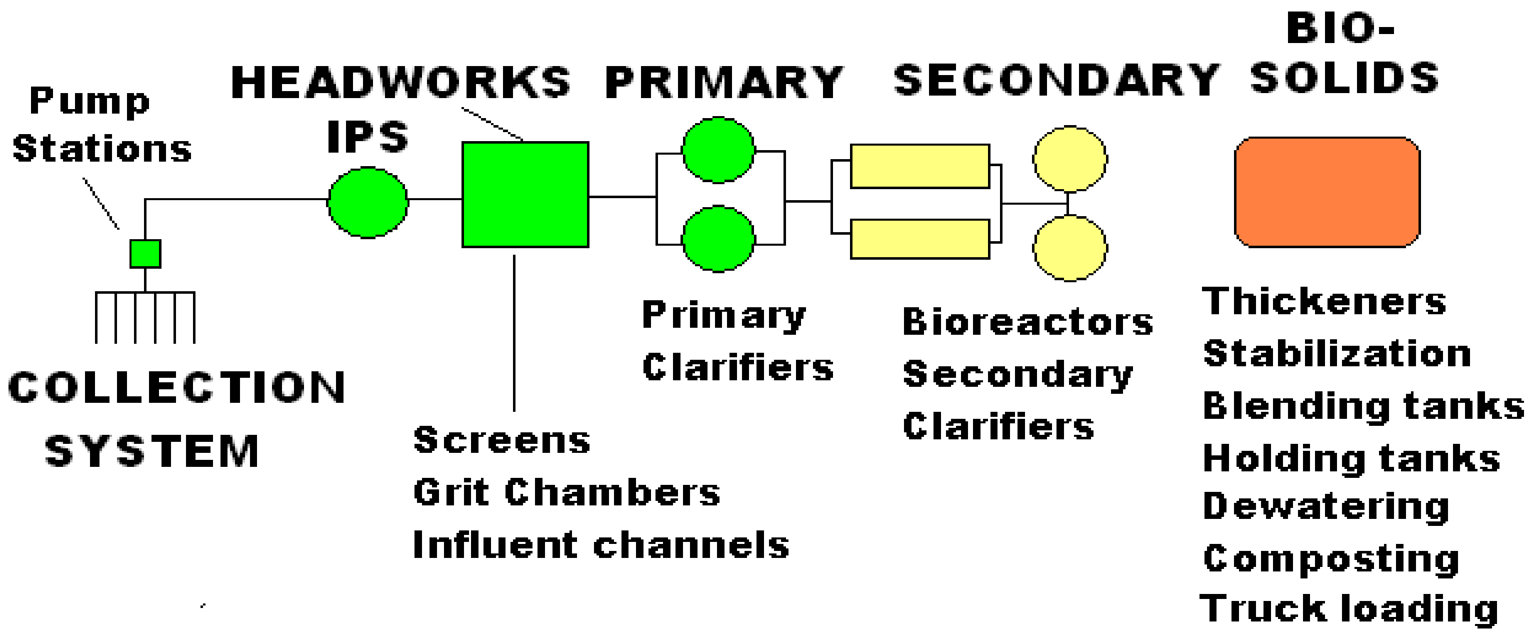
**pH**

- *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.*

# Municipal Odor Control Applications



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# Types of Odors

**Hydrogen Sulfide ($H_2S$)**

- *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 Process*

| Sulphur Compounds | Formula | Odour description | Odour Threshold ppb | Typical Ranges ppb |
|---|---|---|---|---|
| Hydrogen Sulphide | $H_2S$ | Rotten eggs | 0.5 | 50-500000 |
| Dimethyl Sulphide | $CH_3$-S-$CH_3$ | Decayed vegetables | 0.1-2 | 10-1000 |
| Dimethyl Disulphide | $CH_3$-S-S-$CH_3$ | Decayed vegetables | 0.1-2 | 1-100 |
| Methyl Mercaptan | $CH_3$-SH | Decayed cabbage | 0.7 | 10-1000 |
| Ethyl mercaptan | $CH_3$-$CH_2$-SH | Decayed cabbage | 0.2 | 1-100 |
| Carbon disulphide | $CS_2$ | 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 Process

| Nitrogen Compounds | Formula | Odour description | Odour Threshold ppb | Typical Ranges ppb |
|---|---|---|---|---|
| Ammonia | $NH_3$ | Pungent | 17 | 1000-200000 |
| Methylamine | $CH_3NH_2$ | Rotten fish | 53 | 20-200 |
| Dimethylamine | $(CH_3)_2NH$ | Fishy, ammonia | 49 | 20-200 |
| Trimethylamine | $(CH_3)_3N$ | Fishy, ammonia | 40 | 20-200 |
| Skatole | $C_9H_9N$ | Fecal, repulsive | 0.06 | 1-100 |
| Indole | $C_2H_6NH$ | 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 |

# *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.*

# *There are many requirements beyond the Systems*

- Odor containment (covers, buildings)
- Odor conveyance (ductwork, dampers)
- Odor control equipment
- Chemical dosing (chemical tanks, piping, dosing pumps)
- Blowdown streams (neutralization, drainage)
- Exhaust Stack (dispersion modeling)
- Odor monitoring (on-line monitors, performance tests)
- Controls & instrumentation

- Civil works, site preparation
- Mechanical installation
- Electrical installation
- Taxes, duties, customs clearance, handling, local transportation

