Nitrogen Recovery Using a New Generation MaX+ Annamox Reactor for Urine Treatment

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Overview

- Introduction
- Objectives
- Methods
- Results and Discussion
- Conclusion

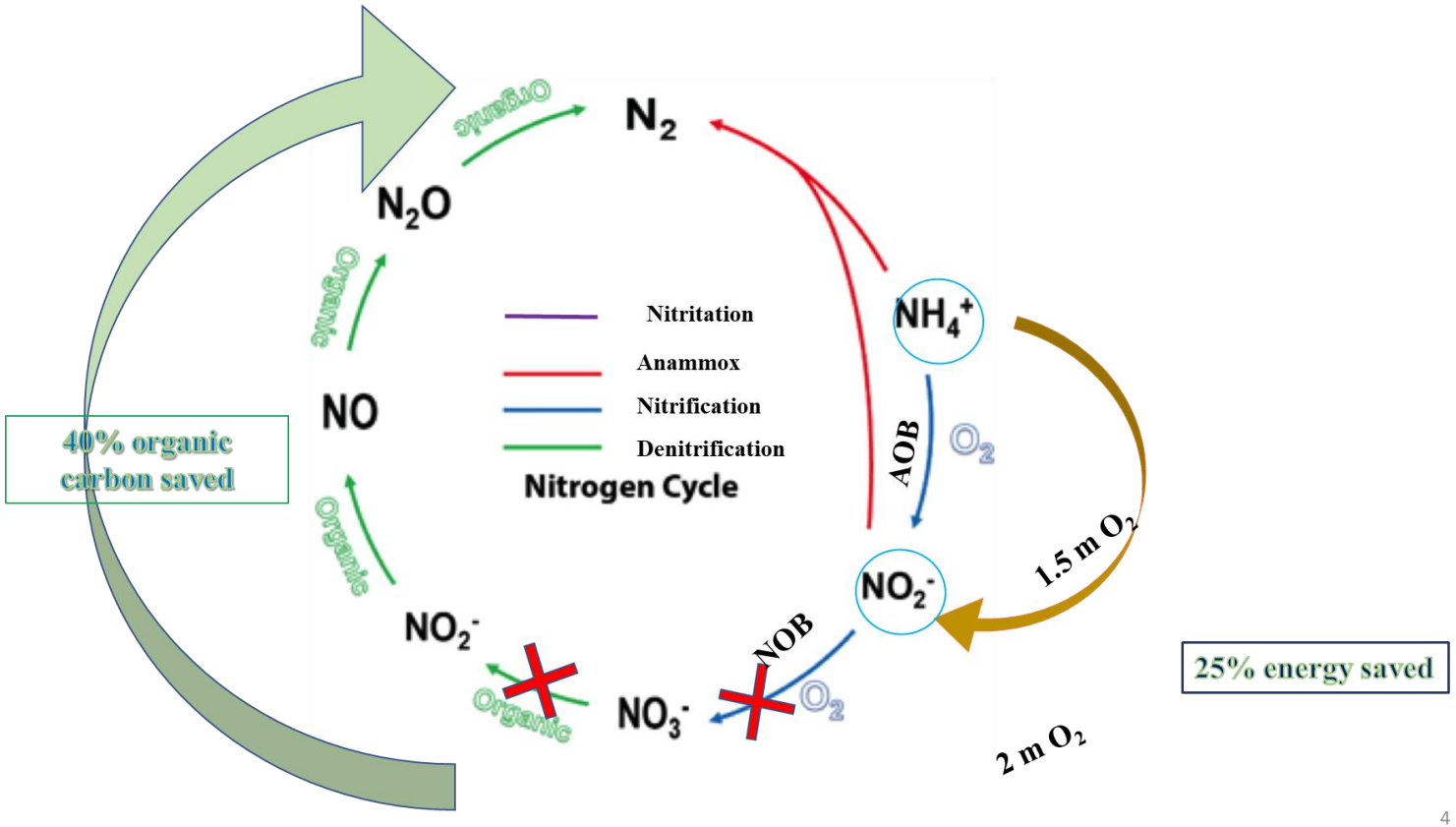
Introduction

*Why does **biological wastewater treatment** matter in low earth orbit (LEO) or in space habitats?*

- Reduce need for physical-chemical treatment
- Reduce consumables and resupply missions
- Stabilize wastewater
- Promote system sustainability
- Recover N_2 gas from treated urine

