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Anaerobic Membrane Bioreactor for Sustainable Wastewater Treatment

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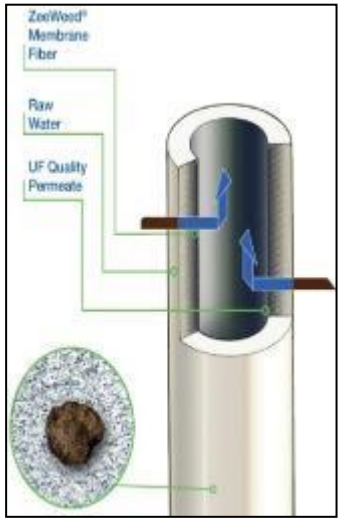
2018 | Enhancing DoD's Mission Effectiveness

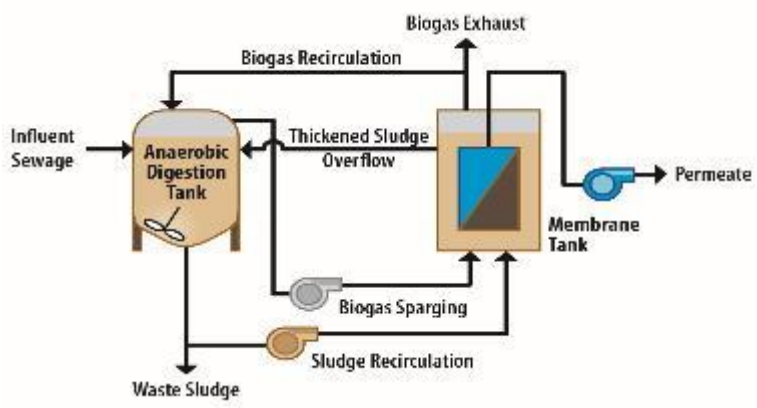
Problem Statement

- Wastewater treatment involves energy-intensive aerobic treatment.
  - Aerobic **energy** demand is associated with **aeration**.
  - Aerobic treatment generates significant **sludge**.

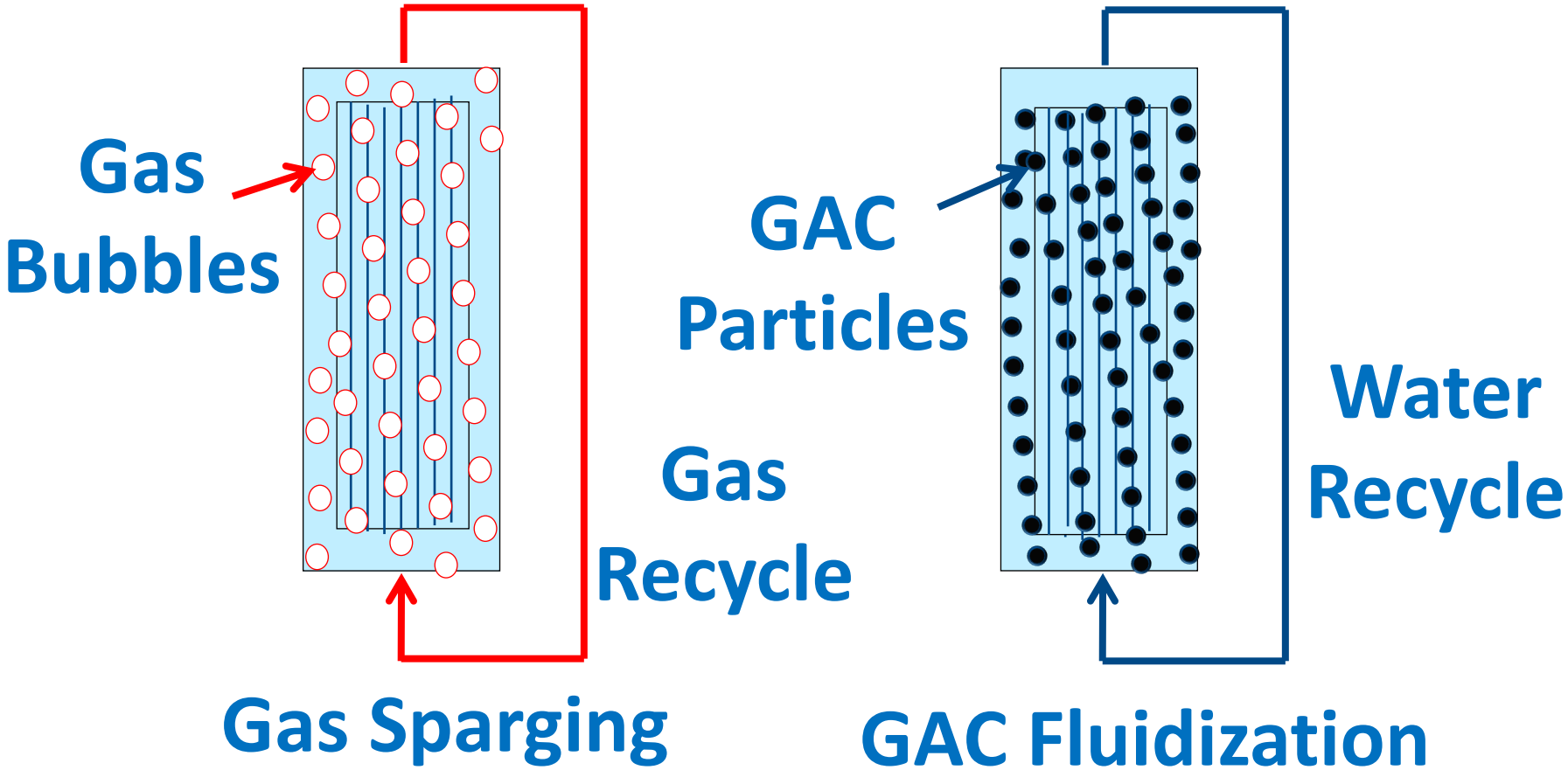
Anaerobic Membrane Bioreactor (AnMBR)

- Combines anaerobic biological treatment and physical membrane separation.
  - Eliminates energy-intensive aeration, produces biogas, and minimizes sludge production.
  - Enables low temperature operation and produces water for reuse.