# Determining Airflow Rate Required

- **Air Changes per hour (ACH) = ventilation rate**

- Occupied spaces “typically” use 12 to 20 ACH

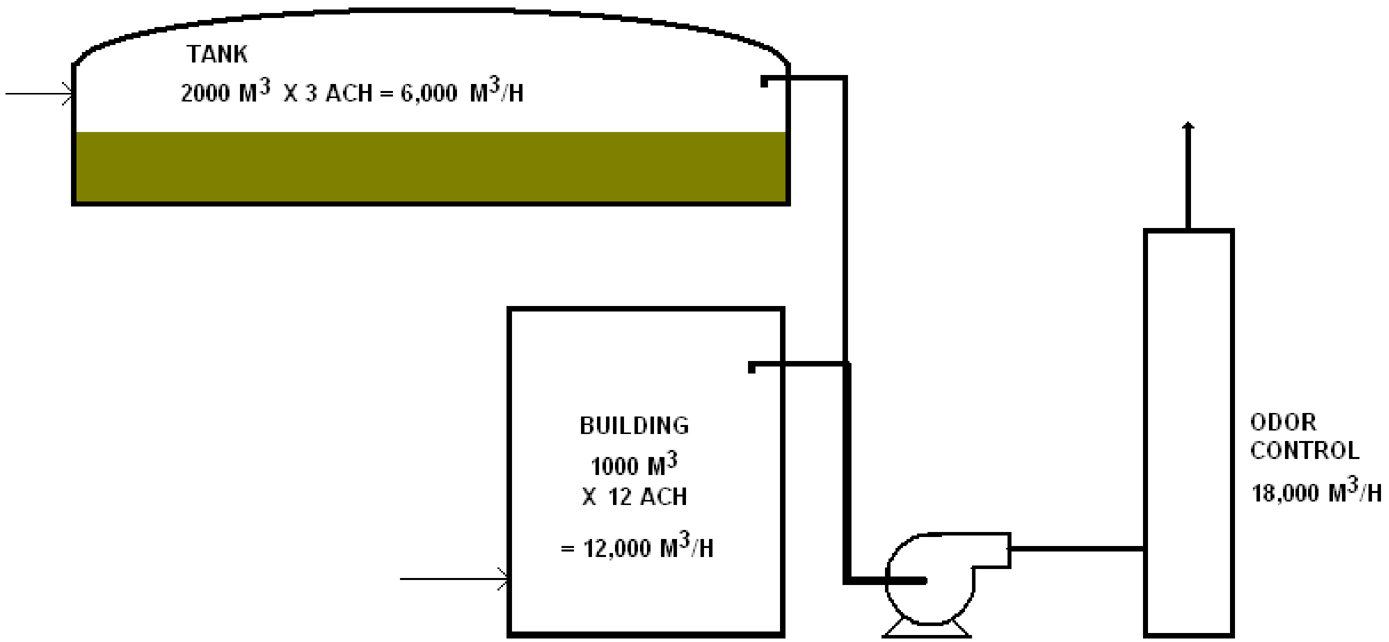
  - » Headworks building
  - » Dewatering building
  - » Pump Stations

- Unoccupied spaces “typically” use 3 to 6 ACH

  - » Storage Tanks
  - » Clarifiers
  - » Wet wells

# Determining Airflow Rate Required

ACH X AIR VOLUME (M3) = AIR FLOW RATE (M3/H)



# *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*

# Chemical Scrubber Systems

- Technology
- Design
- Features & Benefits
- Process Flow Diagram
- General Arrangement Drawing

# Technology Comparison for Chemical scrubbers

**Benefits:**

- **Most reliable and flexible vapor phase treatment technology**
- **High removal efficiency (99.5%+)**
- **Can respond instantly to changing H2S loads**
- **Small footprint required (150 m/min velocity)**
- **Can remove any water soluble compound**
- **Can run intermittently**

**Drawback :**

- **Chemicals required, typically sodium hydroxide (NaOH) and sodium hypochlorite (NaOCl), which can be costly**
- **Footprint becomes an issue mostly in indoor or congested installations**

**Types:**

- **Vertical, counter-current (most efficient)**
- **Horizontal, cross-flow**

# Chemical Scrubber Design Configurations

**There are many ways to contact a liquid and a gas**:

- **Countercurrent vs. Co-current Flow**
  - Refers to relative direction air and liquid flow
  - Countercurrent is more efficient, requiring 50-100% less packing to achieve equivalent performance

- **Single Stage vs. Multiple Stage**
  - Multiple stage provides more process chemistry options and can reduce chemical usage by 50% or more

