Cornell University

Dairy Environmental Systems Program

www.manuremanagement.cornell.edu

PRO-DAIRY

EMISSIONS FROM BIOGAS-FUELED DISTRIBUTED GENERATION UNITS

Part 1: What are the potential emissions from engine-generation sets?

June 2016

INTRODUCTION TO BIOGAS

Biogas is generated from anaerobic digestion of manure and organic wastes. It primarily consists of methane (50-70%), carbon dioxide (25-50%) and water vapor (1-5%). Depending on the feedstock and anaerobic digester conditions, biogas may also contain nitrogen gas (0-5%), hydrogen sulfide (0-7,500 ppm), and ammonia (0-500 ppm). Others volatiles and particulates are trace-level components of biogas[1].

BIOGAS COMBUSTION EMISSIONS

Biogas is primarily methane, but impurities present during combusted results in unique emissions profiles. Emissions also depend on the combustion mechanism (i.e. flare, boiler, engine type). Biogas combustion emissions of interest are carbon monoxide (CO) and dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOCs), and particulate matter (PM). Their generation, health and environmental impacts are briefed below:

Carbon monoxide and dioxide

Both CO and CO_2 are combustion products of carbon-based compounds. Carbon monoxide is highly toxic and generated preferentially under low oxygen conditions. Direct exposure to low levels can reduce blood oxygen, impacting heart and brain function; inhalation of high levels can result in seizure, coma and death. Carbon monoxide reacts with some VOCs to form ground level ozone which impedes lung function causing respiratory symptoms[2]. Carbon dioxide is a greenhouse gas[3].

Nitrogen oxides

Nitrogen oxides, which can be generated during biogas combustion, typically refer to the mono-nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), and their precursors nitric and nitrous acid, respectfully. Nitrogen dioxide is the main component of NO_x and is used as an indicator. According to the EPA, the health risk of short-term NO_x exposure is unclear, but continued or frequent exposure to levels significantly higher than ambient air concentrations may increase incidence of respiratory illness and asthma. NO_2 emissions can react with atmospheric ammonia, water vapor, SO_x and some VOCs to form PM which can cause respiratory disease, and aggravate existing respiratory and heart diseases. In the presence of sunlight NO_x and VOCs can also react to form ground level ozone[4]. Additionally, NO_x emissions cause acidic rain/deposition which lowers pH and can damages lake, stream, soil and forest health[5].

Sulfur oxides

Sulfur dioxide (SO_2) is a major constituent of SO_x and is formed when biogas containing hydrogen sulfide is combusted. Brief exposure to SO_x emissions can negatively impact respiratory health, reduce lung function, and cause asthma like symptoms[6]. Also, like NO_x, SO_x can react with other atmospheric gases to form PM and is a major contributor to acidic deposition and rain[5].

Volatile organic compounds

Volatile organic compounds are carbon based compounds that volatilize under normal atmospheric conditions, partitioning in the atmosphere. Some VOCs emitted from biogas engine-generator sets, such as acrolein, acetaldehyde, formaldehyde, and

methanol, can strongly irritate the skin, eyes, and nasal passages following direct exposer to low-levels (0.1 ppm). Routine exposure to higher-levels can significantly impair pulmonary function. While these VOCs are naturally occurring, they can be produced by incomplete combustion of methane and by reactions of biogas combustion products. Biogas combustion VOCs, like formaldehyde, can also generate nuisance odors and react with other atmospheric emissions to form PM and ground level ozone. Currently, our understanding of VOC emissions from biogas engine-generation sets is limited, though some studies have shown for formaldehyde that emission levels are within an acceptable range[7].

Particulate matter

Particulate matter is a complex mixture of extremely small (< 10 µm) particles and droplets of dust, organics, acids and metals that can be emitted from biogas-fueled engine-generator sets. The PM of concern includes: PM_{10} - inhalable "course particles" or dusts which are smaller than 10 µm and larger than 2.5 µm, and $PM_{2.5}$ - inhalable "fine particles" found in dust and haze which are less than or equal to 2.5 µm. These particles, especially $PM_{2.5}$ can penetrate deep into lung tissue with exposure to high particle levels associated with respiratory problems, aggravated asthma, lung disease, and cardiovascular issues inducing irregular heartbeat, heart attacks and heart disease. Elderly, children, and those with heart or lung disease are most at risk. Particulate matter also damages natural environments by creating haze which reduces visibility and can carry and depositing pollutants and acidity[8].

FACT SHEET SERIES

Emissions from biogas-fueled distributed generation units

Part 1: What are the potential emissions from engine-generation sets?
Part 2: What are the current emission regulations for New York State?
Part 3: Greenhouse gas reduction and other benefits of biogas upgrading.
Part 4: How do operators of engine-generation sets meet applicable emission regulations?

AUTHORS

Jason P. Oliver, PhD	jpo53@cornell.edu	(607) 227-7943
Curt Gooch, PE	cag26@cornell.edu	(607) 225-2088

REFERENCES

[1] Braun, R. 2007. Anaerobic digestion: A multi-faceted process for energy, environmental management and rural development. In: P. Ranalli (ed.), Improvement of Crop Plants for Industrial End Uses, 335–416. **[2]** U.S. Environmental Protection Agency (EPA). 2010. Quantitative risk and exposure assessment for carbon monoxide – Amended. http://www3.epa.gov/ttn/naaqs/standards/co/data/CO-REA-Amended-July2010.pdf **[3]** U.S. Environmental Protection Agency (EPA). 2015a. Overview of greenhouse gases. http://www3.epa.gov/climatechange/ghgemissions/gases/co2.html **[4]** U.S. Environmental Protection Agency (EPA). 2015b. Nitrogen dioxide – Health. http://www3.epa.gov/airquality/nitrogenoxides/health.html **[5]** U.S. Environmental Protection Agency (EPA). 2012. Acid rain. http://www3.epa.gov/acidrain/index.html **[6]** U.S. Environmental Protection Agency (EPA). 2015c. Sulfur dioxide – Health. http://www3.epa.gov/airquality/sulfurdioxide/health.html **[7]** Abdul-Wahab SA, Lohi A, Yetilmezsoy K, Elkamel A, Chan K. 2014. Modeling of formaldehyde and nitrogen oxide from a proposed renewable energy biogas facility in Canada. Journal of Renewable and Sustainable Energy. 6:043121. **[8]** U.S. Environmental Protection Agency (EPA). 2015d. Particulate matter (PM). http://www3.epa.gov/airquality/particlepollution/index.html

USDA NIFA Animal Agriculture in a Changing Climate

NEW YORK STATE OF OPPORTUNITY. NYSERDA