Wet Air Scrubbing
A reliable technology for chemical odor treatment

Presented by:
USFilter
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Odors

- Mainly formed where anaerobic conditions limit oxygen transfer to wastewater

- Typical Odor Causing Compounds
  - Hydrogen Sulfide - most common wastewater odor
  - Reduced Sulfides (Mercaptans, DMDS, DMS)
  - Ammonia

- Driving Forces for Controlling Odors
  - Worker Safety
  - Corrosion Protection
  - Good Neighbor
  - Nuisance Control
Typical Sewer

- Anaerobic conditions cause odorous compounds to form, primarily hydrogen sulfide
Hydrogen Sulfide Concerns

- **Odor:**
  - Rotten Egg Odor, Low Odor Threshold, Highest Concentration among Odor Compounds

- **Safety - Exposure Effects:**
  - Odor (0 - 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**

<table>
<thead>
<tr>
<th>ppm</th>
<th>0.1</th>
<th>3</th>
<th>10</th>
<th>50</th>
<th>100</th>
<th>300</th>
<th>500</th>
<th>1,000</th>
<th>2,000</th>
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<tbody>
<tr>
<td>Odor Threshold</td>
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<td>Offensive Odor</td>
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<td>Headache, Nausea</td>
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<tr>
<td>Throat and Eye Irritation</td>
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<td>Eye Injury</td>
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<tr>
<td>Conjunctivitis, Respiratory Tract Irritation, Olfactory Paralysis</td>
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<td>Pulmonary Edema</td>
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<td>Strong Nervous System Stimulation</td>
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<td>Apnea</td>
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<td>Death</td>
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</tbody>
</table>

- **Rotten Egg Odor Alarm**
- **Serious Eye Injury**
- **Loss of Sense of Smell**
- **Imminent Life Threat**
- **Immediate Collapse**
Hydrogen Sulfide - Corrosion

Oxidation to Sulfuric Acid:

\[ \text{H}_2\text{S} + 2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4 \]

Sulfuric Acid Reacts with Concrete, Metallic, and Composite Pipes and Structures
Conditions Which Promote Sulfide Formation

- Long Force Mains/ Long Detention Times
  - More Time, More Sulfate Uptake, More Sulfide
- High Temperature
  - Increased Biological Activity

Release

- Low pH
  - Decreases Sulfide Solubility
- High Temperature
  - Decreased Sulfide Solubility
- High Turbulence
  - Increases “Stripping”
Other Problem Compounds:

- Organic Sulfur Compounds: Mercaptans, Methyl Sulfides, Etc.
  - Usually Formed and Released with $H_2S$
- Ammonia and Amines
  - Usually Released from Sludge, Especially During pH Adjustment or Heat Treatment
Odor Testing and Identification:

- Identify the Odor Compounds & Concentrations
- Identify the Physical Site Conditions
- Identify the Operational Conditions
Solving the Problem:

- Take a Step-Wise Approach
  - Try Adjustments First
  - Employ “Outside” Technology Second
- If “Outside” Technology is Necessary:
  - Fully Understand the Problem
  - Evaluate the Economic and Process Characteristics of Alternatives
  - Choose the Right Solution!
Treatment Alternatives

VAPOR PHASE
- Provides Point-Source Solution
- Treats Wide Range of Compounds
- Provides Area Ventilation

LIQUID PHASE
- Prevents Atmospheric Sulfide
- Effective Odor and Corrosion Control
- Treats Multiple Odor Release Points
Vapor Phase Odor Control Process

- Absorption (Chemical Reaction)
  - Single-Stage Wet Scrubbers
  - Multiple-Stage Wet Scrubbers
- Adsorption (Physical Process)
  - Carbon Adsorbers
  - Biofilters
- Incineration (Thermal Oxidation)
- Dilution
Technology Comparison - Carbon Adsorbers

- Typically, least capital cost of odor technologies
- Minimal maintenance required
- High removal efficiency until break-through
- Expensive to operate unless H$_2$S is very low (typically under 10 ppm)
- Moderate footprint required (20 m/min velocity)
Technology Comparison - Biofilters