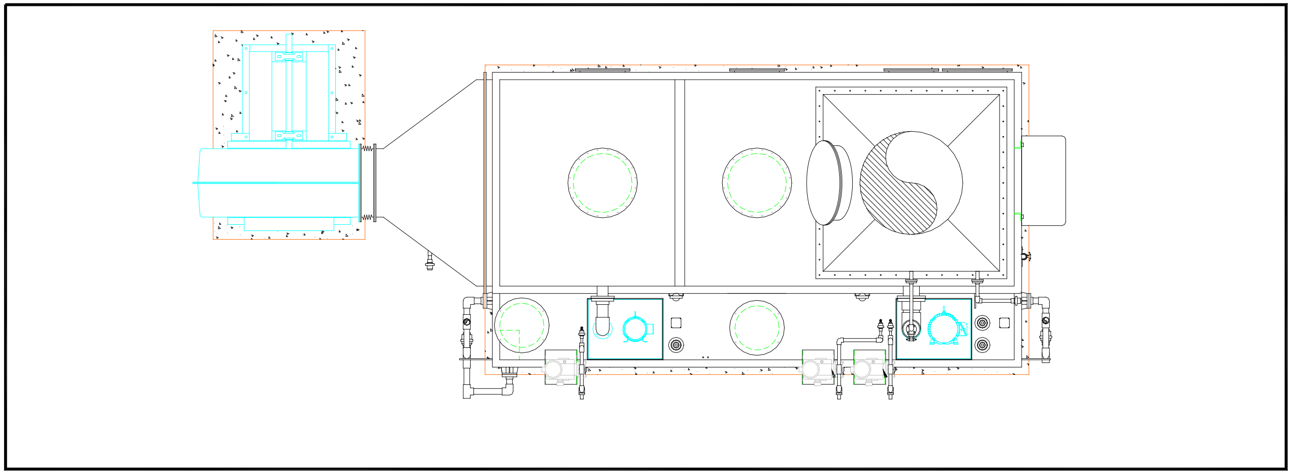
- **Vertical Flow vs. Horizontal Flow**
  - Vertical countercurrent flow gives most efficient mass transfer.
  - Horizontal air flow with vertical downward liquid flow does not provide reactant evenly over packing cross section

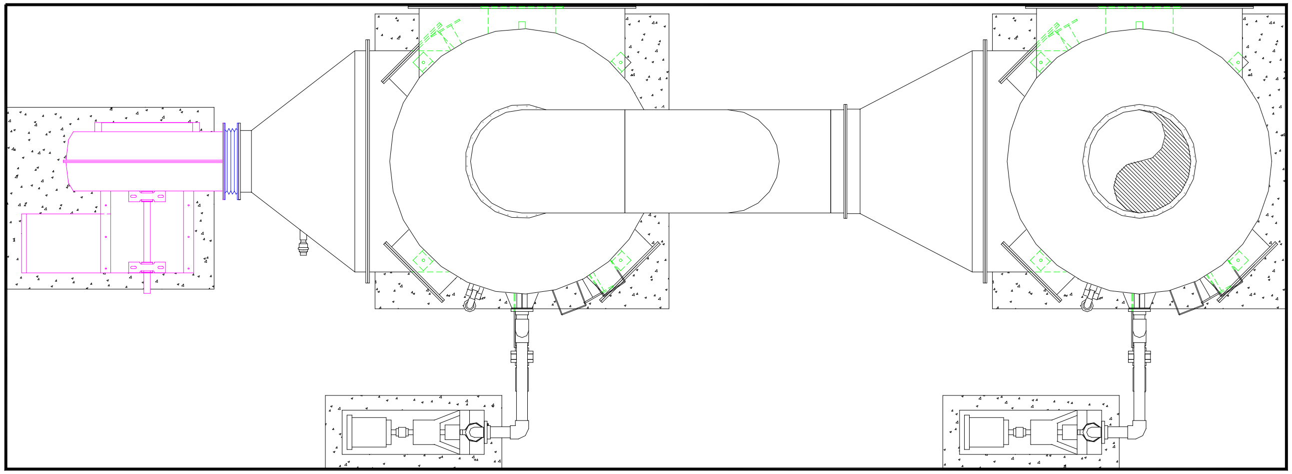
# *New Chemical Package Systems*

- Typical vertical, counter-current "Packed Towers" are often 6.0 meters or more in height.
- Past footprint constraints alleviated by "turning the tower" on its side, which causes the air to travel perpendicular through the vessel in a horizontal, cross-flow arrangement.  This arrangement causes some air to short-circuit across the top of the media.

**Rectangular, packaged units have multiple compartments of packing side-by-side and reduce the height to 3.5 meters or less.  Generally, at least two of these compartments are vertical, counter-current arrangement.  An extended sump allows pumps, probes, instruments and controls to be pre-installed and pre-wired.**

# Footprint Comparison  ( 40,000 m3/h)





# *Chemical Package Systems (CPS Series)*

- Provide the benefits of two-stages of scrubbing in a compact footprint
- Significantly reduced overall height (typically less than 3.5 meters vs. 6.0+ meters for a traditional packed towers

