3.0 DIGESTER GAS QUALITY

Digester gas is composed primarily of methane (CH_4) and carbon dioxide (CO_2), with trace amounts of hydrogen (H_2), nitrogen (N_2), and contaminants such as hydrogen sulfide (H_2S) and organic silicon compounds known as siloxanes. Digester gas is also saturated with moisture; the amount of moisture varies with the operating temperature of the digesters with more moisture present at higher operating temperatures. If the digester gas is left untreated, the moisture and contaminants can cause corrosion or other damage to internal combustion engines, which will increase the maintenance requirements and reduce the useful life of the engines.

To determine the concentrations of various contaminants in the digester gas generated at the Ina Rd WRF, digester gas samples from several locations were collected on December 30, 2008 and January 8, 2009. The samples were analyzed for siloxanes, sulfur compounds and other components at Centek Laboratories, LLC, of Syracuse, New York, a laboratory designated by Applied Filter Technologies, Inc. (AFT). PCRWRD also collected independent digester gas samples on January 6, 2009, these samples were also tested at Centek Laboratories through AFT. A summary of the sampling results is presented in Table 3. The average digester gas quality data based on plant operating data for 2008 are also shown in Table 3 for comparison. Copies of the laboratory reports and the engineering report from AFT are attached in Appendix B.

Table 3. Digester Gas Quality

Parameter	*Units*	Concentration					
		Plant Data[1]	Raw Digester Gas		After Desiccant Dryer	After Refrigerant Dryer	
			B&V[2]	PCRWRD[3]	B&V[2]	B&V[2]	PCRWRD[3]
Composition							
Methane	%	59.3	54.2	56.9	59.9	60.1	62.4
Carbon dioxide	%	40.0	44.5	41.3	37.4	37.2	34.5
Nitrogen	%	0.3	1.0	1.38	2.0	2.1	2.51
Oxygen	%	--	0.27	0.37	0.69	0.65	0.60
Contaminants							
Hydrogen Sulfide	*ppmv*	2,840	3,200	54	4,600	12,000	53
Total Siloxanes	*ppbv*	--	1,654	5,063	4,857	4,865	3,900
Total VOCs	*ppbv*	--	3,239	4,529	9,204	14,745	4,486

[1] *Based on 2008 plant operating data*

[2] *Sample collected by B&V*

[3] *Sample collected by PCRWRD*

The methane concentrations in the digester gas samples fall within the typical range of 55 to 65 percent for digester gas, indicating a well-functioning digestion process (based on B&V experience).

3.1 Digester Gas Contaminants

Moisture

As the digester gas cools from the operating temperature of the digesters to ambient temperatures, some of the moisture in the gas condenses and reacts with the hydrogen sulfide to form sulfuric acid, which can corrode the gas collection and conveyance piping. To reduce the impact of moisture on gas utilization equipment, such as combustion engines, chillers or dryers are often used to cool the gas to approximately 40 °F to remove additional moisture as

condensate. The chilled gas is typically then reheated to ambient temperature before being sent to gas utilization equipment.

Hydrogen Sulfide (H_2S)

Hydrogen sulfide is present in most digester gas samples at typical concentrations ranging from 300 to 2,500 ppmv. The H_2S concentrations measured in the digester gas samples at Ina Rd WRF are highly variable, with higher concentrations detected after the refrigerant dryer. AFT indicated that H_2S concentrations higher than 3000 ppmv are difficult to accurately measure with the method used in the laboratory (Appendix B, pg. 4). Therefore, the average of the raw digester gas and the desiccant samples collected by B&V was selected to determine the gas cleaning requirements. For comparison, Table 4 shows the H_2S concentrations in digester gas from other plants in North America that have experience increased maintenance or damage to equipment due to hydrogen sulfide. Concentrations shown are for untreated (raw) digester gas.

Table 4. H_2S Concentrations in Digester Gas

Location	Concentration *ppmv*	Comments
Pima County, AZ	3,900	Possible increase maintenance due to H_2S
Colorado Springs, CO	2,900	Damage to equipment reported
Denver, CO	< 3,700	Increased maintenance for combustion turbines
Lubbock, TX	10,200 to 14,600	Serious deterioration of boilers
Rockford, IL	900	Damage to engine generators – installed gas cleaning system
San Antonio, TX	2,200	Scrubbing equipment installed for gas to flare to reduce SOx emissions

Hydrogen sulfide combines with moisture to form an acidic solution that corrodes pipes, valves and gas utilization equipment, which at the Ina Rd WRF are combustion engine generators. A typical limit for H_2S is 200 ppmv when the digester gas will be used in engines. However, the media used in the siloxane removal system has a higher affinity for H_2S than for siloxanes. Consequently, if the H_2S concentrations are not reduced to less than 25 ppmv, the life of the siloxane media drops significantly, increasing the overall system O&M costs.