- Relatively low operating cost
- Requires consistent loading or odor break-through will occur
- Requires acclimation period
- Biological process does not remove ammonia or amines
- Large footprint required (1 to 10 m/min velocity)
Technology Comparison - Wet Scrubbers “Packed Towers”

- **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

- **Types:**
  - Vertical, counter-current (most efficient)
  - Horizontal, cross-flow
Vertical, Counter-Current Wet Scrubbers

- Odorous air is forced (via fan) into the bottom of the scrubbing tower and water supplemented with NaOH and NaOCl is circulated to the top of the tower (via recirculation pump).
- Plastic packing media traps the liquid and air and the turbulent contact removes the odors from the air into the liquid and the chemical reactions occur:
  - \(2\text{NaOH} + \text{H}_2\text{S} \rightarrow \text{Na}_2\text{S} + \text{H}_2\text{O}\) (2.35 kg NaOH per kg H2S)
  - \(4\text{NaOCl} + 2\text{NaOH} + \text{H}_2\text{S} \rightarrow 4\text{NaCl} + \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}\) (2.35 kg NaOH and 8.75 kg NaOCl per kg H2S)
- Water is continuously fed and overflowed out of the sump to remove the salt by-products.
- ORP (Oxidation-Reduction Potential) and pH probes and analyzers monitor the levels and alter the injection rates of the chemical feed pumps to ensure the right amount of chemical in the system.
Packed Tower Process Flow Diagram
Two-Stage Packed Tower Scrubber

- Pre-Treatment Stage Eliminates Approximately 70% of Odors Using a Less Expensive Chemical (NaOH alone)
- Complete Utilization of Chemicals Prior to Discharge with Multiple Sumps
- Optimal Process Control
New Low-Profile Packaged Units

- 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.

- Low profile, 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: Two-Stage Packed Tower Scrubber vs. Low-Profile Unit (40,000 m³/hr)
Low-Profile Process Flow Diagram
Low-Profile Systems

- 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)

Three units treating 125,000 m3/hr
## Options Overview by Air Flow Rate:

<table>
<thead>
<tr>
<th>Air Flow rate (cfm)</th>
<th>Scrubbing Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2000</td>
<td>Biological Carbon (dry) Chemical (LO/PRO®, Polystage)</td>
</tr>
<tr>
<td>2000-6000</td>
<td>Chemical (wet): - LO/PRO® - Polystage</td>
</tr>
<tr>
<td>&gt;6000</td>
<td>Chemical: (LO/PRO®) most economical</td>
</tr>
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</table>
Operating Cost Differentiation
# Present Worth Analysis

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Low-Profile Packaged System</th>
<th>Single-Stage Packed Tower</th>
<th>Two-Stage Packed Tower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Flow Rate per System, cfm</td>
<td>7,500</td>
<td>7,500</td>
<td>7,500</td>
</tr>
<tr>
<td>Inlet H2S Concentration, ppmv</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Minimum Removal Effic, %</td>
<td>99.5%</td>
<td>99.5%</td>
<td>99.5%</td>
</tr>
<tr>
<td>No. of Stages</td>
<td>Three</td>
<td>One</td>
<td>Two</td>
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<tr>
<td>Capital Cost (Installed)</td>
<td>$170,400</td>
<td>$148,500</td>
<td>$256,500</td>
</tr>
<tr>
<td>Operating Cost ($/Yr)</td>
<td>$27,775</td>
<td>$59,304</td>
<td>$25,886</td>
</tr>
<tr>
<td>Maintenance ($/Yr)</td>
<td>$2,778</td>
<td>$5,930</td>
<td>$2,589</td>
</tr>
<tr>
<td>Total Recurring Cost ($/Yr)</td>
<td>$30,553</td>
<td>$65,234</td>
<td>$28,475</td>
</tr>
<tr>
<td>Annaluized Capital Cost ($/Yr)</td>
<td>$22,408</td>
<td>$19,528</td>
<td>$33,730</td>
</tr>
<tr>
<td>Total Annual Cost ($/Yr)</td>
<td>$52,960</td>
<td>$84,762</td>
<td>$62,204</td>
</tr>
<tr>
<td><strong>PRESENT WORTH</strong></td>
<td><strong>$402,828</strong></td>
<td><strong>$644,723</strong></td>
<td><strong>$473,142</strong></td>
</tr>
</tbody>
</table>