Nitrogen Cycle

***Instead of nitrification then denitrification, we skip to anammox reaction**



Partial Nitritation

$$(1)\ Organics + O_2 \rightarrow CO_2 + H_2O$$

$$(2)\ AN + 1.5O_2 \rightarrow NO_2- + H_2O + 2H^+$$

Anammox Reaction

$$(3)\ AN + 1.32NO_2 + 0.066HCO_3 - + 0.13H^+ \rightarrow 1.02N_2 + 0.26NO_3 - + 0.066CH_2O_{0.5}N_{0.15} + 2.03H_2O$$

Nitritation and Anammox Reaction

Advantages:

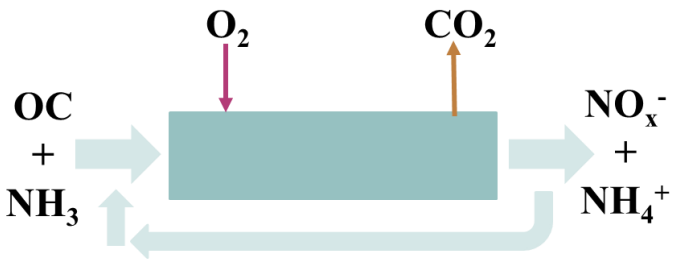
- Low solids production rate
- Requires little organic carbon (OC) and oxygen

Disadvantages:

- Slow growth rate
- Sensitive to oxygen in the environment

Previous Studies (Jalili, 2022)