**All Components Pre-Installed**

**Factory Assembled and Tested**

**Field Assembly Limited to Fan, Stack and Chemical Storage Tanks**

**Ease of Installation**

**Start-up Simplicity**

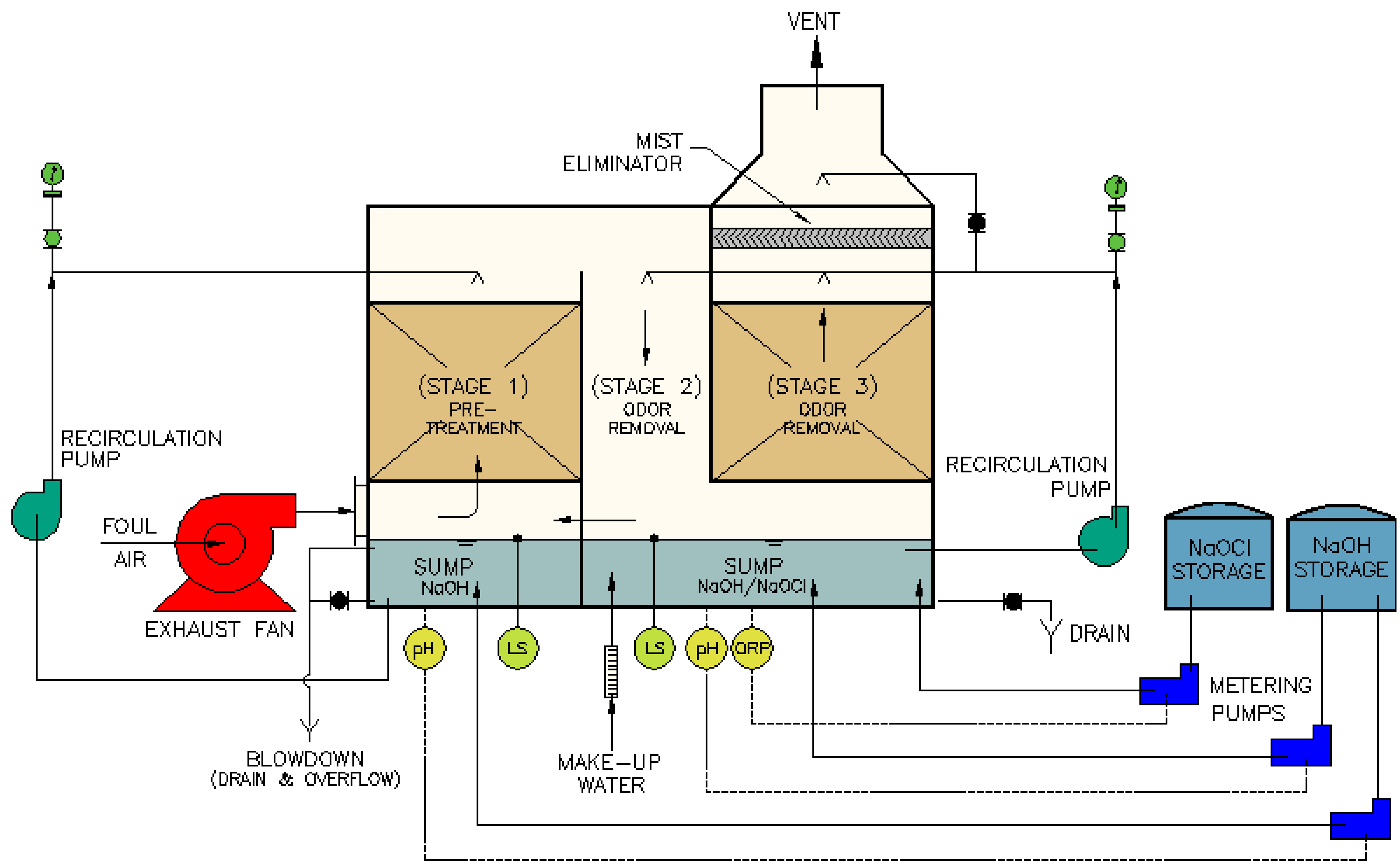
**System Responsibility**

**Guaranteed Performance (99.5%+ Removal)**

# Minimal Chemical Consumption

- Pre-treatment stage eliminates approximately 70% of odors using a less expensive chemical
- Complete utilization of chemicals prior to discharge with multiple sumps
- Counter-current chemistry
- Optimal process control

# Process Flow Diagram



# Multiple Stage Process Configurations

- **The multi-stage Process Can Be Configured in Several Ways:**
- **(2-Stage or 3-Stage designs)**

– **For H2S removal up to 100 ppm**
  **Stage 1 = NaOH,**
  **Stage 2 = NaOCl + NaOH**

– **For high H2S (> 100 ppm)**
  **Stage 1 & Stage 2 = NaOH**
  **Stage 3 = NaOH + NaOCl)**

– **For NH3/amines and H2S/sulfides**
  **Stage 1 = H2SO4**
  **Stage 2 = NaOH**
  **Stage 3 = NaOCl + NaOH**

– **For high mercaptans and organic sulfides**
  **Stage 1 = NaOCl + NaOH**
  **Stage 2 = NaOH**

# Multi-stage Scrubber Chemistry

**Ammonia Stage: Optional**

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO$$

**H2S Pre-treatment Stage: may be one or more stages**

$$H_2S + 2NaOH \longrightarrow Na_2S + 2H_2O$$

**H2S Final Polishing Stage**

$$H_2S + 2NaOH + 4NaOCl \longrightarrow Na_2SO4 + 4NaCl + 2H_2O$$

# Biological Odor Control Systems

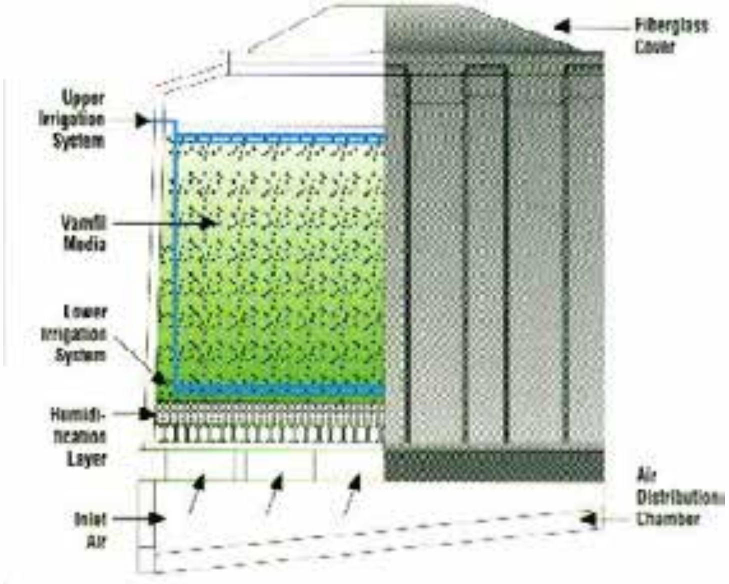

# Biological Process

- *Biological odor control systems are designed to promote the growth of sulfur-oxidizing bacteria which under proper conditions will biologically oxidize $H_2S$ and other sulfur compounds to soluble sulfates*