Ultrafiltration Membrane Fouling Management



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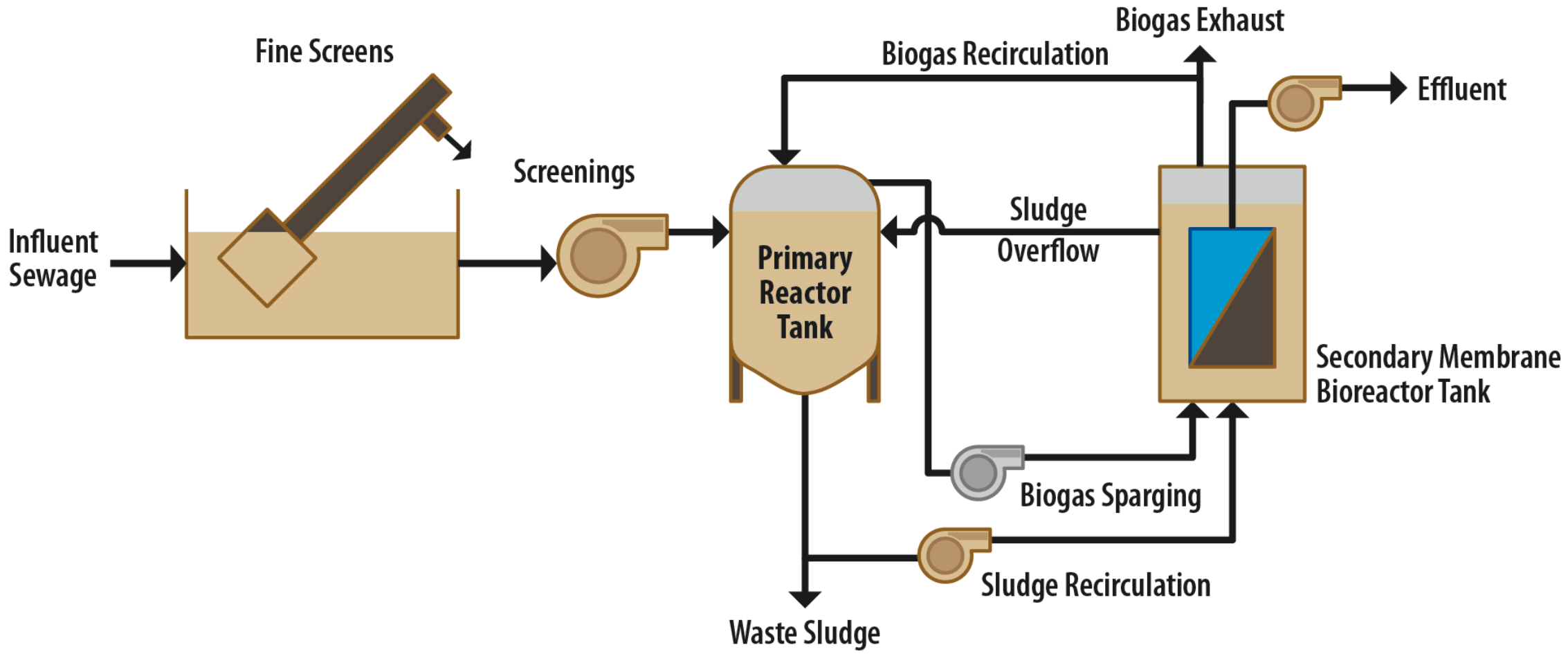
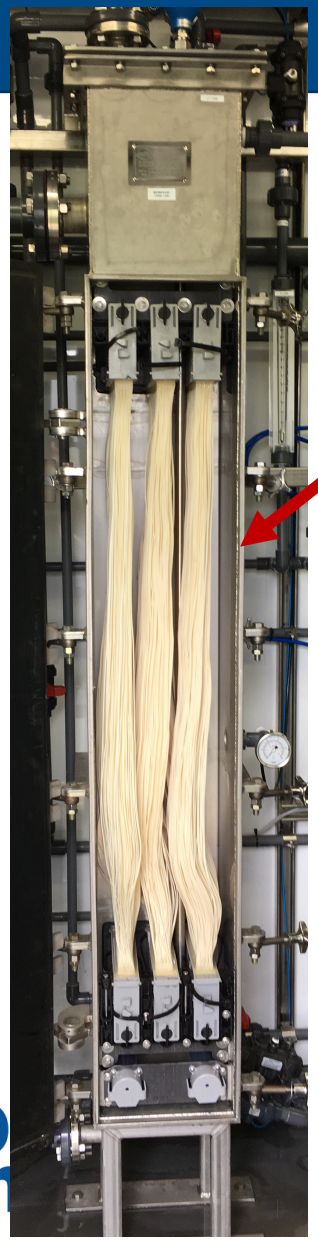
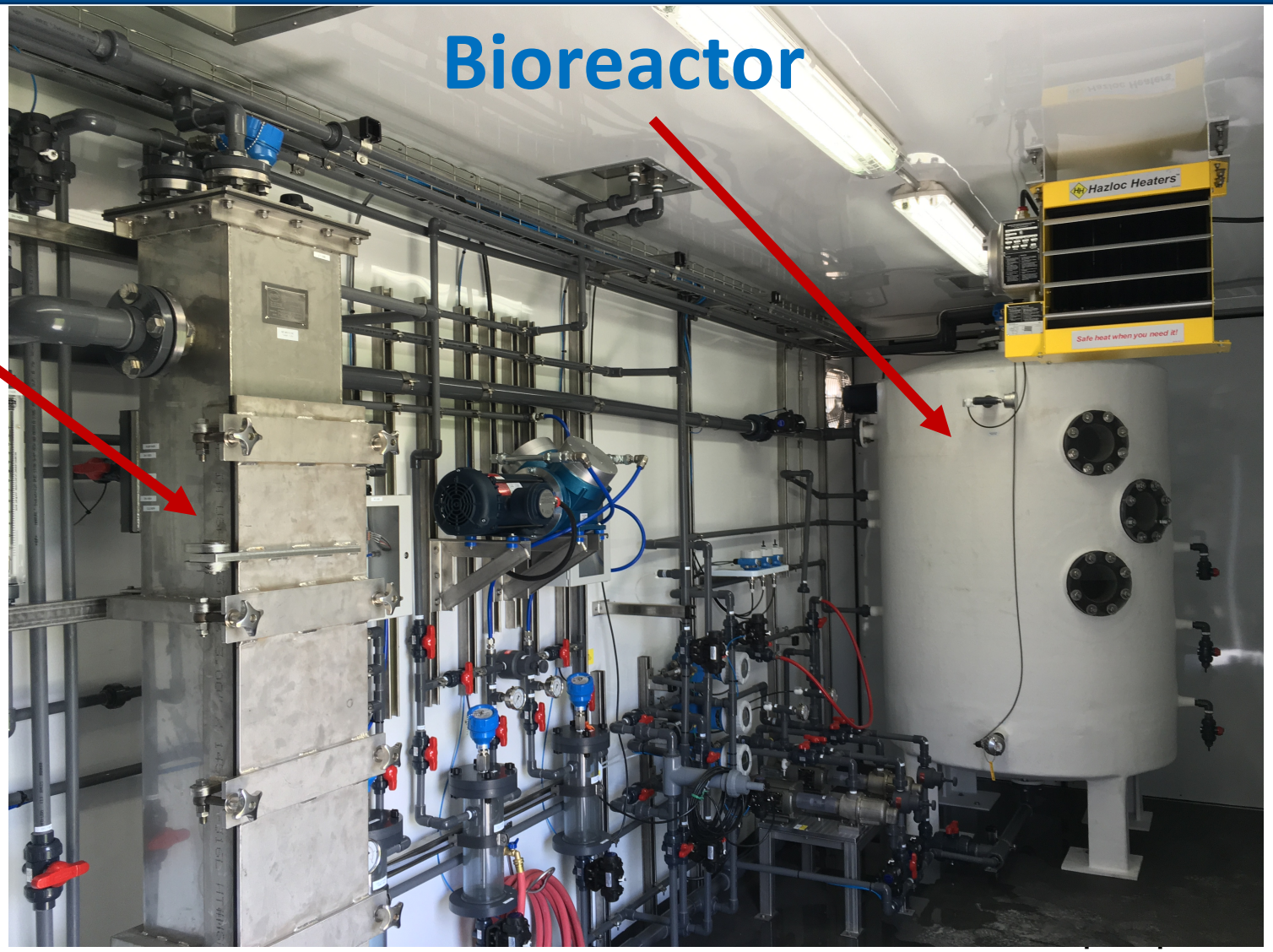
Gas-Sparged AnMBR Configuration



Gas-Sparged AnMBR

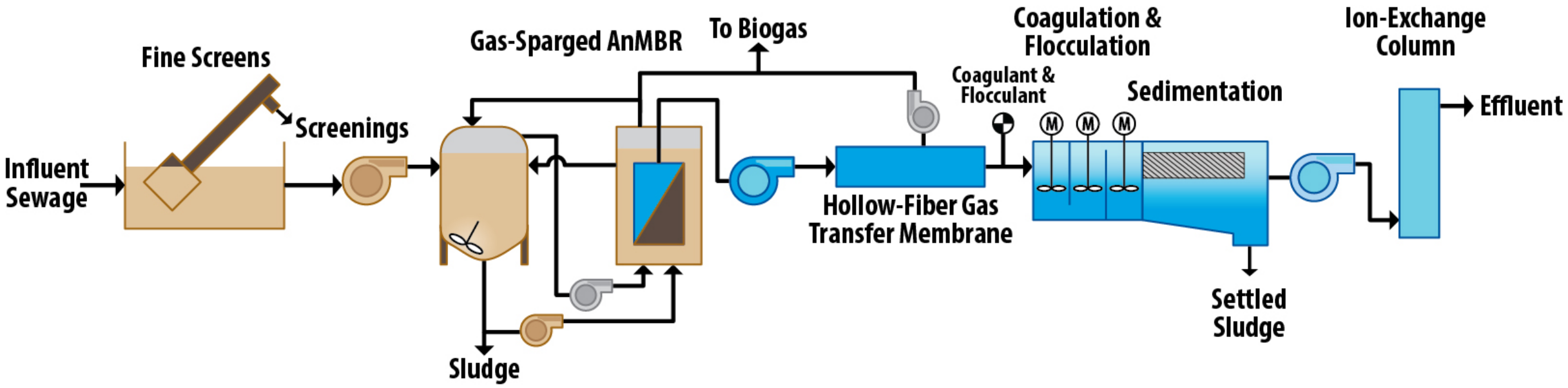


Membranes



Bioreactor

Gas-Sparged AnMBR Configuration Including Downstream Processes



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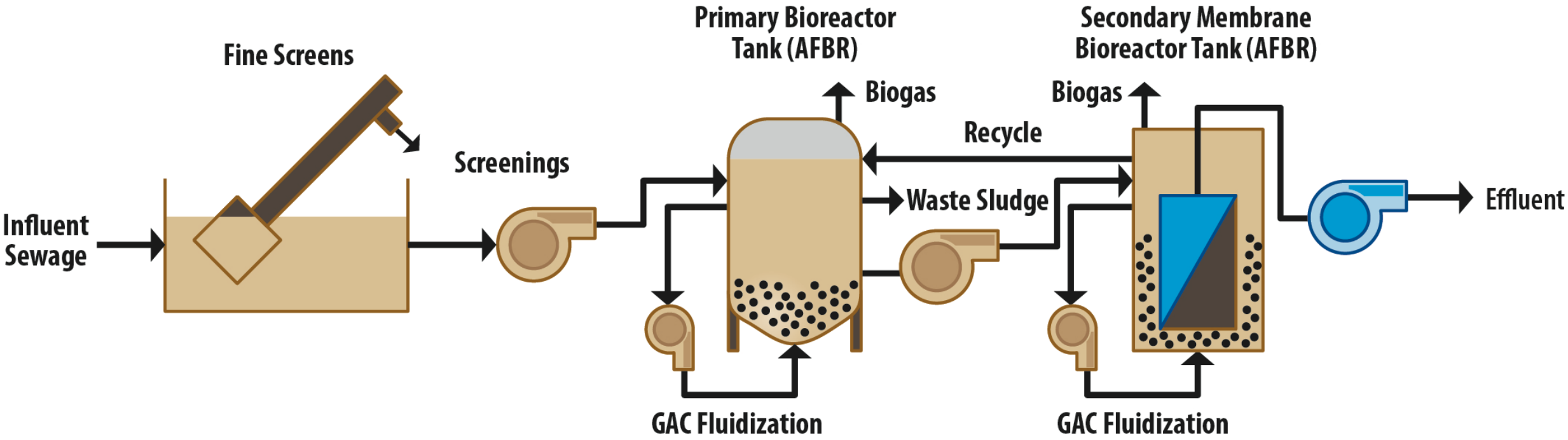
GAC-Fluidized AnMBR Configuration