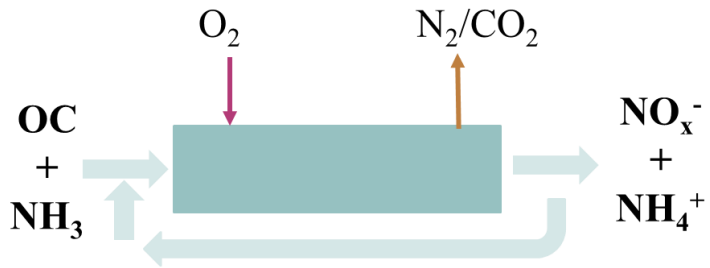
Single stage aerobic C and N oxidation



System performance limited by alkalinity

>90% OC oxidation
~50% N oxidation

Simultaneous oxidation/denitrification

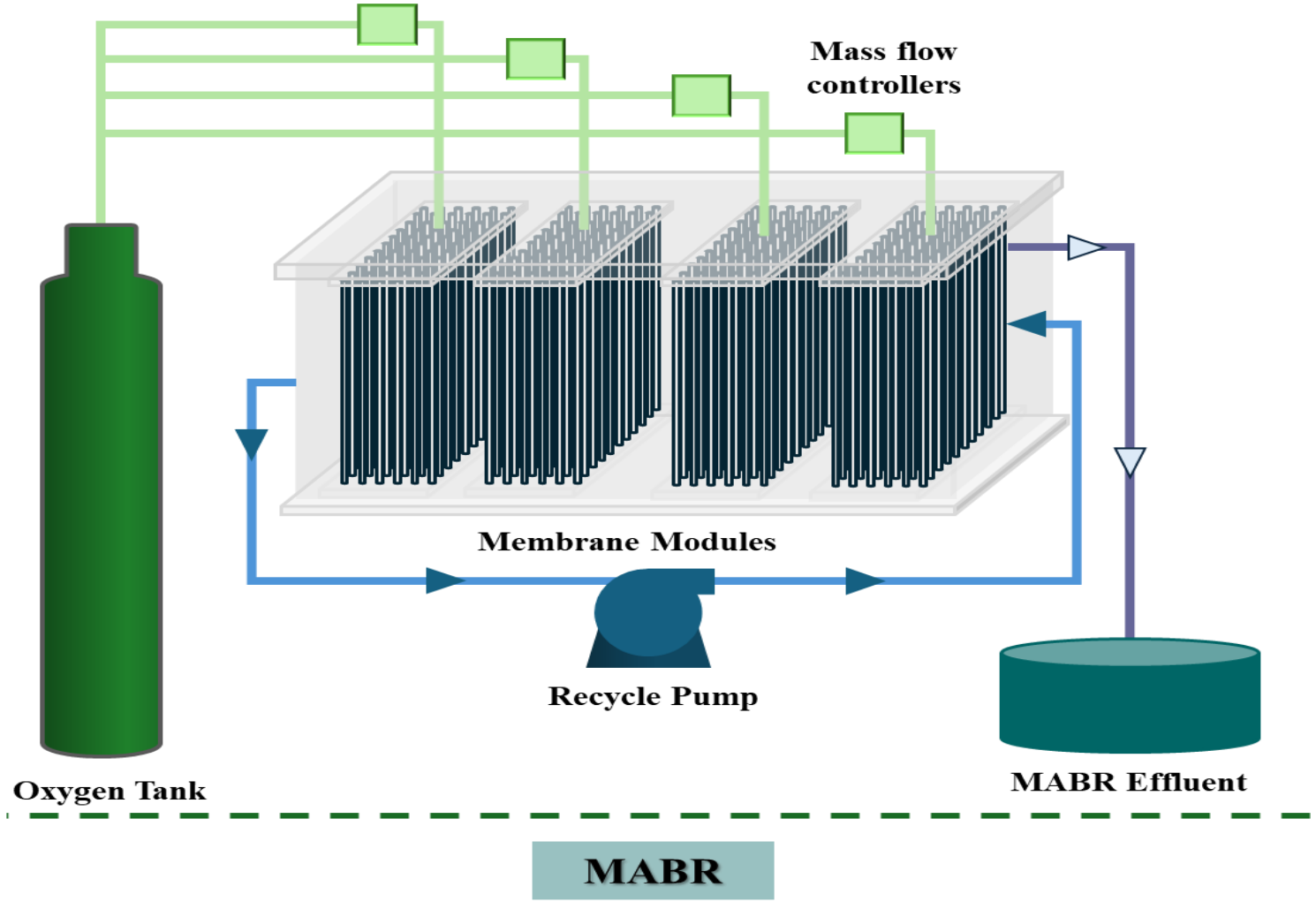


System performance limited by alkalinity and OC/TN <1

>90% OC oxidation
~60% N oxidation
~40% N removal

Previous Work

Partial Nitritation – Membrane Aerated Bioreactor (MABR)



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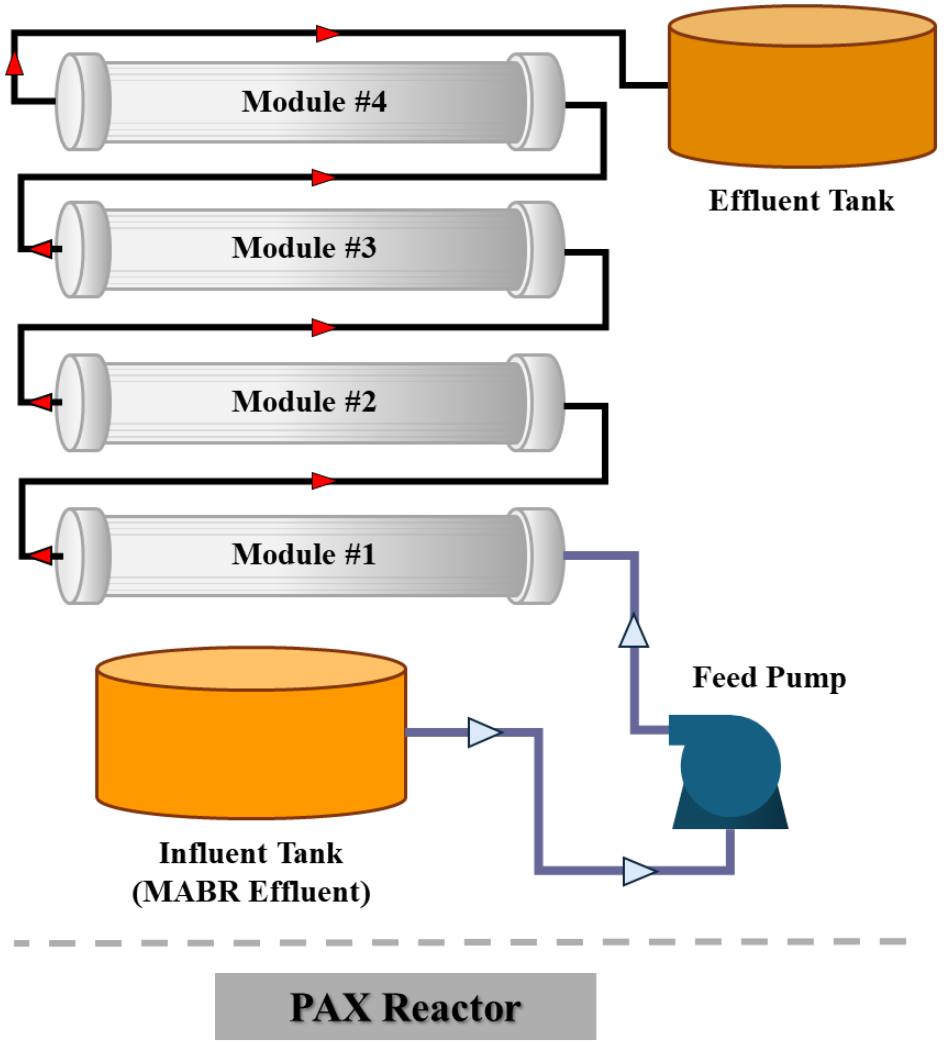
MABR Operation