- *Requires a liquid film to transfer odorous compounds from the gas phase to liquid and make those compounds "bioavailable"*

- *$H_2S$ is removed under acidic pH conditions and generates acid ($H_2SO_4$)*

- *Organic odors require higher residence time and neutral pH conditions*



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# *Requirements of Sulfur-Oxidizing Bacteria*

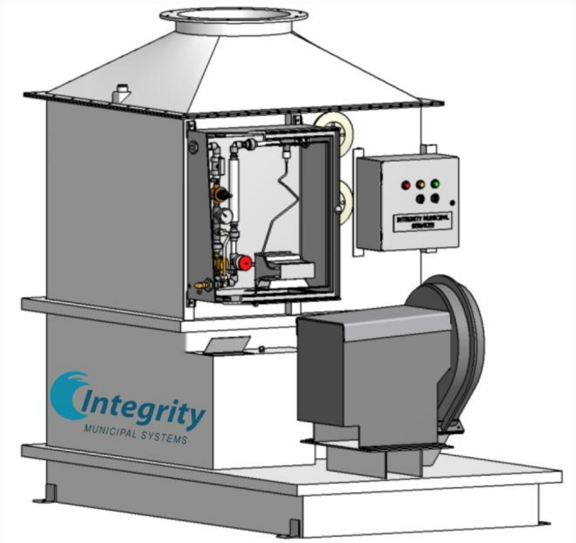
- *Energy source:*
  - *$H_2S$ and other sulfur compounds*
- *Carbon source:*
  - *Organic matter (heterotrophic bacteria)*
  - *Carbon dioxide (autotrophic bacteria)*
- *Nutrients: nitrate, phosphate, potassium*
- *Water*
- *Oxygen ($H_2S + O_2 \rightarrow H_2SO_4$)*
- *Temperature (10 to 50°C)*
- *Time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

# *Sulfur-Oxidizing Bacteria*

| Species | Primary Electron Donor | pH Range |
| --- | --- | --- |
| Thiobacillus - grow poorly in organic media | | |
| *Thiobacillus thioparus* | $H_2S$, sulfides, sulfur, thiosulfate | 6 to 8 |
| *Thiobacillus denitrificans* | $H_2S$, sulfur, thiosulfate | 6 to 8 |
| *Thiobacillus neapolitanus* | sulfur, thiosulfate | 5 to 8 |
| *Thiobacillus thiooxidans* | $H_2S$, 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* | $H_2S$, thiosulfate | 6 to 8 |
| *Thiotrix* | $H_2S$ | 6 to 8 |
| *Thiomicrospira* | $H_2S$, thiosulfate | 6 to 8 |
| *Thermothrix* | $H_2S$, sulfite, thiosulfate | 6.5 to 7.5 |
| *Sulfolobus* | $H_2S$, sulfur | 1 to 4 |

# Biological Odor Control System

- *Two-stage biological system that provides point source odor control.*
- *Biological reaction phase for the removal of $H_2S$ in the first stage with an inert inorganic media widely used for biological treatment*
- *Polishing Second stag for $H_2S$ and organic odors*
- *Compact design*
- *99 +% removal Efficiency*
- *Capacities up to 6000 $m^3/h$*
- *Plug & Play Installation*

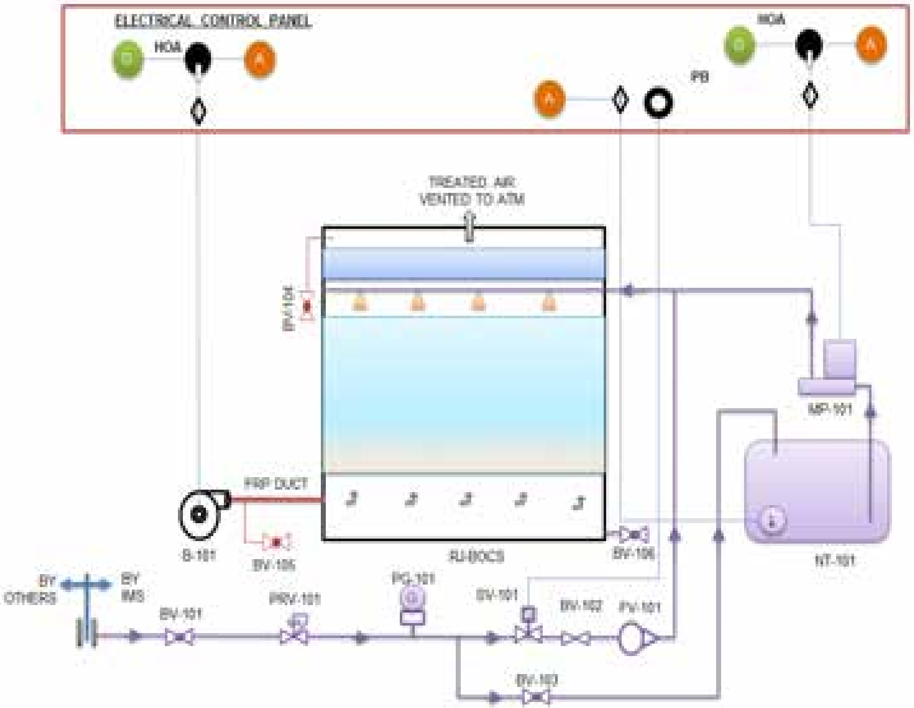



I-BOx™

# How It Works

***The system is comprised of two distinct process stages that can designed to be site specific depending on the type and concentration of odorous compounds***