GAC-Fluidized AnMBR

Fluidized Bed Bioreactor

Membranes

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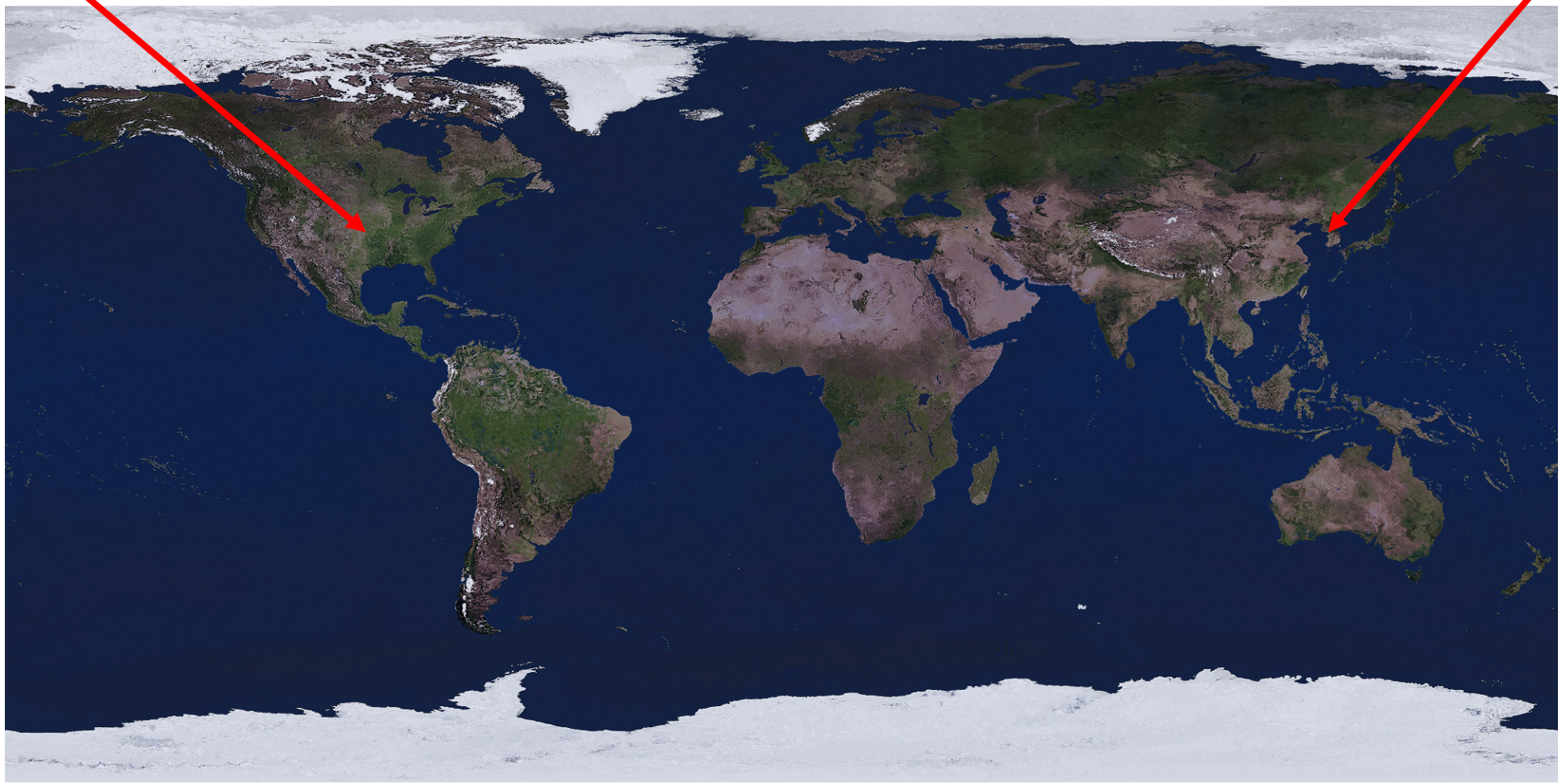
“Side-By-Side” Comparison

Ft. Riley, Kansas

Bucheon, Korea



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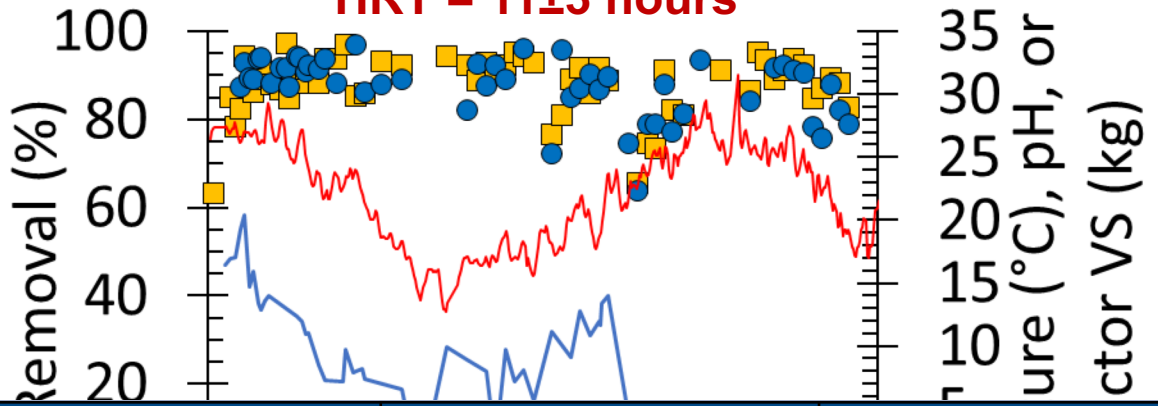
Better Effluent Quality in the GAC-Fluidized AnMBR

- Similar percent removals of BOD_5 and COD
- Lower hydraulic residence time and effluent concentrations in GAC-fluidized AnMBR

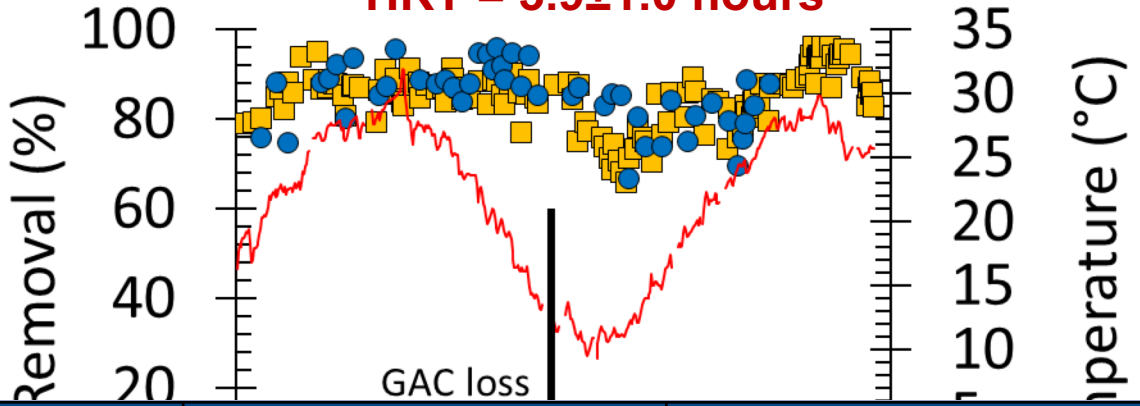
Gas-Sparged AnMBR

HRT = 11±3 hours



GAC-Fluidized AnMBR

HRT = 3.9±1.0 hours



AnMBR	BOD_5 in (mg/L)	BOD_5 out (mg/L)	COD in (mg/L)	COD out (mg/L)
Gas-Sparged	250±130	25±12	620±240	58±27
GAC-Fluidized	140±40	15±9	210±50	29±9