CH2M Hill is currently designing facilities to add ferric salts to the digesters in the future. If adopted by PCRWRD, the ferric salt addition will reduce H_2S concentrations in the digester gas, which will lower the overall H_2S removal operating costs for the digester gas treatment system, either by prolonging the life of the media used in the dry scrubbers, or by reducing the chemical usage in the wet (chemical) scrubbers. The design hydrogen sulfide concentration does not affect the design capacity for the digester gas treatment system, since the equipment sizing is based on digester gas flow rates. The digester gas treatment system will be based on a hydrogen sulfide concentration of 3,900 ppmv, as given in Table 2.

Siloxanes

Siloxanes are organic compounds of silicon that have only recently been recognized as a contaminant in digester gas. The presence of these compounds in digester gas is related to their increased use in personal care products, such as shampoos, deodorants, detergents, and antiperspirants that use siloxanes to improve the physical characteristics of the product. Siloxanes in many forms are also used in a wide range of commercial, industrial, and medical products.

Siloxanes are volatile and are released into the gas phase during the anaerobic digestion process. Combustion of digester gas results in oxidation of siloxanes to silicon dioxide (SiO_2). SiO_2 is an abrasive solid, similar to fine sand, which can accumulate on moving parts or heat exchange surfaces, causing accelerated wear, contamination of lubrication oil and loss of heat transfer efficiency.

Prior to 2000, siloxanes were detected as D4 siloxanes, but were reported as "total siloxanes." More recently, samples are analyzed for all the siloxane compounds, and typically only D4 and D5 siloxanes are found in concentrations above the detection limits. However, D6 siloxanes are increasing and beginning to reach detection limits as well. The concentrations of the various siloxane compounds are summed and reported as the total siloxanes. Total siloxane concentration is the number of interest when assessing the potential impact of siloxanes on combustion equipment.

The siloxane concentration in the digester gas samples collected by B&V at the Ina Rd WRF are illustrated in Figure 1 (identified as Site 21) along with siloxane concentration data from other wastewater treatment facilities compiled by Black & Veatch, for comparison purposes. A number of the data points are for D4 siloxanes only. The sample sites are listed in Table 5.

Table 5. Sample Sites for Siloxanes Measurements Shown in Figure 1

Site Numbers	Location	Comments
1 through 8	Various	Early data, probably D4 only
8 through 10	California	
9, 12 and 14 through 17	Upper Midwest	Recent data
13	Southwest	
18 through 20	Ashbridges Bay, Toronto	Before and after gas dryer
21	Columbia WWTP, MO	August 2007
22	Pima County, AZ	December 2008 – January 2009