**Notes:**
- Assumed installation of 30% of capital cost for packaged unit and 40% of capital costs for towers.
- Power assumed to be $0.06/kwh, NaOH assumed to be $1.00/gal, NaOCl assumed to be $0.65/gal.
- Maintenance is assumed to be 10% of operating cost.
- Present Worth: linear depreciation, 15 yr lifetime, 10% cost of money.
- All amounts in USDollars.
- For example only.
# Qualitative Comparison of Vapor-Phase Technologies

<table>
<thead>
<tr>
<th></th>
<th>Single-stage Wet scrubber</th>
<th>Multistage Wet scrubber</th>
<th>Engineered Biofilter</th>
<th>Carbon adsorption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sulfide/Sulfur compounds treated</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Ammonia/nitrogen compounds treated</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Sulfur &amp; nitrogen compounds treated</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Footprint (based on 142 m³/min) system</strong></td>
<td>Small (20 ft x 20 ft) Includes Chem Tank</td>
<td>Medium (20 ft x 25 ft) Includes Chem Tank</td>
<td>Large (30 ft x 40 ft)</td>
<td>Small (15 ft x 20 ft)</td>
</tr>
<tr>
<td><strong>Cyclical operation (on-off capability)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Economic Comparison of Vapor-phase Technologies

<table>
<thead>
<tr>
<th></th>
<th>Single-stage Wet Scrubber</th>
<th>Multistage Wet Scrubber</th>
<th>Engineered Biofilter</th>
<th>Carbon Adsorption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Cost</strong></td>
<td>$75,000</td>
<td>$110,000</td>
<td>$180,000</td>
<td>$90,000</td>
</tr>
<tr>
<td><strong>Annual Power Cost</strong></td>
<td>$5150</td>
<td>$7800</td>
<td>$4600</td>
<td>$4600</td>
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<tr>
<td>(13 kW [17 hp])</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Annual Sodium Hydroxide Cost</strong></td>
<td>$4600</td>
<td>$4600</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>(106 L/d [28 gal/d])</td>
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<tr>
<td><strong>Annual Sodium Hypochlorite Cost</strong></td>
<td>$47,600</td>
<td>$11,000</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
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<tr>
<td>(681 L/d [180 gal/d])</td>
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<tr>
<td><strong>Annual Carbon Cost</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>$67,000</td>
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<td>19,000 kg/yr (42,000 lb/yr)</td>
</tr>
<tr>
<td><strong>Annual Media Cost</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>$34,000</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Annual Maintenance Labor Cost</strong></td>
<td>$3,900</td>
<td>$3,900</td>
<td>$2,600</td>
<td>$2,600</td>
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<tr>
<td>(3 h/wk)</td>
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<td></td>
<td>(2 h/wk)</td>
<td></td>
</tr>
<tr>
<td><strong>Total Annual Operating Cost</strong></td>
<td>$63,900</td>
<td>$24,650</td>
<td>$41,200</td>
<td>$74,200</td>
</tr>
<tr>
<td><strong>Total Present-Value Cost, 10-Year Life</strong></td>
<td>$467,000</td>
<td>$261,000</td>
<td>$433,000</td>
<td>$546,000</td>
</tr>
</tbody>
</table>

1. Based on $0.07 per kW/h.
2. Based on 25% solution, $1.70/L ($0.45/gal).
3. Based on 12.5% solution, $2.76/L ($0.73/gal).
4. Based on $0.73/kg ($1.60/lb).
5. Annualized based on complete media replacement in 5 years.
6. Based on $25/h.

Note: All comparisons are based on a 142-m³/min (5000-ft³/min), 50 ppm hydrogen sulfide system treating ventilation air.
QUESTIONS?

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THANK YOU