Electronic Supporting Information for

Anaerobic Membrane Bioreactor Treatment of Domestic Wastewater at Psychrophilic Temperatures Ranging from 15 to 3°C

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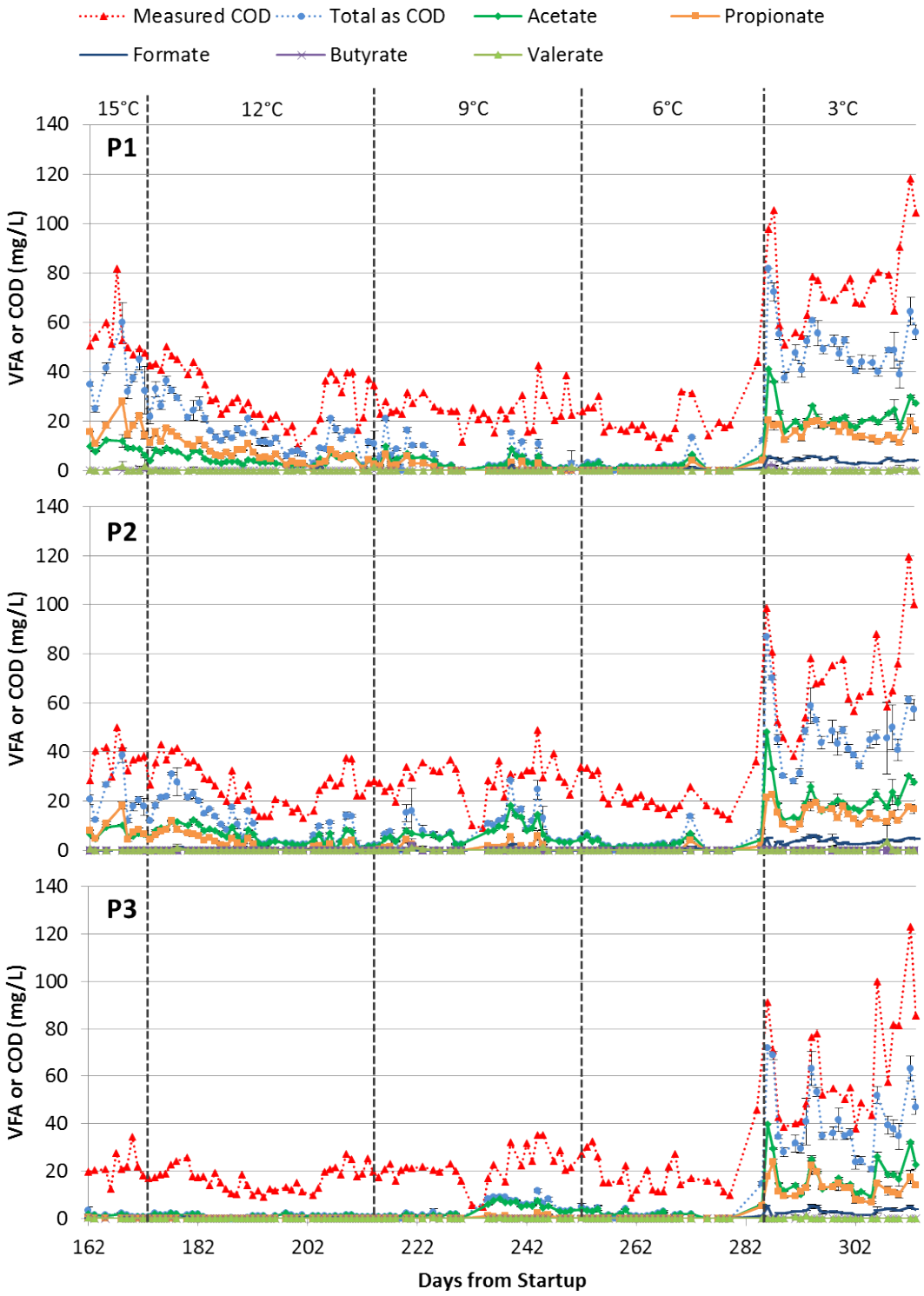


Figure S1. P1, P2, and P3 permeate VFA concentrations (concentrations are expressed as the actual compound, not as COD), calculated COD contribution from measured VFAs (indicated as Total as COD in legend), and measured COD during days 162-313. Error bars represent standard deviations of triplicate IC injections. The method detection limit for each VFA was <0.15 mg/L.