- Over 95 % organic carbon removed
- pH maintained at 6.5-7
- 55% of NH_3 converted to NO_2^-
- NO_2^- ~100% of NO_x

Previous Work

Packed-Bed Anammox (Pancopia Anammox) PAX Reactor



Anammox Reaction

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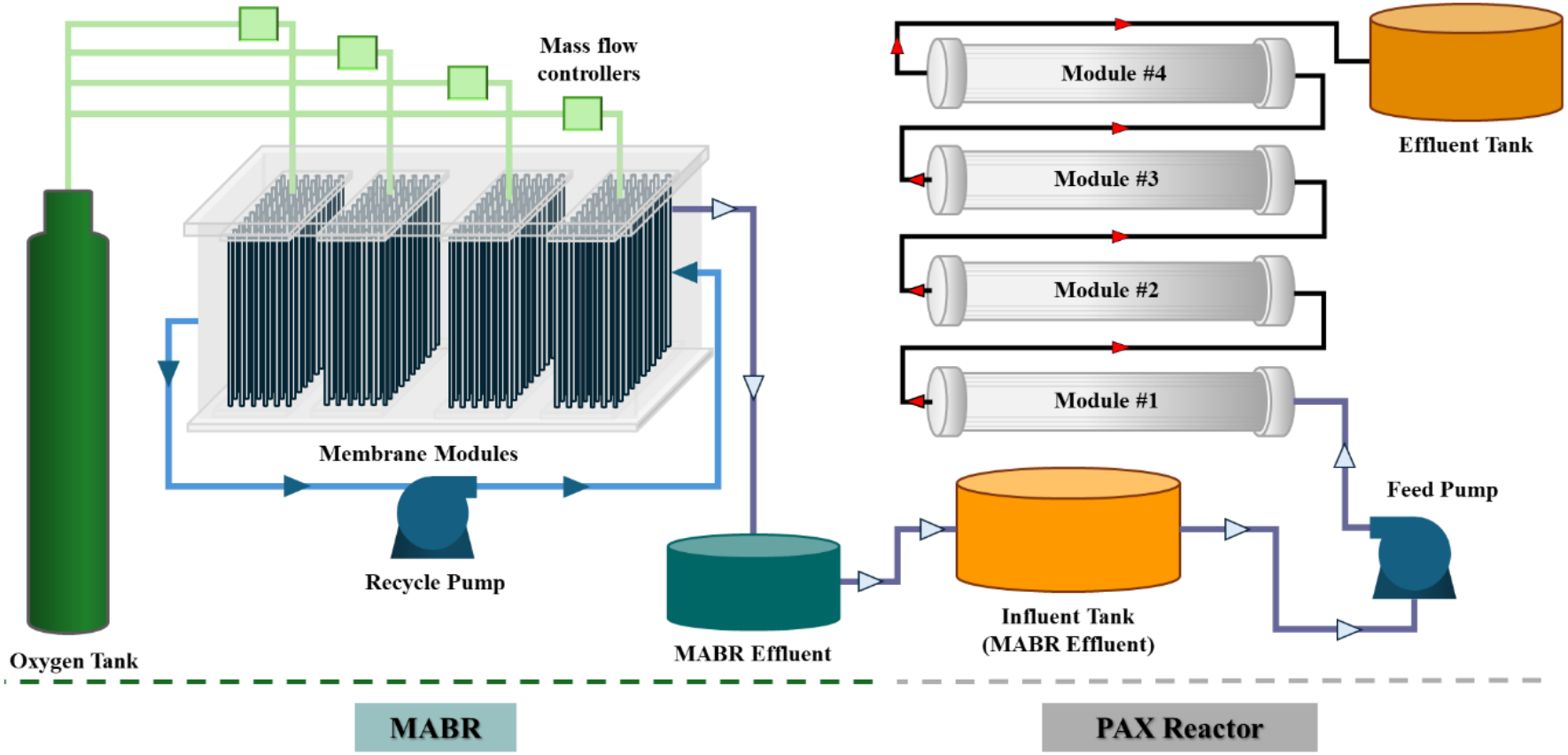
PAX Operation