- ***<u>Stage 1</u>*** *is designed to remove primarily hydrogen sulfide ($H_2S$) by promoting the growth of acidophilic, sulfur-oxidizing bacteria*
- ***<u>Stage 2</u>*** *is used to remove any remaining hydrogen sulfide as well as other odorous organic compounds.*



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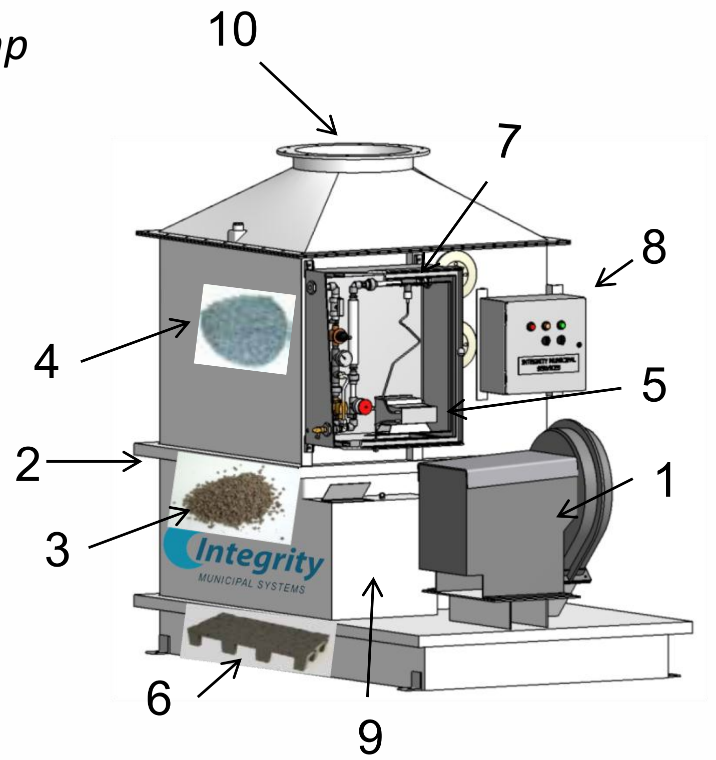
# Major System Components

1. FRP Exhaust Fan with Transition to Vessel Inlet
2. Premium Vinyl Ester FRP Vessel with Extended Sump
3. Inorganic Biological Media (Stage 1)
4. Activated Carbon Media (Stage 2)
5. Nutrient Pump
6. Air Distribution System
7. Water panel with Media Irrigation System
8. FRP Control Panel with VFD
9. Nutrient Tank
10. FRP Exhaust Stack



# I-BOx™ Media

CLAY MEDIA

PELLETIZED CARBON MEDIA

# I-BOx™ Advantages

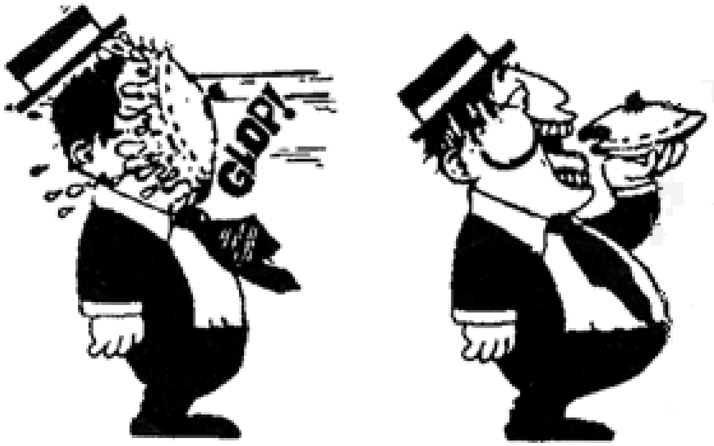
- *High air flow rate (~450 $m^3/h$ per $m^2$, compared to 100 $m^3/h$ per $m^2$ for conventional organic biofilters)*
- *Inorganic media biofilter → long media life, preferential development of autotrophic bacteria*
- *Quick acclimation → specialized media adsorbs odors during acclimation period, for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

# Carbon Odor Control Systems


# ADSORPTION vs. ABSORPTION

**ADsorption —** *physical adherence of molecules to surface of media*

**Absorption —** *soaking up of molecules into media or solution*



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# Available Odor Control Carbons

**Standard, Untreated Granular or Pelletized Activated Carbon**

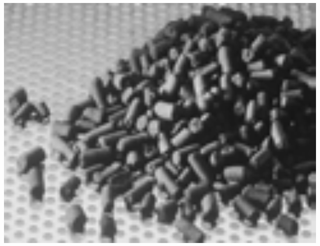
- *Bituminous Coal Based*
- *Coconut Shell Based*