COD removal · BOD removal · Temperature · Bioreactor VS mass

COD removal · BOD removal · Temperature

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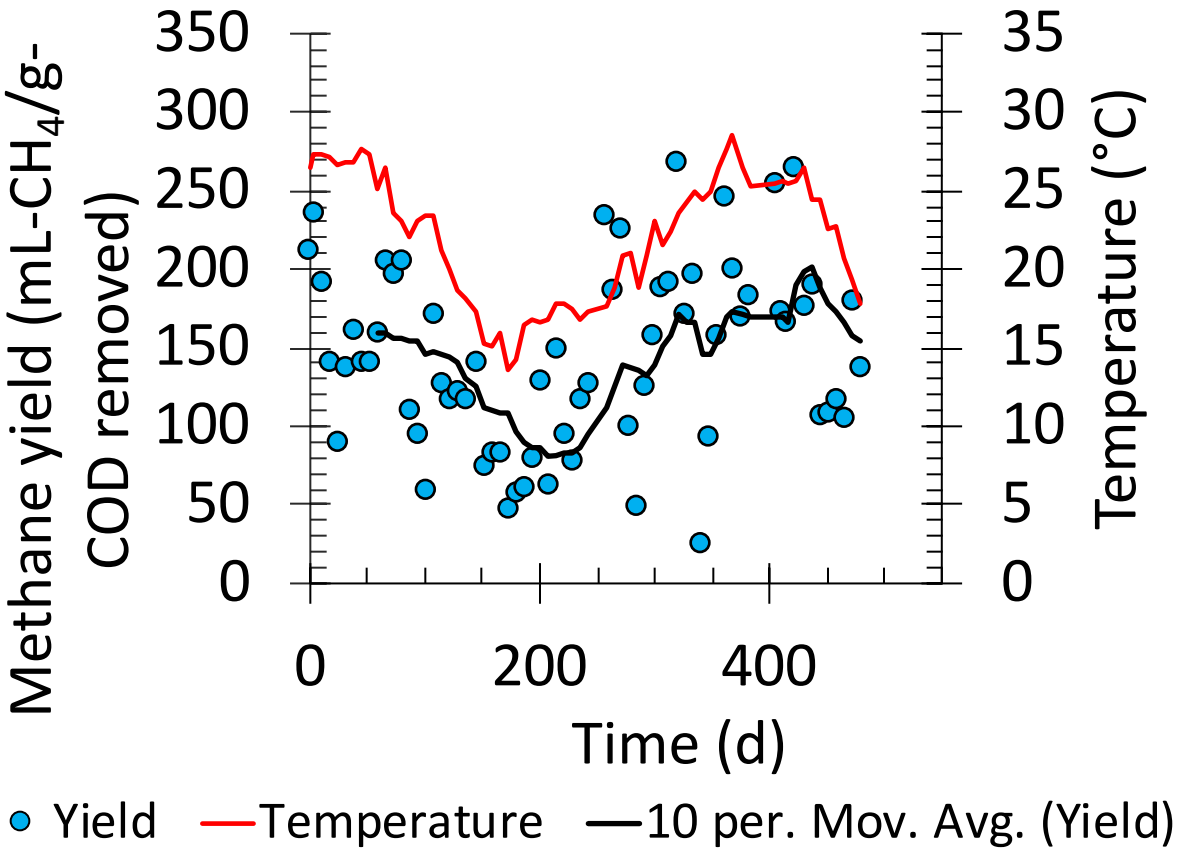
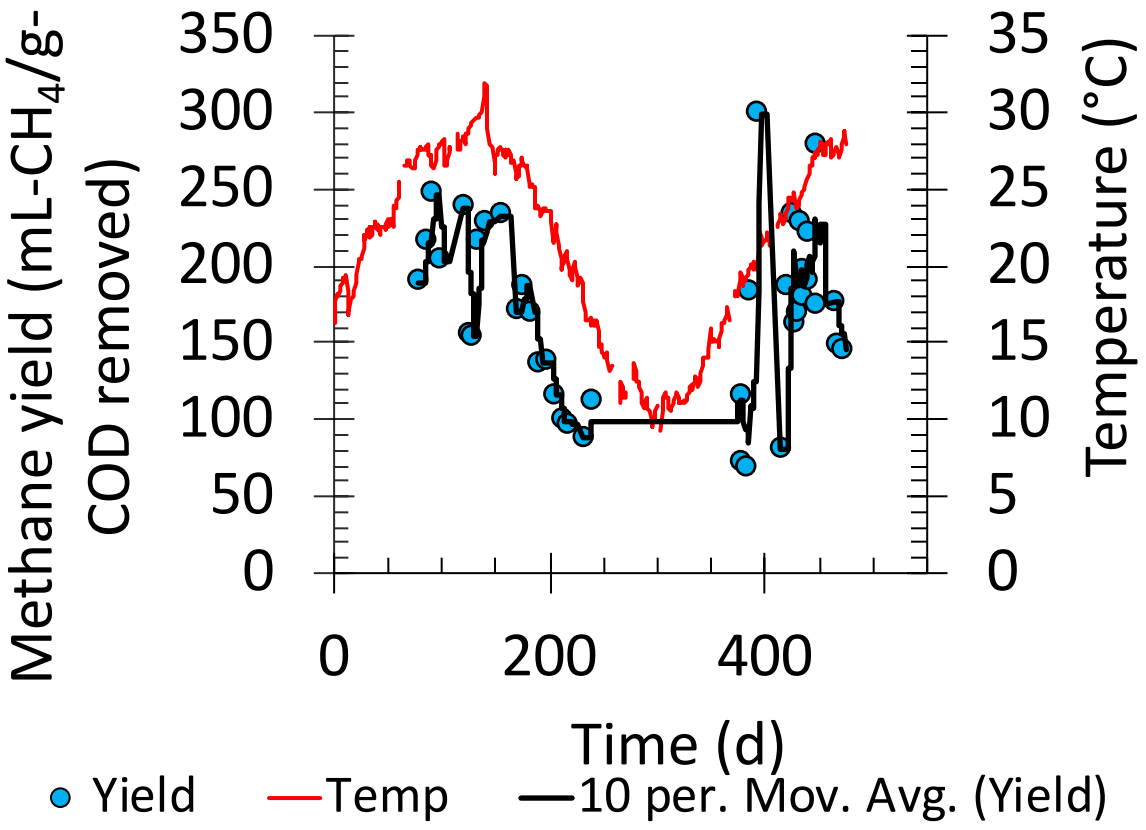
Total Methane Yield Dependent on Temperature

- Less solids hydrolysis at lower temperatures
- Leads to greater sludge yield

Gas-Sparged AnMBR



GAC-Fluidized AnMBR



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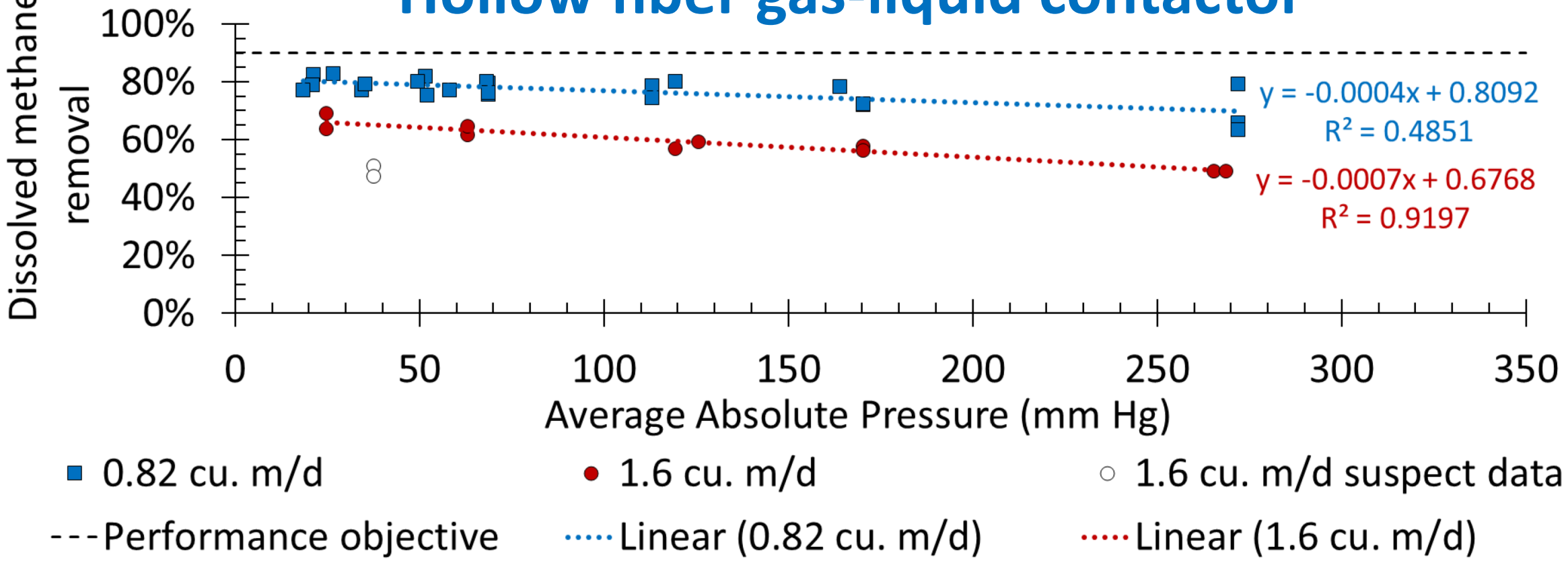
Dissolved Methane Recovered

- Dissolved methane removal important to mitigate greenhouse gas emissions and recover energy
- Removed 79±2% dissolved methane