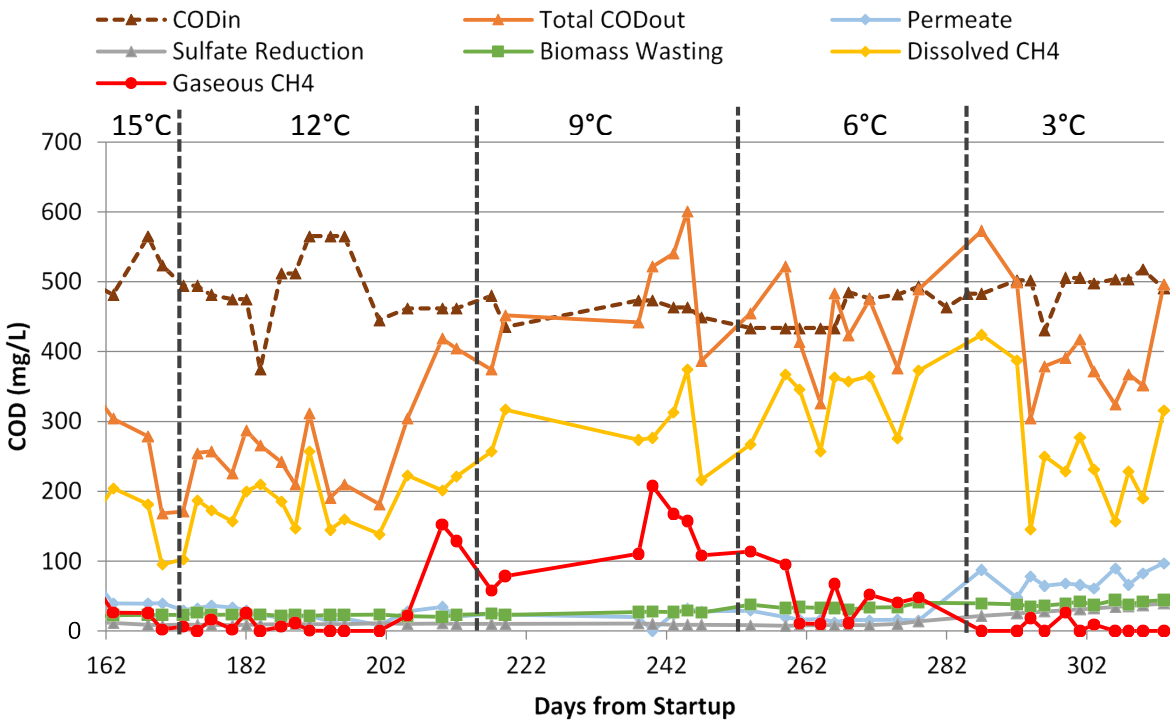
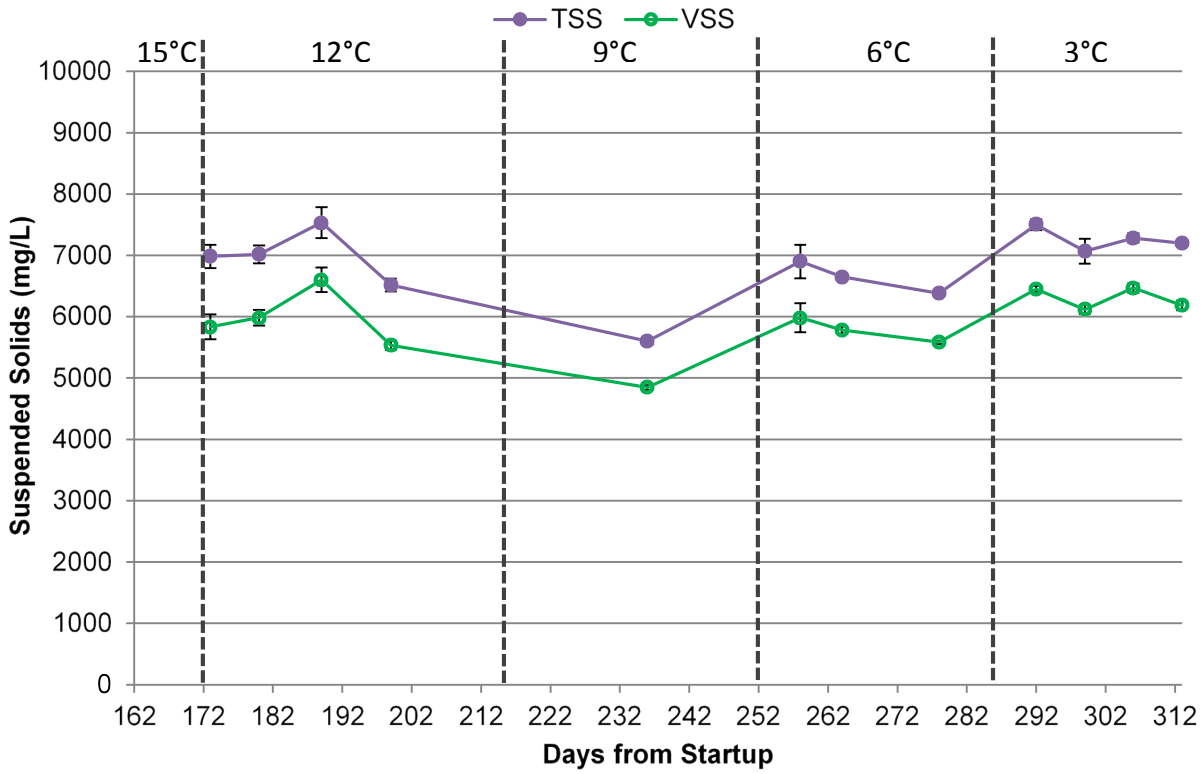