**Chemically Treated Activated Carbons**

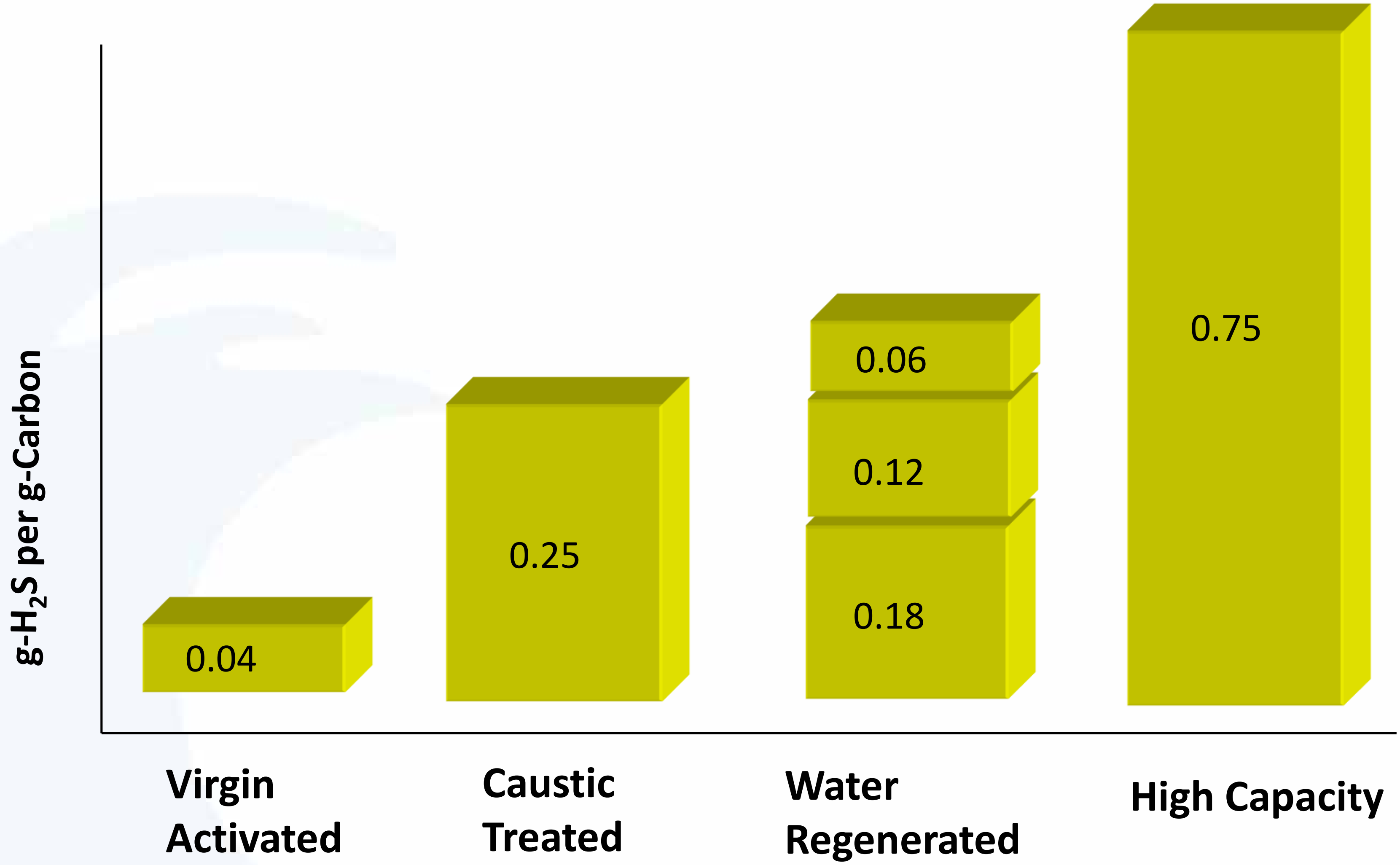
- *Caustic Impregnated, KOH and NaOH*
- *KI Impregnated*

**"High Capacity" Carbons Based Adsorbents**

- *Water regenerable carbon*
- *Natural high mineral carbon media*
- *Sulfur Selective Odor Control Media*

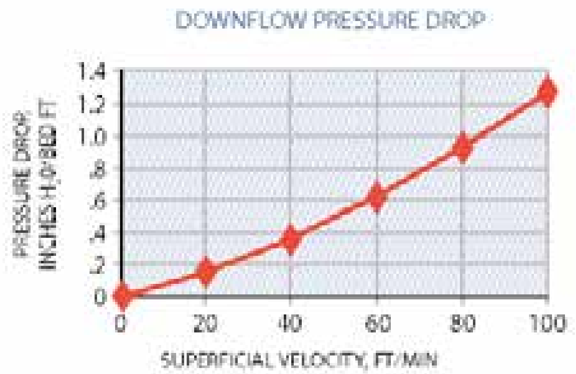


# *Carbon Capacity Comparison*

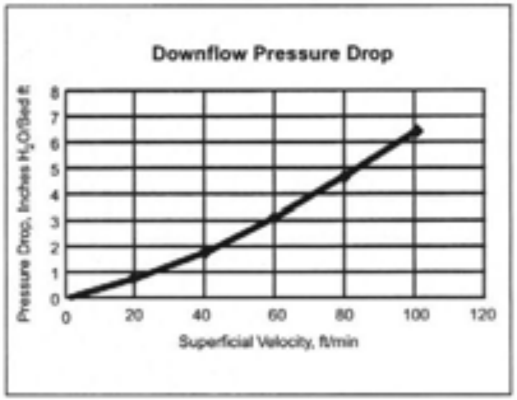


# *Granular vs. Pelletized Carbons*

Granular and Pelletized carbons have similar odor removal capabilities, however pelletized carbons have much lower pressure drop, and hence lower energy usage.