Hollow fiber gas-liquid contactor



3M 2.5×8 Industrial Extra-Flow Liqui-Cel™ membrane contactor

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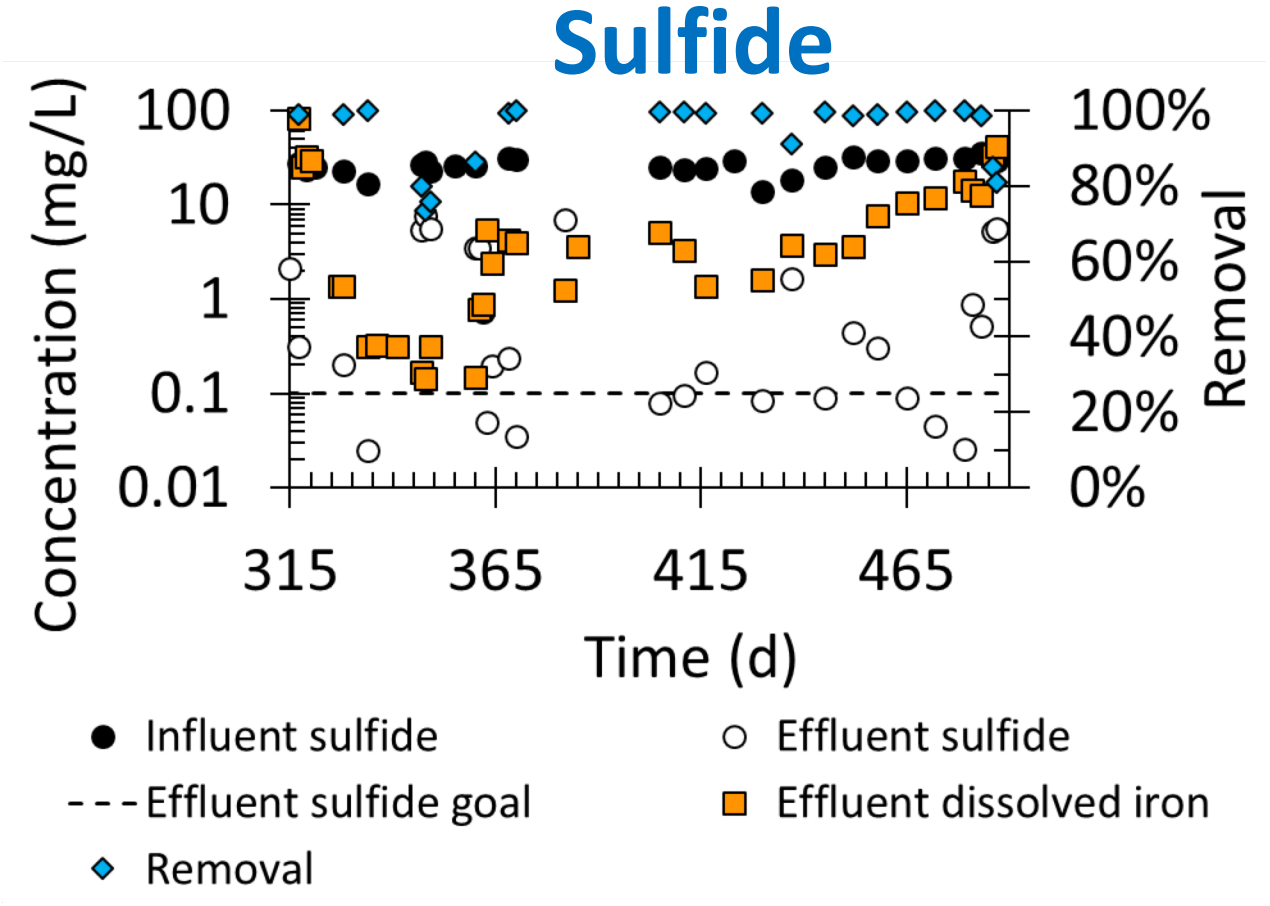
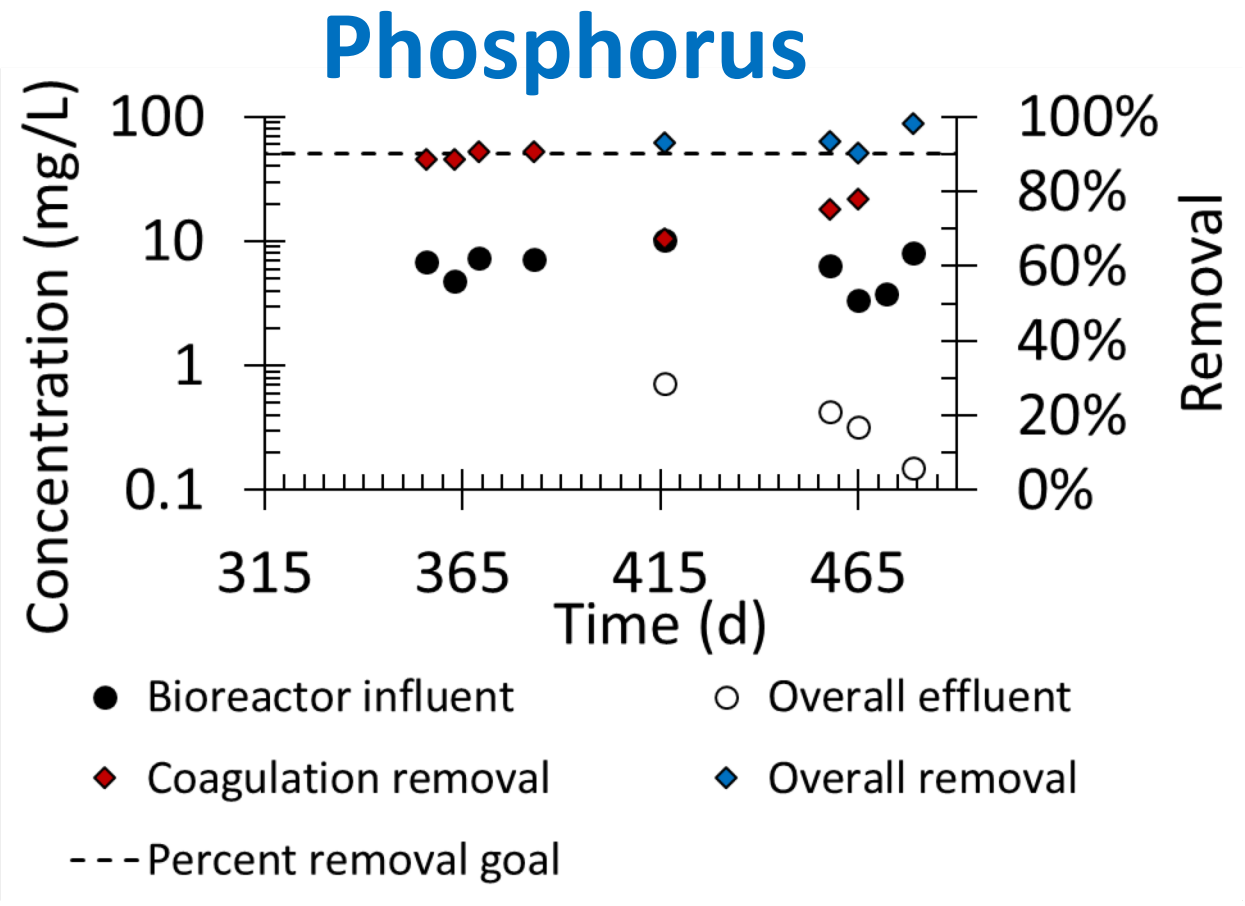
Sulfide and Phosphorus Removed by Coagulation

- Sulfide removal 99±2% and phosphorus removal 94±3%
- Chemical-intensive process





115 mg/L $FeCl_3$
30 mg/L aluminum chlorohydrate
1 mg/L polymer

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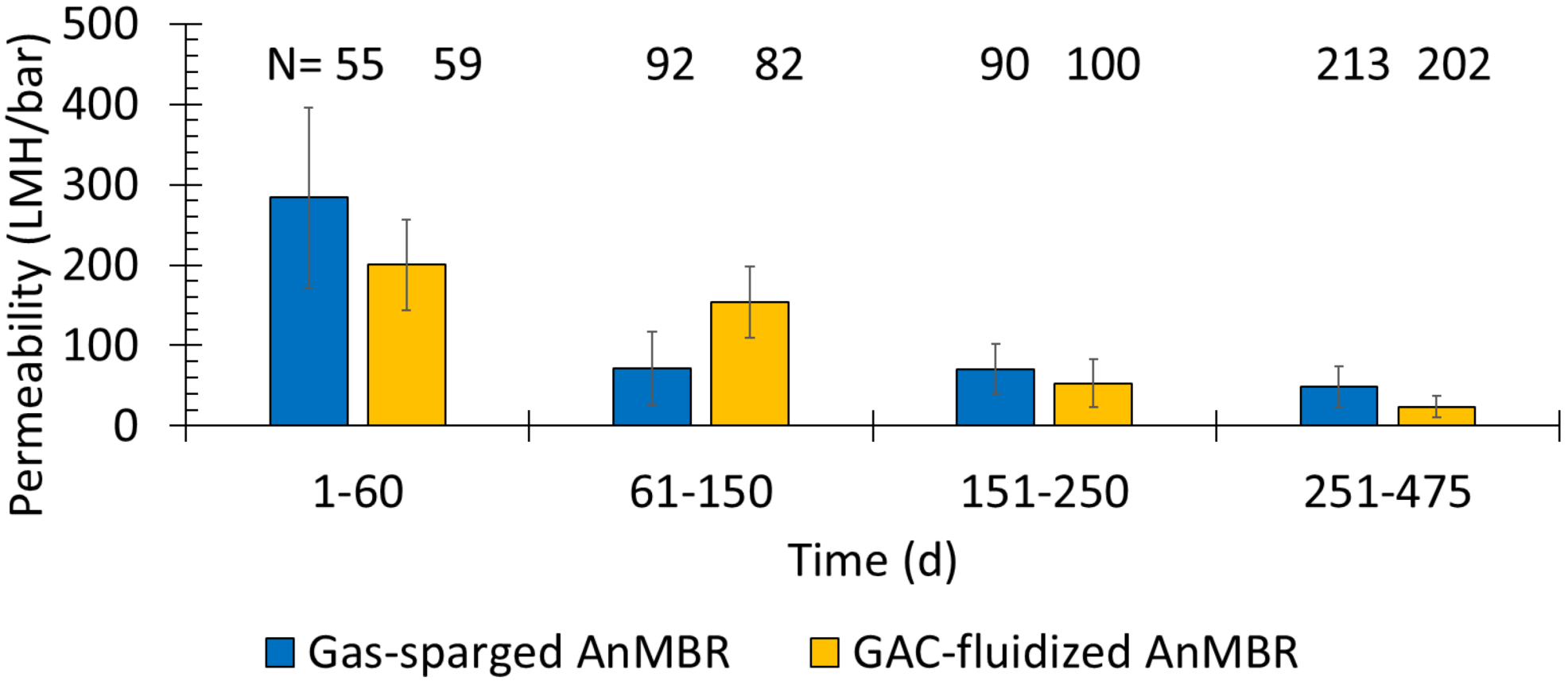
UF Membrane Performance Better in Gas-Sparged AnMBR

- More flexible because of gas-sparging flow rate can be varied
- Greater permeability at higher suspended and colloidal solids concentrations



