Biogas Processing for Utilities
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Raw Biogas Characteristics

- Pressure (less than 1 psig)
  - Common: 2 – 8 inches of water column
  - Municipal applications: up to 15 inches of water column

- Makeup by Major Constituents:
  - Constituent | Concentration
  - Methane (CH\(_4\)) | 55 to 60 %
  - Carbon Dioxide (CO\(_2\)) | 40 to 45 %
  - Nitrogen (N\(_2\)) | 0.4 to 1.2 %
  - Oxygen (O\(_2\)) | 0.0 to 0.4%
  - Hydrogen Sulfide (H\(_2\)S) | 0.02 to 0.4%

- Saturated with water
Digester

Input:
Any organic waste

Farm
Urban
Wastewater

Digestate (liquid + solids)

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Dryer

- Virtually all biogas needs to be dried
- Systems may use more than one step in combination
- The sequence of steps are often chosen depending on what steps are used to process the biogas. It may be ideal for the gas to be hot or cold.
Silica Gel

- Removes siloxanes
- Required to keep silica from plating onto hot surfaces during combustion as silicon dioxide (sand or glass).
- Silica Gel
  - Good potential for removal of certain siloxanes from biogas
  - High adsorption capacity
  - Selectively retains organic silicon compounds
- Cooling
  - Siloxanes can be removed from the cooled gas with condensation water
  - Highly dependent on temperature and pressure
- Specialty Media (Al$_2$O$_3$, ZnO, etc.)

boiler tubes fouled with silica

siloxane removal filter
(on a municipal digester biogas system)
Activated Carbon

- Removes both sulfides and siloxanes by adsorption
  - process is non-selective
- Activated carbon is often used for its high surface area and catalytic properties
- Can be made from wood, coconut shells, charcoal
- Performance affected by gas temp. and moisture (better on dry, cool/warm gas)
Sulfatreat

- Removes sulfides
- Uses unique combination of iron oxides react with sulfides (H₂S) to produce iron sulfide. An activator oxide catalytically enhances the reactive adsorption phenomenon: Fe₃O₄/Fe₂O₃(s) + H₂S(g) → FeS²(s) + H₂O(l)
- Can be single vessel or lead/lag with 2 vessels in series
- Reaction times are relatively slow in comparison to conventional carbon or alumina systems
Iron Sponge

- Removes sulfides
- Iron sponge generally refers to wood chips impregnated with iron oxide
- Upflow/Downflow of gas through packed bed of iron sponge based on provider
- Iron oxide (Fe₂O₃) reacts with sulfides (H₂S) to produce iron sulfide (Fe₂S₃) and water (H₂O): 2 Fe₂O₃(s) + 6 H₂S(g) → 2 Fe₂S₃(s) + 6 H₂O(l)
- Must drain excess water occasionally so as not to flood the bed
- Bed can be regenerated several times before needing replacement

Raw Biogas → Iron Sponge → Desulfurized Biogas, Iron Sulfide + Water

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Biofiltration

- Removes sulfides (and commonly used for odor control)
- Uses microbes living on a support matrix to remove sulfides
- Microbes oxidize reduced sulfur compounds to sulfate
- Sulfides absorb into a liquid film and are then metabolized by the microbial cells
- Supplied as:
  - Above grade packed towers
  - Below grade systems filled with natural media like wood chips or peat moss.
- Three major types:
  - bioscrubber
  - biofilter
  - biotrickling filter

Fig. 5. Systems for removal of H₂S: (a) bioscrubber; (b) biofilter; (c) biotrickling filter.
Water Wash

- Biogas enters
- Carbon dioxide and other polar molecules have a higher solubility in water than methane. Therefore water can be used to remove contaminants from biogas.
- If the contaminants are removed or ‘scrubbed’ at high pressure (~130 psig), the water can be continuously regenerated or ‘stripped’ in a separate low pressure vessel (~3 psig).
- High quality biogas (renewable natural gas) exits.

Product Gas

CH$_4$: 96-98%
CO$_2$: 1-2%
H$_2$S: < 4 ppm
Amine Scrubber

- Raw biogas enters and is pressurized up to 100 psig
- Sulfides (H₂S) are removed
- Biogas then flows upward through a packed column where the carbon dioxide (CO₂) and sulfides are absorbed within the counter flowing amine
  - Once the saturated amine leaves the scrubber and the carbon dioxide is driven off to the atmosphere, the amine may be further treated by heating it
- High quality biogas (renewable natural gas) exits

*In some systems, the sulfides are removed in the packed column based on amine type and site conditions

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Membrane Separation

- Biogas enters. The membrane separates the methane by **retaining** it ("retentate"). Undesirable molecules like carbon dioxide (CO₂), water (H₂O), sulfides (H₂S), and ammonia (NH₃) **pass through** the membrane ("permeate"). High quality biogas (renewable natural gas) exits.
- Membranes are made of polymers and, for gas separation, are typically formed into very thin, hollow fibers. These fibers are clustered into modules consisting of thousands of fibers. A high pressure pump forces the gas through the fiber into a lumen hole that runs down the center of the fiber where it is collected with permeate from other fibers.
- To improve separation, multiple stages may be used. Two-stage systems are common (shown below) which increase the longevity of the membrane modules. Most installations include a desulfurization and drying step before raw biogas is sent through the membrane.

Product Gas

- **CH₄**: 86-98%
- **CO₂**: 1-2%
- **H₂S**: < 4 ppm
Pressure Swing Adsorption (PSA)

- Biogas enters.
- An adsorbing material, usually carbon molecular sieve or zeolite, preferentially adsorbs carbon dioxide and other highly adsorbed compounds at pressure (~100 psig) to upgrade the biogas.
- Systems often have multiple tanks for separation, with only one in service at a time.
- High quality biogas (renewable natural gas) exits.

**Product Gas**
- CH₄: 96-98%
- CO₂: 1-2%
- H₂S: < 4 ppm

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