BIOGAS UPGRADING - DESULFURIZATION
Part 3: Biotrickling filters for H_2S - Overview of configuration and design

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BIOTRICKLING FILTERS

Biotrickling filters (BTF) are irrigated reactors with a packed bed colonized by microbial growths capable of degrading contaminants from a passing gas. Essentially BTFs are a tank with raw biogas plumbed in to permeate filter media and upgraded biogas exiting. Air and recycled nutrient water support the microbial activity on this media. The liquid phase also aids pollutant capture and removal of the microbial breakdown products. A demister on the outlet prevents water droplets from escaping (Figure 1.).

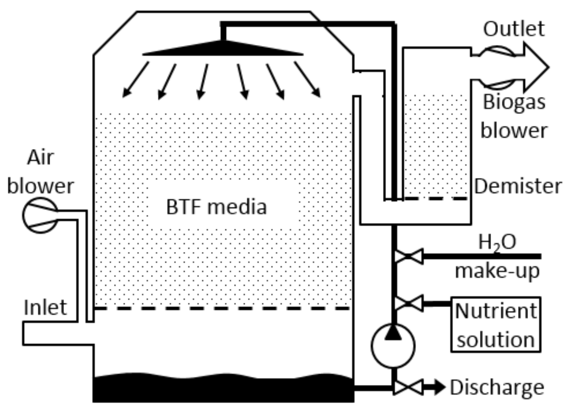

Figure 1. Schematic of typical biogas desulfurization biotrickling filter design

PROCESS DESIGN OPTIONS

Sizing

A BTF must be large enough to handle the maximum biogas flow rate capacity and pollutant concentrations of the facility. Typical BTFs for biogas upgrading (500-10,000 ppm_v H_2S) are designed for a 0.5-20 min. empty bed retention time (Equation 1).

$$\text{EBRT} = \frac{V_f}{Q} \qquad (1)$$

where EBRT = empty bed retention time (s), V_f = volume of filter media (ft^3), and Q = flow rate (biogas and air combined) through the system (ft^3/s). *In NYS, desulfurizing BTFs are ~20-40 ft. tall, ~8-12 ft. diameter, with a ~7-8 min. EBRT.*

Biogas flow configuration

Relative to the downward flow of the nutrient water, flow of the biogas can be co-, cross- or counter-current. While co-current configurations have been used, they typically have lower desulfurization performances than cross- or counter-current designs. Counter-current configurations have the highest potential performance due to their high driving forces for absorption. Cross-flow configurations offer the advantages of lower pressure drop than counter-flow designs and may be less susceptible to uneven water distributions in the media, but their shorter residence times reduce desulfurization potential. Fans and blowers must be capable of overcoming the pressure drop of the system, have variable speed controls, and are arranged just before the biogas engine-generation sets to ensure proper flow into the engines. *In NYS, most BTFs are counter-current.*

Liquid flow configuration

The BTF trickling-phase must be delivered evenly to the media to prevent localized drying and channeling of unconditioned biogas. Spray nozzles must be resistant to corrosion and fouling while delivering a mist small enough to provide large surface area, yet large enough to be captured by the demister. Nutrient water is re-circulated to reduce water usage. When the concentration of accumulated breakdown products (e.g. sulfates) becomes too high, the water is discharged. pH and electrical conductivity meters are used to control this discharge and may be used to dose nutrients. In *NYS, most* *desulfurizing BTFs are equipped with a conductivity meter in addition to a pH meter.*

Packing material and dimensions

BTF media must have significant surface area suitable for microbial attachment, high bulk porosity to permit air flow, chemical and structural stability to ensure its longevity, be light-weight, and low-cost. While structured media and mesh have been used, desulfurization BTFs are use randomly packed with Pall or Raschig rings, moving bed bioreactor (MBBR) media, bio-balls, or foam cubes. *In NYS, polypropylene Pall rings and MBBR media are typical.*

Temperature

BTFs for biogas desulfurization are typically designed to operate under mesophilic conditions (70-110°F). *In NYS, most BTFs are operated near 90°F.*

Oxygen

Both oxygen and nitrate can be used to stimulate microbial H_2S oxidation. While biogas is not diluted with air in an anoxic BTF, addition of nitrate salts are required which adds cost and may increase mineral build up on BTF media. *In NYS, aerobic desulfurization BTFs are used and oxygen is supplied as ambient air via blowers.*

pH

Desulfurizing BTFs can operate at neutral (pH 6-8) and acidic (pH 1-4) conditions, with *Thiobacillus* sp. and *Acidithiobacillus* sp. the dominant sulfur oxidizing bacteria in neutral and acidic systems, respectively. Both designs can achieve high performances though rapid pH changes can impact desulfurization. *In NYS, most systems operate under acidic conditions (pH 1-2).*

PERFORMANCE & COST

Removal efficiencies of 80-100% have been reported for inlet H_2S concentrations of 2,000-12,000 ppm_v. Capital costs can be \$200,000 - \$300,000 for 2000 - 4000 cow dairies with operating costs, which include labor and maintenance, around \$20,000/yr.

FACT SHEET SERIES

Biogas upgrading - Desulfurization

Part 1: What are the available technologies for desulfurization of biogas?
Part 2: Microbial underpinnings of H_2S biological filtration.
Part 3: Biotrickling filters for H_2S - Overview of configuration and design.
Part 4: Biotrickling filters for H_2S - Process control options.

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