LMH (membrane flux) = L m^{-2} h^{-1}

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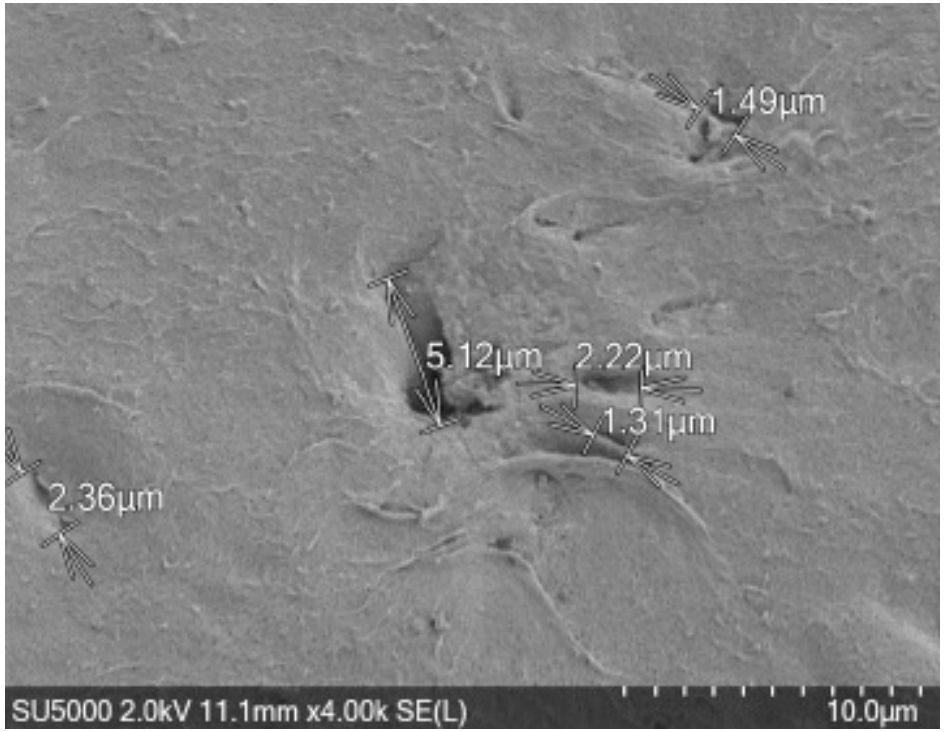
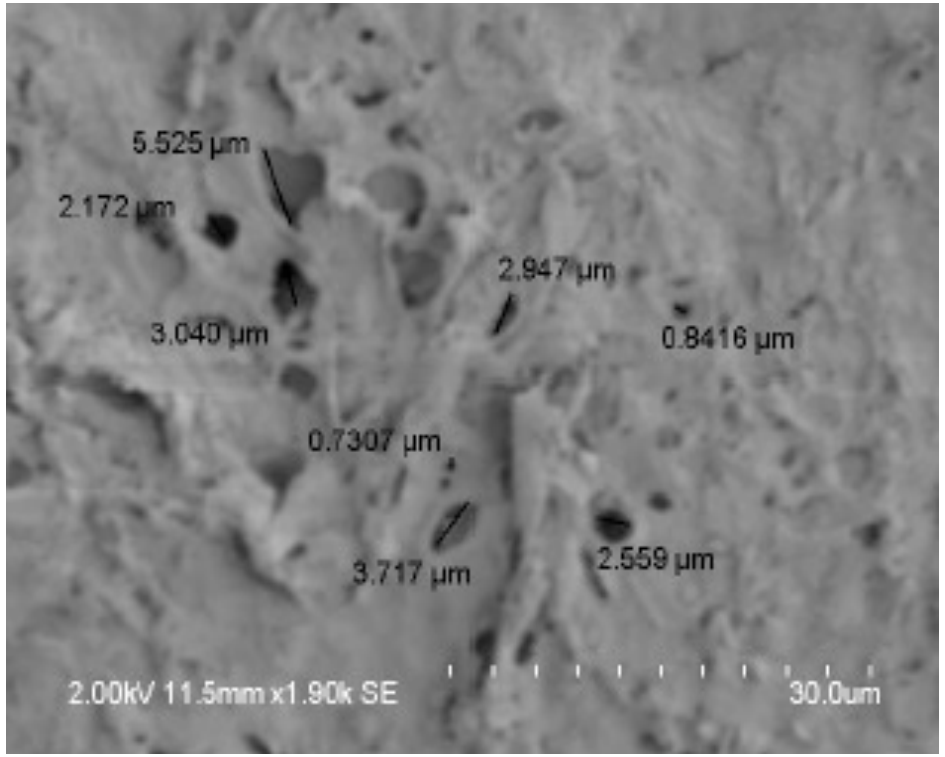
UF Membrane Abraded by GAC in GAC-Fluidized AnMBR

- Gas-sparged AnMBR is more robust

Gas-Sparged AnMBR



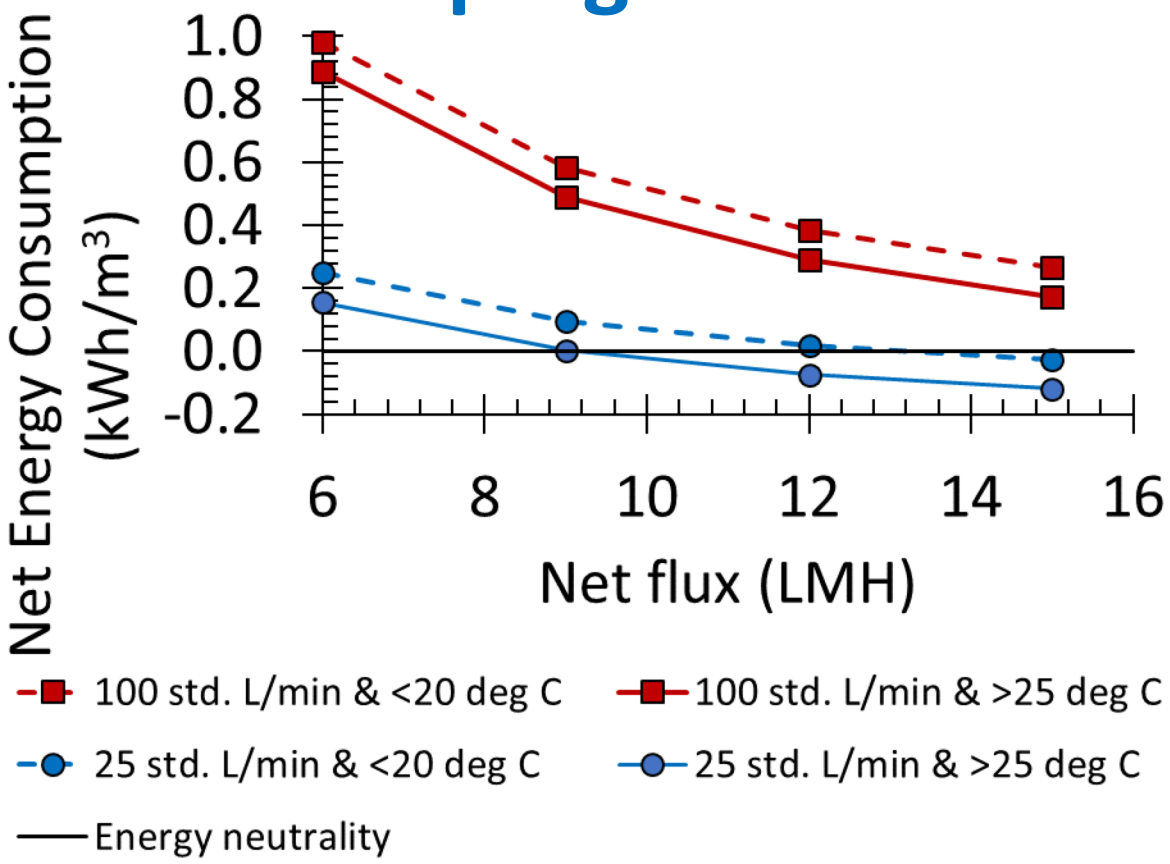
GAC-Fluidized AnMBR



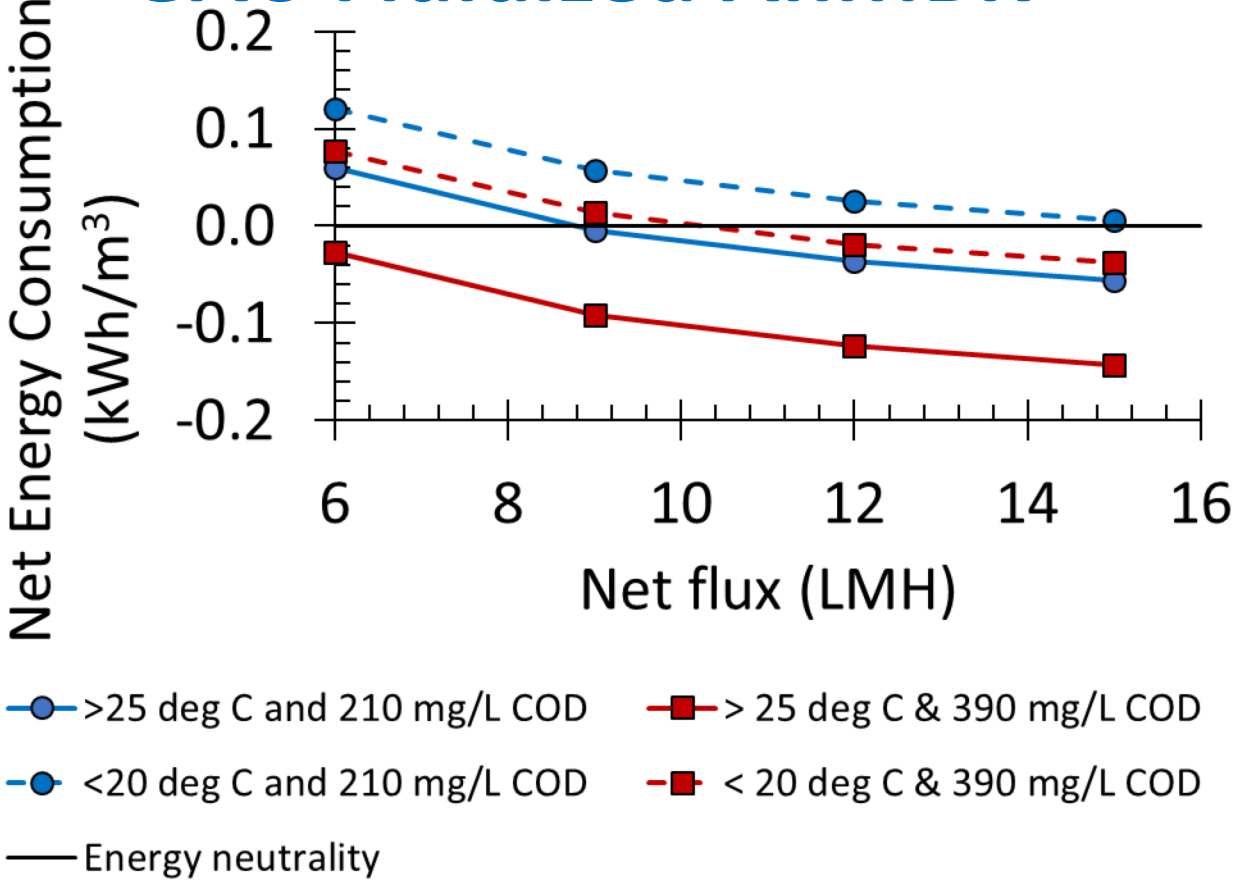
Energy-Neutral or -Positive Operation Possible