Figure S2. COD mass balance for days 162-313. Total COD_{out} is the summation of measured permeate COD, measured dissolved methane, measured gaseous methane, theoretical COD removal from measured sulfate reduction, and theoretical COD from measured biomass wasting. An issue with the biogas collection system during days 162-205 prevented accurate measurement of biogas production during that time.



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96 **Figure S3. Total suspended solids (TSS) and volatile suspended solids (VSS) in the bioreactor during days**
97 **162-313. Error bars represent the standard deviations of triplicate measurements.**
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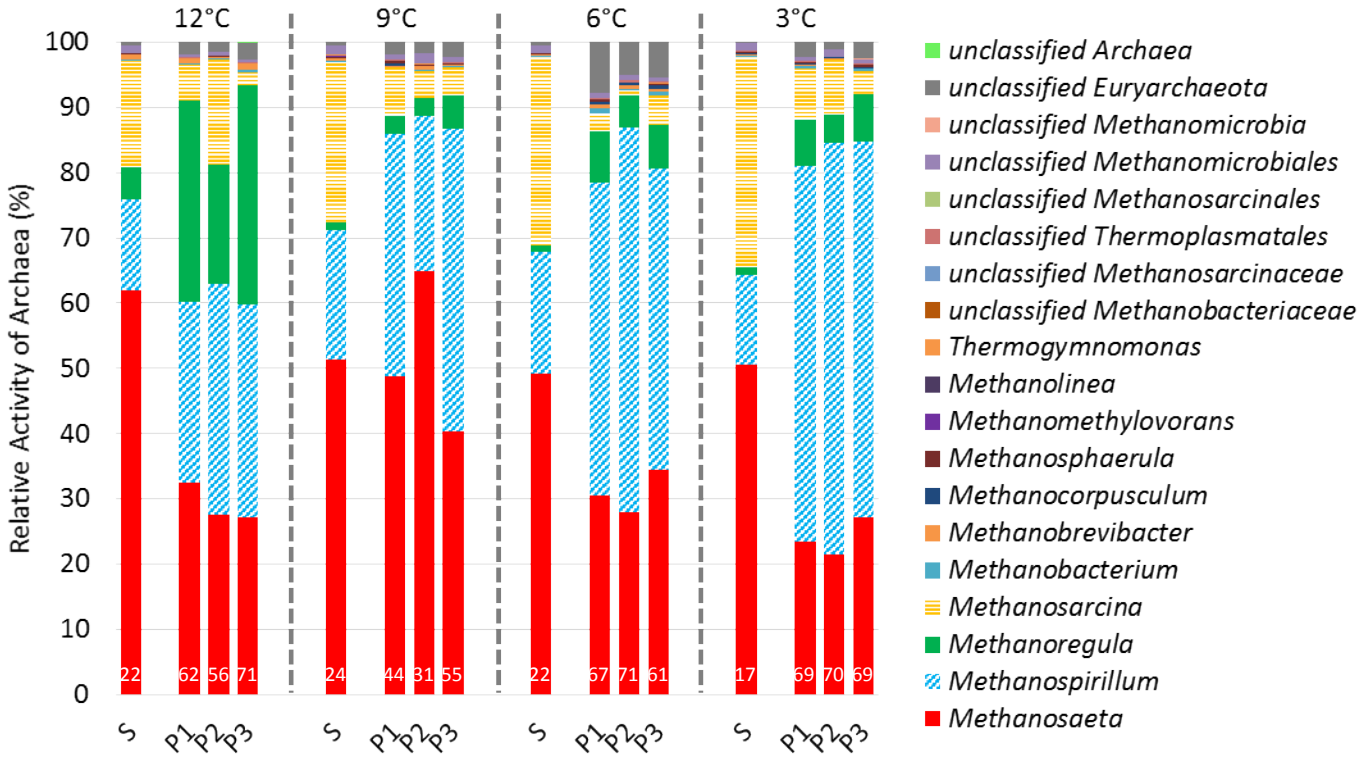

