HYDROGEN SULFIDE REMOVAL FROM BIOGAS

Part 2B: 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 sulfur oxidizing bacteria (SOB). As raw biogas is blown through the media, hydrogen sulfide (H_2S) is removed from the biogas and metabolized by the SOB. Air and recycled nutrient water support the activity of the SOB. The liquid-phase also aids pollutant capture and removal of the sulfate waste generated by SOB. A demister helps dry the cleaned biogas (Figure 1.).

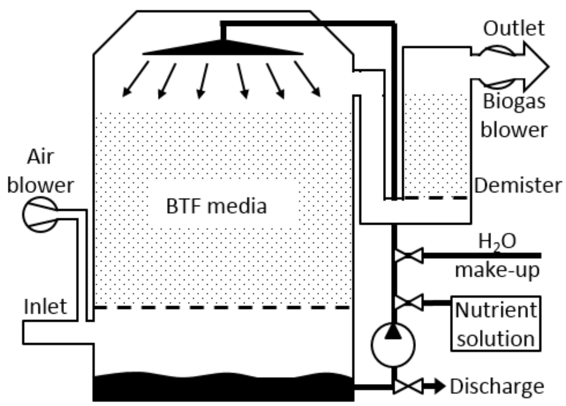

Figure 1. Cross-section of typical biogas biotrickling filter design. Raw-biogas enters at the inlet and treated-biogas leaves the outlet. Trickling phase (sulfur-laden nutrient water) is recirculated, and periodically discharged and replenished with make-up water and nutrients.

IMPORTANT DESIGN PARAMETERS

Sizing

A BTF must be large enough to handle the maximum biogas flow rate and H_2S concentration. When biogas H_2S concentration is not known, required BTF vessel size can be estimate using the flow rate and a rule of thumb empty bed residence time using Equation 1.

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

where V_f = volume of filter media (ft^3), EBRT = empty bed retention time (min.), and Q = flow rate (biogas and air combined) through the system (ft^3/min.). *In NYS, typical BTF use a 7-8 min EBRT. With flow rates of 100-400 cfm, farms may need media volumes of 700-2,800 ft^2, resulting in 20-40 ft. tall and 8-12 ft. in diameter vessels depending on the gas flow rate.*

Longer EBRTs are required for higher H_2S biogas concentrations. *In NYS typical H_2S concentrations are 500-6,000 ppm.* When biogas concentration is known, required biofilter volumes can be estimated using a rule of thumb volumetric loading rate of H_2S using Equation 2.

$$V_f = \frac{\text{Q} \times \text{C}_G}{LR} \qquad (2)$$

where C_G is the biogas H_2S concentration (lb./ft^3) and LR is the hydrogen sulfide loading rate (lb./ft^3/h). T*ypical BTF loading rates in NYS are 0.18-0.20 lb. H_2S/ft^3/h.*

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. Blowers must be capable of overcoming the pressure drop of the system and meet the supply needs of the biogas-fueled engine-generator sets. M*ost NYS BTFs are counter-current.*

Trickling phase

The BTF trickling-phase must be delivered evenly to the media to prevent localized drying and channeling of biogas. Spray nozzles must resist corrosion and fouling while delivering a mist small enough to provide large surface area, yet large enough to be captured by the demister or other water removal devices (e.g. chillers). Nutrient water is re-circulated to reduce water usage. When the concentration of accumulated breakdown products (e.g. sulfates) becomes too high, a portion of the recirculating water must be replaced with fresh water. This can be controlled by a time set-point, pH meters and/or electrical conductivity meters. In *NYS, most desulfurizing BTFs are flushed every 2 hours but are also equipped with a pH meter and/or a conductivity meter*.

Packing material

Ideal BTF media has high surface area for microbial attachment, high bulk porosity to permit air flow, chemical and structural stability to ensure longevity, is light-weight, and affordable. Pall or Raschig rings, moving bed bioreactor (MBBR) media, bio-balls, or foam cubes can all be used. *In NYS, BTF are randomly packed with polypropylene Pall rings or MBBR media.*

Temperature, Oxygen & pH

BTF for biogas H_2S removal typically operate under mesophilic conditions (70-110°F) using reclaimed heat from the biogas-fueled engine-generator set (when co-localized) or an auxiliary boiler system. *In NYS, most BTFs are operated near 90°F.*

To supply oxygen, air is typically fed into a BTF at 10-12% of the gas flow using a blower. The target vessel oxygen concentration is ~2%.

Extreme care must be taken to not over supply air which will dilute biogas and potentially create an explosive methane/oxygen mixture!

BTF for biogas H_2S removal can operate at neutral (pH 6-8) and acidic (pH 1-4) conditions. Both designs can achieve high performances though rapid pH changes can impact H_2S removal rates. M*ost BTF in NYS operate under acidic conditions (pH 1-2).*

PERFORMANCE & COST

Removal efficiencies of 80-100% have been measured by the authors' for inlet H_2S concentrations of 2,000-12,000 ppm_v. Capital costs can be $200,000-$300,000 for 2,000-4,000 cow dairies with operating costs, which include labor and maintenance, around $20,000/yr.

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