- Temperature, wastewater strength, and sparging energy determine result
- Less energy than conventional activated sludge (0.3 to 0.6 kWh/m^3)

Gas-Sparged AnMBR

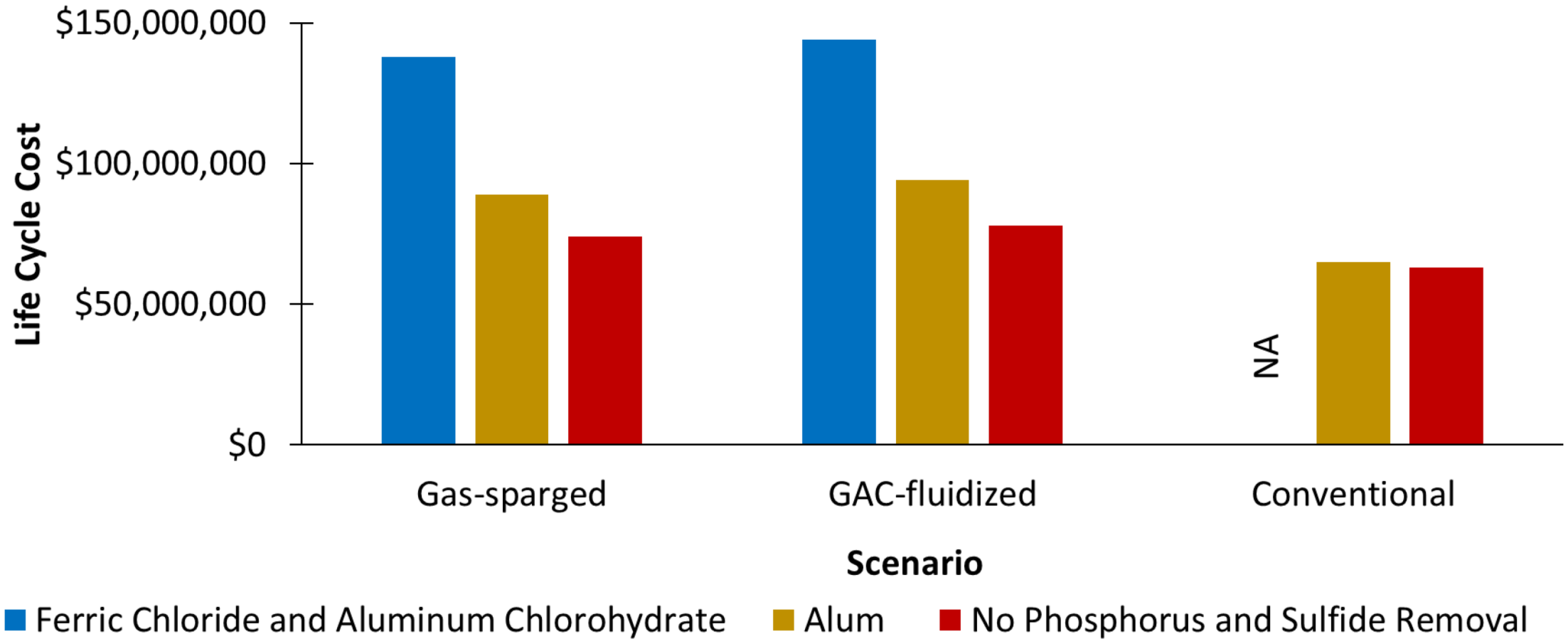


GAC-Fluidized AnMBR



Chemical Use Drives AnMBR Costs

- Chemicals for sulfide removal dominate operating costs
- Membrane cleaning and replacement, and GAC replacement also contribute



5 million gallons/day
20-year life
7% discount rate

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Conclusions

- BOD_5 and COD removals better in the GAC-fluidized AnMBR down to 15°C
- Ultrafiltration membrane performance better in the gas-sparged AnMBR
- Energy efficiency better in the GAC-fluidized AnMBR
- Dissolved methane removal using hollow-fiber contactors possible but alternatives exist
- Cost and lifecycle environmental impacts driven by chemical use for sulfide removal
- Alternative chemical-free methods of sulfide removal should be evaluated
- A hybrid fluidized-bed followed by a gas-sparged membrane AnMBR is recommended for further evaluation

Acknowledgements

- Funding provided by ESTCP and EPA
- Multiple partners involved
  - Perry McCarty, Stanford
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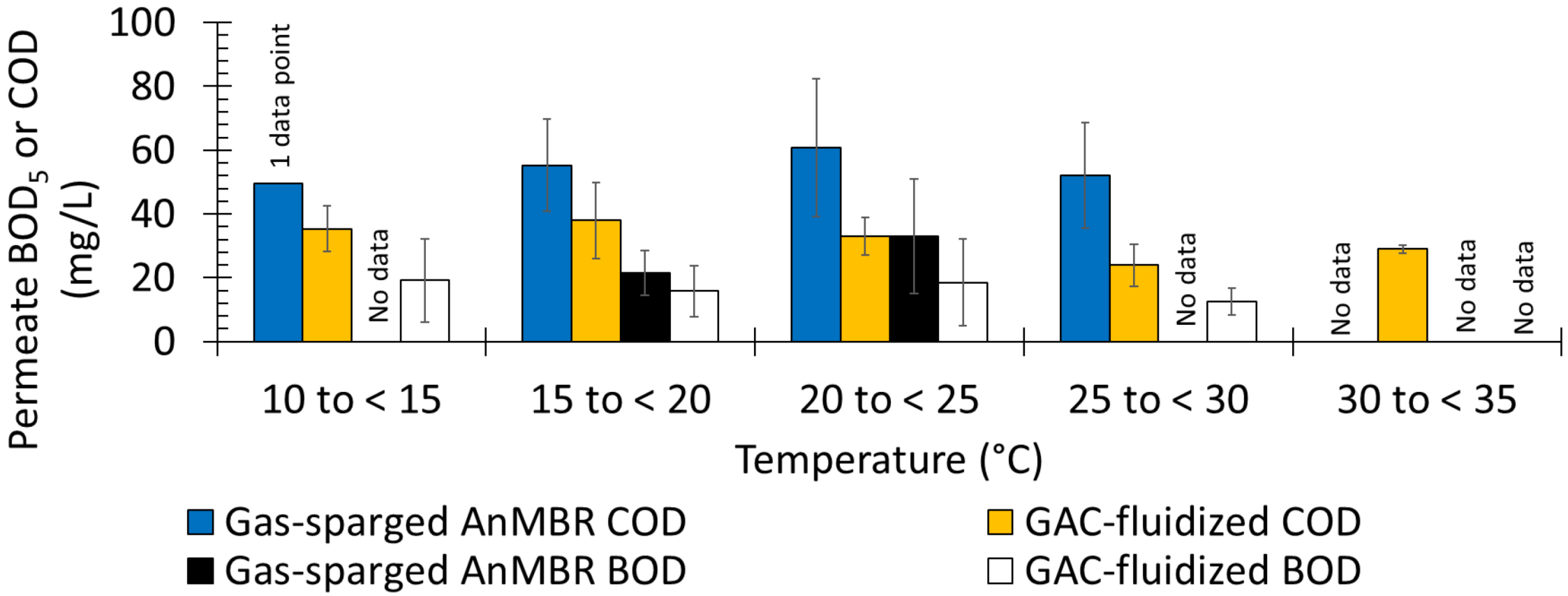
  - Sonny Maga, US Navy EXWC
  - Bruce Rittmann, Arizona State Univ.
  - Ft. Riley
  - Bucheon Gulpo wastewater treatment plant
  - City of Topeka
  - Suez

Thank You!