Pelletized Carbon



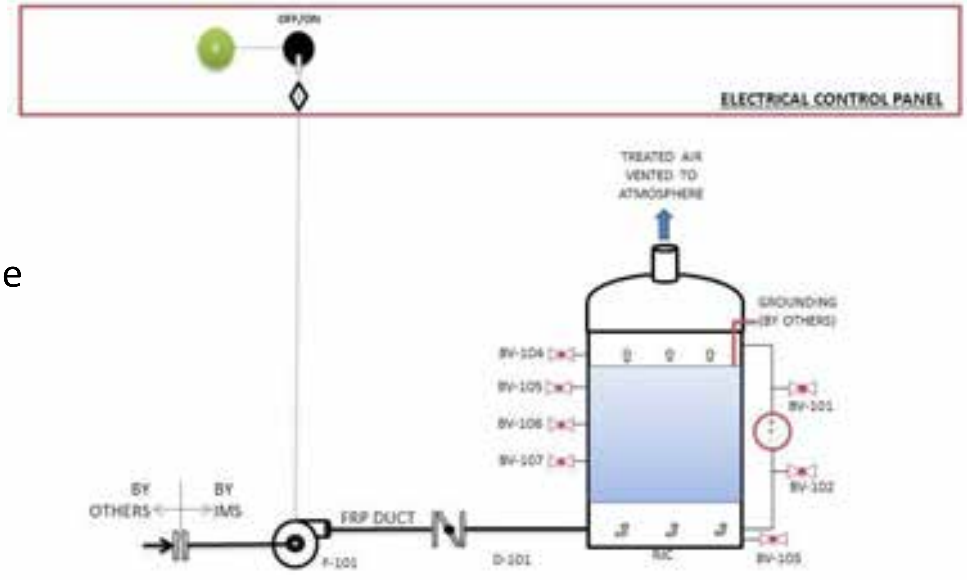

Granular carbon

# Factors That Influence the Carbon Loading Capacity

- *Relative Humidity*
- *Temperature*
- *Contaminant Properties*
- *Contaminant Concentration*
- *Pressure (Vacuum)*
- *Gas Flow Rate (EBCT) and Superficial Velocity*
- *Heat of Adsorption*
- *System Configuration*

# How It Works

The exhaust fan operates continuously, pulling foul air from the process area and passing it through the carbon media. A volume control damper at the system inlet allows regulation of airflow through the carbon adsorber.




Inside the vessel, the foul air flows through a densely packed bed of activated carbon. The odorous compounds are removed from the airstream through a combination of physical adsorption and chemisorption.

Odorous compounds are physically adsorbed in the carbon pores, and some may undergo chemical reaction to form elemental sulfur and sulfuric acid. This process continues until the activated carbon pores are filled up and the odorous compounds break through and are released out the stack.

# Single & Dual Bed Carbon Adsorbers

- *Air flow rates to 6,800 cfm (11,600 m3/h) for single bed, and 20,000 cfm (34,000 m3/h) for dual bed*
- *FRP construction*
- *Fan, stack, dampers, duct ship separately for field installation*
- *Media must be field installed*
- *Optional Acoustic enclosure*
- *Optional Grease filter*
- *Media change out more difficult in dual bed designs*



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# Skid Mounted Carbon Adsorbers

- Compact systems up to 1400 cfm (2,400 $m^3/h$)
- Factory assembled & skid mounted
- FRP or polypropylene construction
- FRP Exhaust Fan
- Conventional or High Capacity carbo
- Variable speed fan option
- Acoustic enclosure option
- Grease filter option

# Is Carbon a Viable Technology?

**Advantages:**

- *Lower capital cost*
- *Treat $H_2S$ and many organic odors*
- *Moderate air flow capacity (1000 $m^3/h/m^2$)*
- *Good response to odor spikes*


**Disadvantages:**

- *Limited $H_2S$/odor capacity*
- *Can be high operating cost because media replacement/regeneration can be expensive*
- *Limited capacity for some organics odors*

**Best Application:**

- *Low odor levels (< ~1-20 ppm)*
- *Polishing stage behind chemical or biological systems*

# *Factors to Consider*

**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

**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 $H_2S$ loadings*
- *And are effective for a wider range of odorous compounds ($H_2S$, $NH_3$, amines, organic sulfides).*

# *Each Technology has its Niche*

**Biological Systems:**

- *Have very low operating and maintenance costs*
- *Do not require handling of hazardous chemicals.*
- *Operating cost is not proportional to $H_2S$ concentration (hence they are well suited to high $H_2S$ applications)*

# *Each Technology has its Niche*

**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.*

# Summary OC Technology Selection

| TYPE | CAPITAL COST | OPERATING COST | MAINTEN-ANCE | FOOT-PRINT | ODOR REMOVAL | H2S PPM | H2S % REMOVAL | NH3? |
|---|---|---|---|---|---|---|---|---|
| CHEMICAL SCRUBBERS | $$ | $$$ | $$$ | Small | > 95% | 0 - 50 + | 99.9% | YES |
| BIO-TRICKLING SCRUBBERS | $$$ | $ | $$ | Large | 75-90% | 2 - 500 ppm | 99.0% | Some |
| HIGH CAPACITY CARBON | $ | $$+ | $+ | Medium | > 90% | 0-20 ppm | 99.9% | NO |
| VIRGIN ACTIVATED CARBON | $ | $$+ | $+ | Medium | > 90% | < 1 ppm | 99.9% | NO |

# Applications

## Information needed to select appropriate technology

- *Air Flow Rate or Ventilation Rate*
- *$H_2S$ Concentration (average and peak)*
- *Required level of odor removal ($H_2S$ and OU)*

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

# Contacts

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