Benefits of Digester Gas Scrubbing at the Dayton WWTP

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Overview

• Characterization of Digester Gas
• Undesirable Constituents
• Gas Scrubbing Technologies
• Gas Scrubber Case Study at Dayton WWTP
  • Process Selection
  • Implementation into Existing System
  • Start-up Issues
Digester Gas

- Gas produced during reduction of organic matter under anaerobic conditions.
- Composed primarily of methane and carbon dioxide.
- Fuel (heat) value of digester gas is typically 550 to 650 BTU/CF.
- Contains lesser quantities of other gases such as hydrogen sulfide, nitrogen, water vapor, and volatile organic compounds (specifically siloxanes).
Composition of Digester Gas

- Methane, CH$_4$: 60 – 65%
- Carbon dioxide, CO$_2$: 35 – 40%
- Water Vapor, H$_2$O: 1 – 6%
- Nitrogen, N$_2$: <1%
- Hydrogen sulfide, H$_2$S: 100 to 3,000 ppm
- Siloxanes: 100 to 10,000 ppb

Heat value of methane is approximately 1,000 BTU/CF
Undesirable Digester Gas Components

- Hydrogen Sulfide
  - Siloxanes
  - Particulates
  - Water Vapor
- Carbon Dioxide
  - Nitrogen
Hydrogen sulfide, H$_2$S

- H$_2$S gas when combined with water vapor produces a weak acid: *hydrosulfuric acid*
- Corrosive to metals
  - Combustion chamber
  - Intake and exhaust piping
- Produces sulfur dioxide during combustion
- Target concentration in feed gas: <100 ppm
The word *siloxane* is derived from the words *silicon*, *oxygen*, and *alkane*.

They belong to the wider class of organo-silicon volatile organic compounds (VOCs).

Siloxanes can be found in products such as cosmetics, deodorants, de-foamers, toothpaste, water repelling windshield coatings, lubricants, food additives, and soaps.

Most common siloxane types found in digester gas are the D3, D4, and D5 compounds.

Recommended target concentration:

- Reciprocating engines and boilers <100 ppb
- Turbines / Micro-turbines < 50 ppb
Effect of Siloxanes

• Siloxanes degrade to silicates (SiO$_2$ & SiO$_3$) at high temperature and create impermeable glass particles. These particles bond onto hot metal surfaces.

• Reciprocating piston engines – forms deposits and hot spots in the combustion chamber, valves, valve seats, piston crowns and cylinder walls.

Siloxane damage to upper cylinder area and piston
Effect of Siloxanes

- Boilers – deposits a coating of silicate on boiler tubes that lowers heat transfer efficiency.
- Gas turbines – deposits on turbine blades leading to blade erosion and a significant drop in operating efficiency.
Other Digester Gas Components

- **Particulates**
  - Form deposits on engine surfaces and boiler equipment

- **Carbon Dioxide**
  - Inert gas, lowers heat value of digester gas

- **Nitrogen**
  - Inert gas

- **Water Vapor**
  - “Wet” gas is more corrosive to machinery
  - Lowers heat value
• Definition – Process of removing one or more undesirable components from a gas stream.
  • Typically targeted at removing hydrogen sulfide (H₂S), siloxanes, and particulates.
  • Optional removal of carbon dioxide, nitrogen, and water vapor for specific applications.
Reasons for Gas Scrubbing

- Decrease engine maintenance intervals
- Improve fuel (heat) value
- Improve engine performance – more power!
- Sell gas to utility (pipeline quality)
- Produce compressed natural gas (CNG) for City fleet use
- Provide higher quality fuel to boiler
- Happier maintenance staff!
Gas Scrubbing Technologies

• Unit Processes
  • Adsorption (Dry Scrubbing)
  • Wet Scrubbing
  • Refrigeration (Chilling)

• Pressure Swing Adsorption (PSA)
  • Molecular Sieve Media
Adsorption (Dry Scrubbing)

- Passing gas through adsorption media such as activated carbon, activated alumina, iron sponge, or synthetic resins.
  - Component is adsorbed onto media.
  - Media is either exhausted and replaced or regenerated

- Gas Scrubbing Usage:
  - Iron sponge (iron oxide on wood chips) for removing $\text{H}_2\text{S}$
  - Activated carbon, activated alumina for siloxane removal
Wet Scrubbing

- A method of passing the gas through water or another liquid medium for the purpose of removing particulates or other gases.

Gas Scrubbing Usage
- CO$_2$ removal – carbon dioxide is soluble in water.
- Particulate removal
Refrigeration (Chilling)

- Mechanical refrigeration that removes moisture by lowering the temperature of the gas to condense the water vapor. Other impurities also removed in condensate.

- Removes:
  - Moisture - dewpoint < 40°F
  - 90 - 100% particulates
  - 70 - 80% siloxanes
  - 20 - 30% H₂S
Pressure Swing Adsorption (PSA)

• A mechanical pressure switching system that rapidly cycles from adsorption to regeneration.
• Uses molecular sieve media and other adsorption media to allow the passage of methane but reject carbon dioxide, H\textsubscript{2}S, and siloxanes.
Molecular Sieve Media

- Specialized adsorption media that traps (adsorbs) smaller molecules in media while allowing larger molecules to pass through. Media can be rapidly regenerated.

- Digester Gas Scrubbing - Traps carbon dioxide, nitrogen, and other smaller molecules while allowing methane to pass through media.