- **For more information:**
- https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Wastewater-and-Drinking-Water/ER-201434/ER-201434/(modified)/31Dec2015

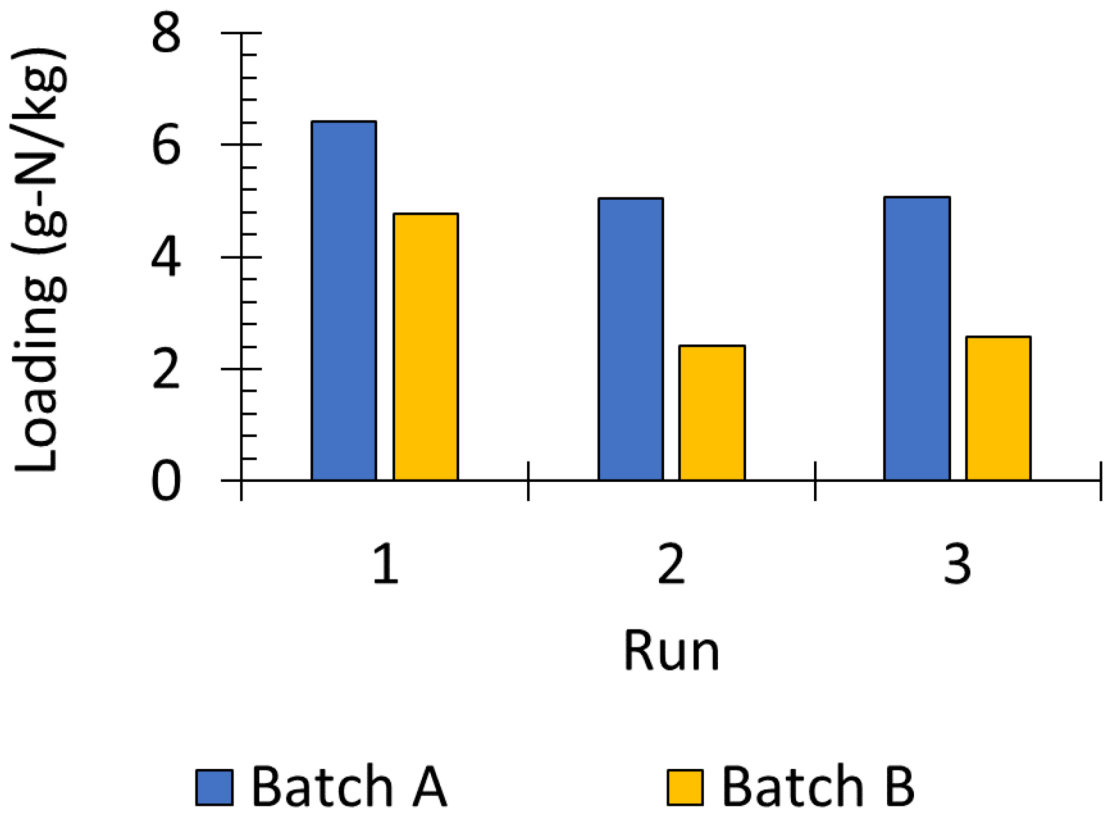
Treatment Observed Over a Wide Temperature Range

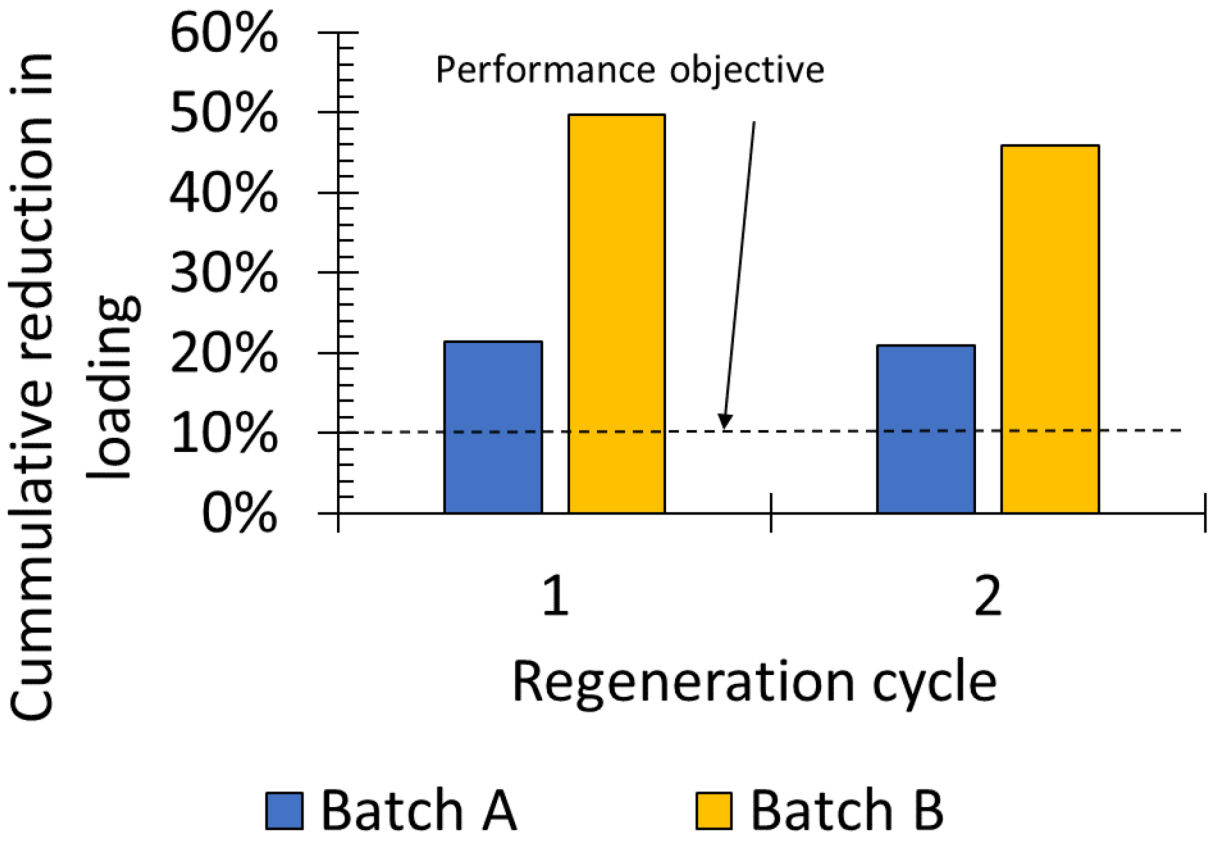
- More efficient treatment by GAC-fluidized AnMBR at similar organic loading rates
- 60% shorter hydraulic retention time (3.9±1.0 versus 11±3 hours)



Ammonia Removed by Clinoptilolite Zeolite

- Ammonia reduced 99.9±0.1% (goal >90%)
- Loading reduced over time because of iron coagulant carryover





Ammonia reduced from 37±4 to 0.05±0.05 mg-N/L

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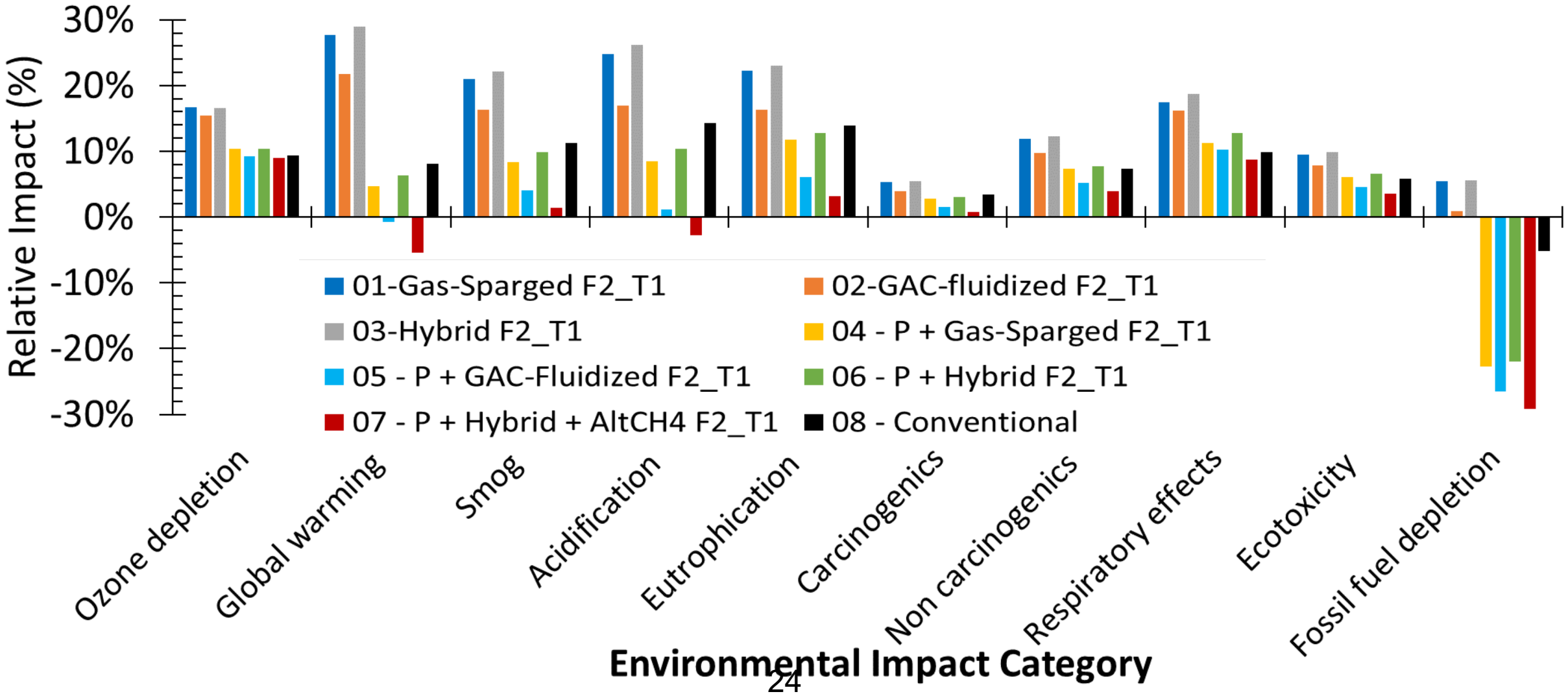
Chemical Use Drives Lifecycle Environmental Impacts

- Impacts below are relative to processes with sulfide removal using coagulation
- Relative impacts without chemical use less than conventional for certain AnMBR configurations