Figure S4. Relative activity of *Archaea* in the suspended biomass (S) and biofilm (P1, P2, and P3) based on 16S rRNA sequencing at operational temperatures of 12, 9, 6, and 3°C. Data are expressed as a percentage and were normalized using the total number of archaeal 16S rRNA sequences. Numbers at the bottom of each bar represent the relative activity of hydrogenotrophic methanogens (all methanogens except *Methanosaeta* spp. and *Methanosarcina* spp.).

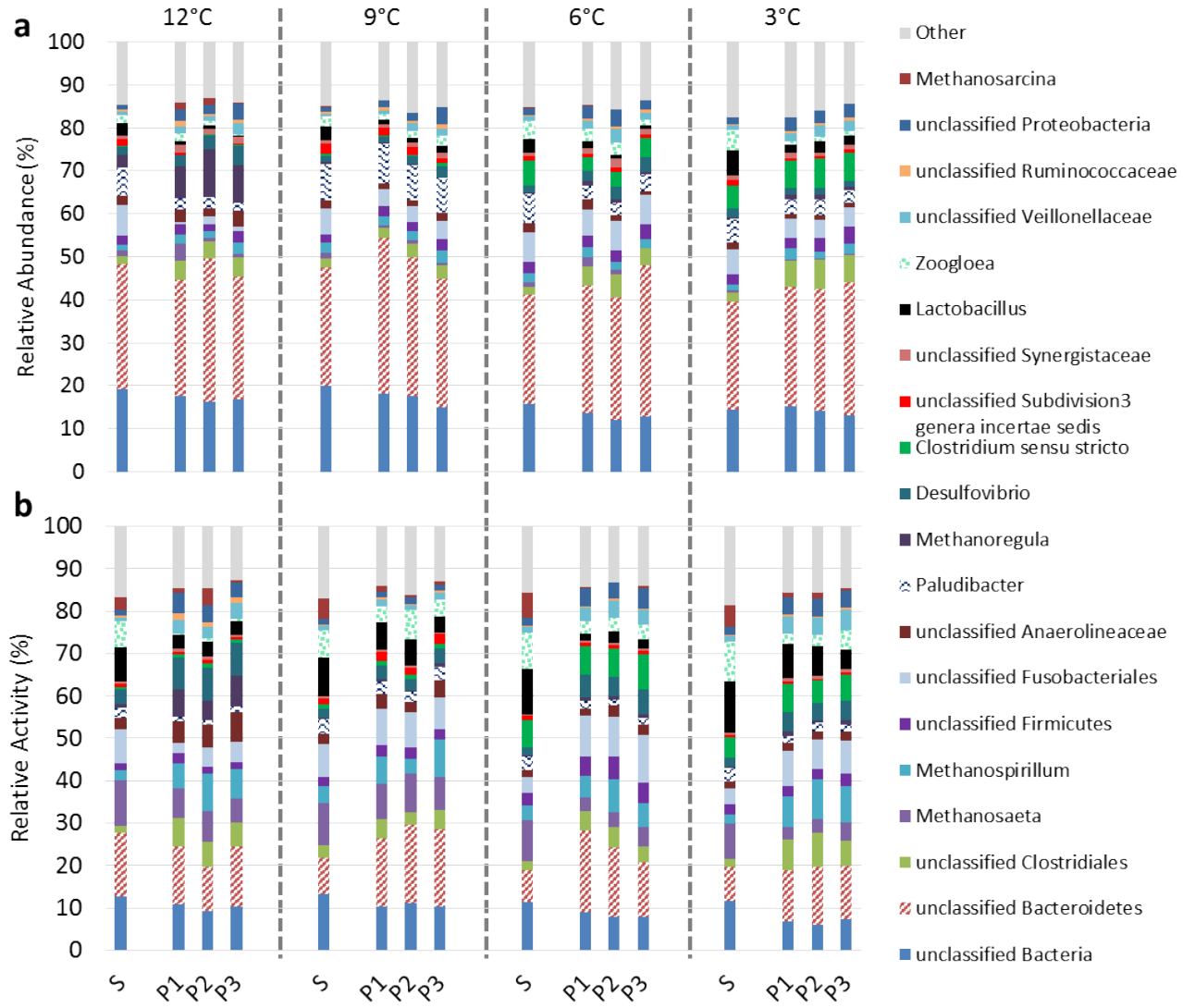

Figure S5. (a) Relative abundance based on 16S rDNA sequencing and (b) relative activity based on 16S rRNA sequencing of the top 20 phylotypes to total community in the suspended biomass (S) and biofilm (P1, P2, and P3) at operational temperatures of 12, 9, 6, and 3°C. Data are expressed as a percentage and were normalized using the total number of 16S rDNA sequences (a) and 16S rRNA sequences (b) (including both *Archaea* and *Bacteria*).