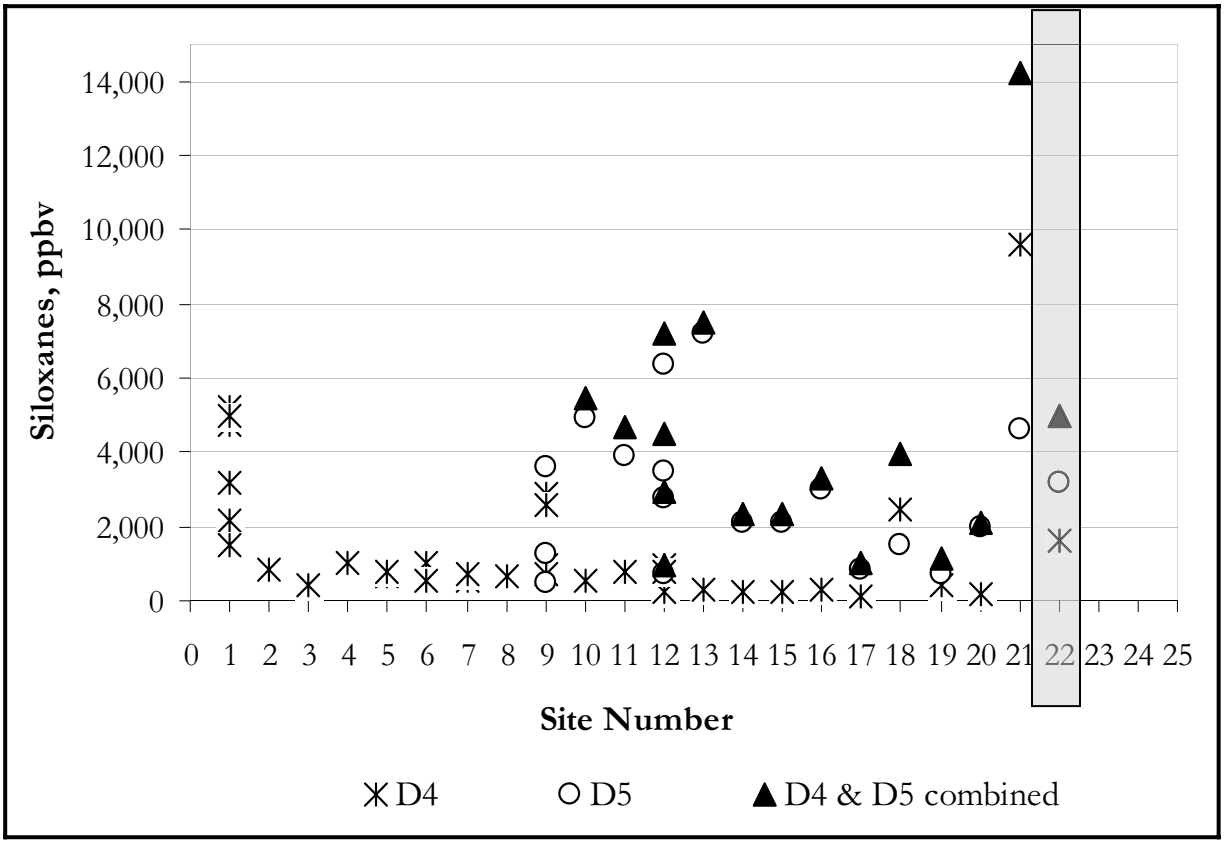

Figure 1. Comparison of Siloxane Concentrations in Digester Gas

The siloxane concentrations in the Ina Rd WRF digester gas samples fall in the middle to upper end of the typical concentration range (2,000 to 8,000 ppbv) observed at other facilities. Siloxanes are typically detrimental to gas utilization equipment at these concentrations.

The design contaminant concentration values for hydrogen sulfide and siloxanes in the raw digester gas are summarized below in Table 6. These values, along with the digester gas flow rates presented in Table 1, will be used to size the digester gas cleaning equipment for the proposed digester gas cleaning system.

Table 6. Contaminant Concentrations in Raw Gas – Basis for Cleaning System Design

Contaminant	Units	Concentration
Hydrogen Sulfide	*ppmv*	3,900
Siloxanes	*ppbv*	5,000

The digester gas sampling conducted only provides a snapshot of the digester gas at the time of sampling. The gas composition, especially the concentrations of hydrogen sulfide and siloxanes, may change with time depending on the feed characteristics and operating conditions of the digesters. The changes in contaminant concentrations can affect the media life and operation and maintenance costs. During the initial years of operation, it is advisable for the County to undertake a regular sampling and analysis program to quantify the contaminants and identify the variations in gas composition and the operating cost requirements.

3.2 Target Gas Quality for Use in Engine Generators

The design limits listed in Table 7 are based on utilizing the digester gas in engine generators.

Table 7. Gas Quality Requirements for Use in Engine Generators

Contaminant	Units	Design Limits
Moisture	--	40 ºF dew point minimum
Hydrogen Sulfide	*ppmv*	Less than 25[1]
Siloxanes	*ppbv*	Less than 150

[1] *Requirement to avoid impacts to siloxane removal system*

The target concentration for H_2S is based on the limits recommended by the gas cleaning system supplier for optimum media life in the downstream siloxane removal system. Higher H_2S concentrations in the digester gas to the siloxane scrubbers will reduce media life due to the higher affinity of the siloxane removal media for H_2S. As a result, the proposed H_2S concentration limit is lower than the limits typically required for digester gas use in engine generators.

The target concentration for siloxanes was established based on the standards recommended by an internal combustion engine supplier. Since engines are most affected by siloxanes in the gas, the siloxanes limits on engines represent the most severe limitations for the cleaning system.