Angstrom – length equal to $1 \times 10^{-10}$ meter
PSA Cycle Diagram

Pressure Phase – Adsorbing

- Feed gas flows upward thru media bed
- Targeted compounds are trapped or adsorbed in the media bed
- CH4 passes thru the bed
- Over time the bed will become saturated

Vacuum Phase – Purging and Regenerating

- Pressure is released thru the bottom of adsorbent bed
- Releases adsorbed compounds as Tail gas

Methane > 98%
CO2 = 1 to 2%
Small Methane Purge

CO2
H2S
Siloxanes
H2O

Molecular sieve media and adsorption medias

Vacuum Pump

“Tail Gas”
Gas Scrubbing Approaches

• Unit Processes in Series
  • Series of unit processes to remove each undesirable component.

  *Example: Remove H2S, CO2, Particulates and Siloxanes*
  
  *Processes: Iron sponge adsorption ➔ Wet scrubber ➔ Chiller ➔ Activated Carbon*

• Pressure Swing Adsorption (PSA)
  • Remove multiple gas components in single process.
  • Utilizes molecular sieve media
The City of Dayton Wastewater Treatment Plant is located at 2800 Guthrie Road, Dayton, OH 45417. Its design capacity is 72 MGD with a peak capacity of 180 MGD. The plant provides preliminary, primary, secondary, advanced secondary (nitrification), filtration, chlorination/dechlorination and post-aeration to all wastewater. Additional background and technical information on the facilities and its operation can be found on the internet at http://water.cityofdayton.org/Water/wwtp_main.asp
Gas Utilizing Equipment

- Co-generation Engines
  - 3 Waukesha Engines
  - Dual fuel: Digester Gas and Natural Gas.
  - Lean burn engines
  - 900 kw each on clean gas
  - 720 kw each on digester gas
- Present Strategy:
  - Peak Demand Shaving.
  - Running engines only during high flow to reduce periods of high demand.
Gas Utilizing Equipment

- Boilers
  - 3 HURST Hot water boilers
  - 350 Horse Power
  - Design: 3 Pass Wet-Back
  - Capacity: 14.7 Million BTU/Hour
  - Hot water Temperature: 180 °F
Previous Digester Gas Schematic

ANAEROBIC DIGESTERS (700,000 SCFD)

WASTE GAS BURNERS

COGEN ENGINES
720 KW each on DG
900 KW each on NG

BOILERS

DG, 65% METHANE

COMPRESSORS

CHILLER

GAS SPHERE (50 PSI)

LEGEND

VALVE
EX. DG PIPING
Process Selection

• Problems with the dirty gas since engines were installed in 1989.
• In 1994 Consultant studied to clean the Digester gas and evaluated different methods.
• Found Gas Chiller was the best and most economical method to clean the Digester gas. Added Chiller in 1995.
• Still Siloxane was not removed completely.
• We were impressed with the new method of gas scrubbing.
• Received American Recovery and Reinvestment Act money in 2009 to finance the project.
PSA Gas Scrubber Specifications

- Designed Capacity: 1,000,000 SCFD
- Clean gas
  - 524,000 SCFD
  - Methane: > 98%
  - CO$_2$: < 2%
- Tail Gas
  - 476,000 SCFD
  - Methane: 22%

### Biogas Feed Properties

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### Clean Gas Properties

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<tr>
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<td>HHV BTU/FT3</td>
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Location of PSA Gas Scrubber

Location of PSA Gas Scrubber next to Co-generation Building
Major Components of PSA Gas Scrubber

- Feed Compressor
  - Type: Reciprocating
  - Capacity: 1 Million SCFD
  - 60 HP Motor
  - Compresses from 40-50 to 105 PSIG

- Vacuum Compressor
  - Type: Liquid Ring
  - Capacity: 0.5 Million SCFD
  - 150 HP Motor
  - Reduces from -3 to -18 in of HG
Major Components of PSA Gas Scrubber

• Adsorber Vessels
  • Four Adsorbers: On-line, De-pressurizing, Re-pressurizing, and Purging.
• Buffer Tanks
  • Two Equalization and Two Repressurization Tanks
• Tail Gas Buffer Tank
• Purge Tank
PSA Gas Scrubber

- This slide shows:
  - Connection to the tail gas burner from tail gas buffer tank.
  - Connection of clean gas to the tail gas burner in case we can not use the clean gas.
PSA Gas Scrubber

- This slide shows:
  - Digester gas insulated piping to the PSA from Co-generation building Chiller.
  - Clean gas red piping to the Boiler and Co-generation Engines.
Tail Gas Flare

• Tail Gas Burning obstacles
  • Existing flare would not work because of low methane contents in tail gas.
  • Getting a new permit from Regional Air Pollution Control Agency (RAPCA).
  • Long lead time on customized flare
  • Zeeco is the only known lean burning flare supplier
Advantages of PSA Scrubbing

- No consumables. PSA media has 5+ year life
- Single process versus multiple processes
- Less liquid discharge (compared to wet scrubbing for CO2 removal)
- Lower maintenance cost - WE HOPE
- Lower operating cost - We HOPE
Scrubber Start-up

• Generator startup issues
  • Connect to the Natural Gas Line
  • Retune the engines to accept clean gas

• Boiler startup issues
  • Adjusted the burners in two boilers to accept the Clean gas
Cost of the project

• Received American Recovery and Reinvestment Act (ARRA) money for the project.
• Pay back period will be between 5-10 years.
  • By using clean gas reduction in maintenance cost of the engines and boilers.
  • Sell the gas to Gas Company or
  • Build a CNG station
THANK YOU

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