Supplementary Calculations

The following calculations demonstrate that for the operational conditions and observed performance data for the bench-scale AnMBR at 15°C, the biogas can contain >90% as experimentally observed.

Stoichiometric reaction (Rittmann and McCarty, 2001):

$$\frac{1}{50}C_{10}H_{19}O_3N + \frac{11}{100}H_2O = \frac{11}{200}CO_2 + \frac{1}{8}CH_4 + \frac{1}{50}NH_4^+ + \frac{1}{50}HCO_3^-$$

Hydraulic retention time, HRT = 16 h
Reactor volume, V = 4 L
Influent flow rate, Q_{liquid} = V/HRT = 6 L/d
Influent COD concentration = 450 mg/L as COD
Permeate COD concentration = 50 mg/L as COD

$$COD\ removal = Influent - Permeate = \frac{450\ mg\ COD}{L} - \frac{50\ mg\ COD}{L} = \frac{400\ mg\ COD}{L}$$

$$C_{10}H_{19}O_3N\ removal = \frac{400\ mg\ COD}{L} * \frac{1\ g\ C_{10}H_{19}O_3N}{1.99\ g\ COD} * \frac{1\ mol\ C_{10}H_{19}O_3N}{201\ g\ C_{10}H_{19}O_3N} = 1\ mM\ C_{10}H_{19}O_3N$$

$$1\ mM\ C_{10}H_{19}O_3N * \frac{\frac{1}{8}}{\frac{1}{50}} = 6.25\ mM\ CH_4$$

$$1\ mM\ C_{10}H_{19}O_3N * \frac{\frac{11}{200}}{\frac{1}{50}} = 2.75\ mM\ CO_2$$

Total CH_4 and CO_2 production:

$$Total\ CH_4\ production = 6.25\ mM\ CH_4 * \frac{16\ g}{mmol} * \frac{6\ L}{d} = \frac{600\ mg}{d}$$

$$Total\ CO_2\ production = 2.75\ mM\ CO_2 * \frac{44\ g}{mmol} * \frac{6\ L}{d} = \frac{726\ mg}{d}$$

Dissolved CH_4 and CO_2 production:

$$Dissolved\ CH_4\ production = \frac{P_{CH_4} * \frac{55.6\ mol}{L} * \frac{16\ g}{mol} * \frac{1\,000\ mg}{g} * \frac{6\ L}{d} * CH_4\ oversaturation}{H_{CH_4}}$$

P_{CH_4} = Partial pressure of CH_4
H_{CH_4} = Henry's law constant, 34 269 atm at 15°C
$CH_4\ oversaturation$ = 2 (assumption based on bench-scale data)

$$Dissolved\ CO_2\ production = \frac{P_{CO_2} * \frac{55.6\ mol}{L} * \frac{44\ g}{mol} * \frac{1\,000\ mg}{g} * \frac{6\ L}{d}}{H_{CO_2}}$$

P_{CO_2} = Partial pressure of CO_2

H_{CO_2} = Henry's law constant, 1 273 atm at 15°C

Gaseous CH_4 and CO_2 production:

$$Gaseous\ CH_4\ production = P_{CH_4} * Q_{gas} * \frac{1\ mol * K}{0.0821\ L * atm} * \frac{1}{288\ K} * \frac{16\ g}{mol} * \frac{1\,000\ mg}{g}$$

$$Gaseous\ CO_2\ production = P_{CO_2} * Q_{gas} * \frac{1\ mol * K}{0.0821\ L * atm} * \frac{1}{288\ K} * \frac{44\ g}{mol} * \frac{1\,000\ mg}{g}$$

Q_{gas} = 0.45 L/d (assumption based on bench-scale data)

Total mass balance:

$$Total\ CH_4\ production = Dissolved\ CH_4\ production + Gaseous\ CH_4\ production$$

$$Total\ CO_2\ production = Dissolved\ CO_2\ production + Gaseous\ CO_2\ production$$

Solving for $P_{CH_4}\ and\ P_{CO_2}$,

P_{CH_4} = 0.94
P_{CO_2} = 0.059

(error of ± 20 mg/d in mass balance)