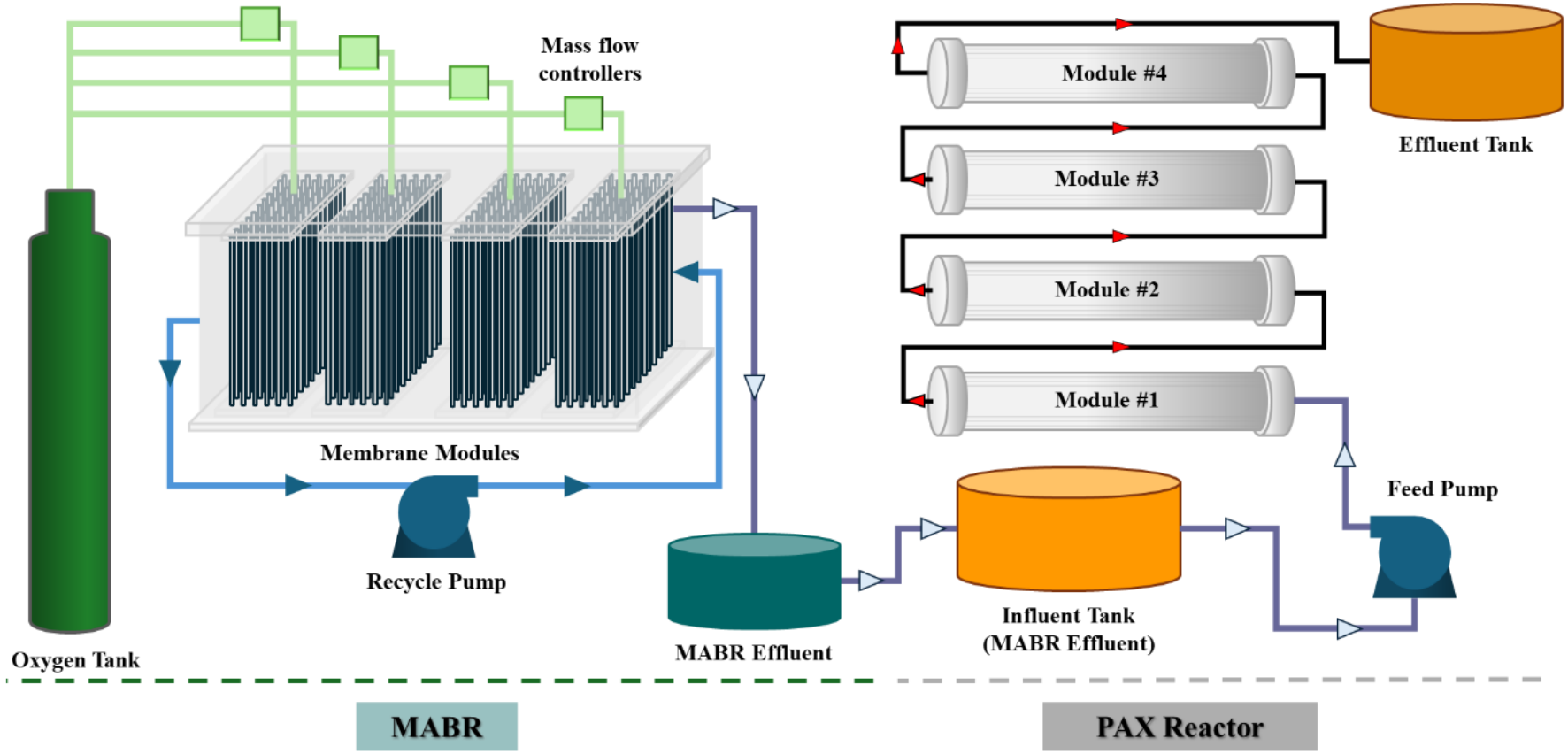
- Maintained NO_2^- concentration <1 mg-N/L
- Maintained NH_3 concentration < 280mg-N/L

MABR-PAX Two-Stage Treatment



- Four modules filled with Polyether Polyurethan Poret foam
- ~100% of nitrogen converted to N_2
- Low concentrations of NOx off-gases

MABR-PAX Two-Stage Treatment



- Produced N_2 gas often trapped in modules of PAX reducing wetted volumes
- Solution flow inside modules may not have gone through foam consistently

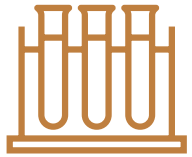
Objectives

1. Design a new simple more robust anammox system (MABR-MaX+ system) to treat high strength nitrogen-based wastewater

2. Measure the performance, reliability, and impact of off gas production (N_2, CO_2, N_2O, NO, NO_2, and NH_3)

Methods

Water Quality



Daily Operation over 8-month period

Daily Samples Analyzing:

- TOC, TN, Anions, pH, and DO

MABR Operations

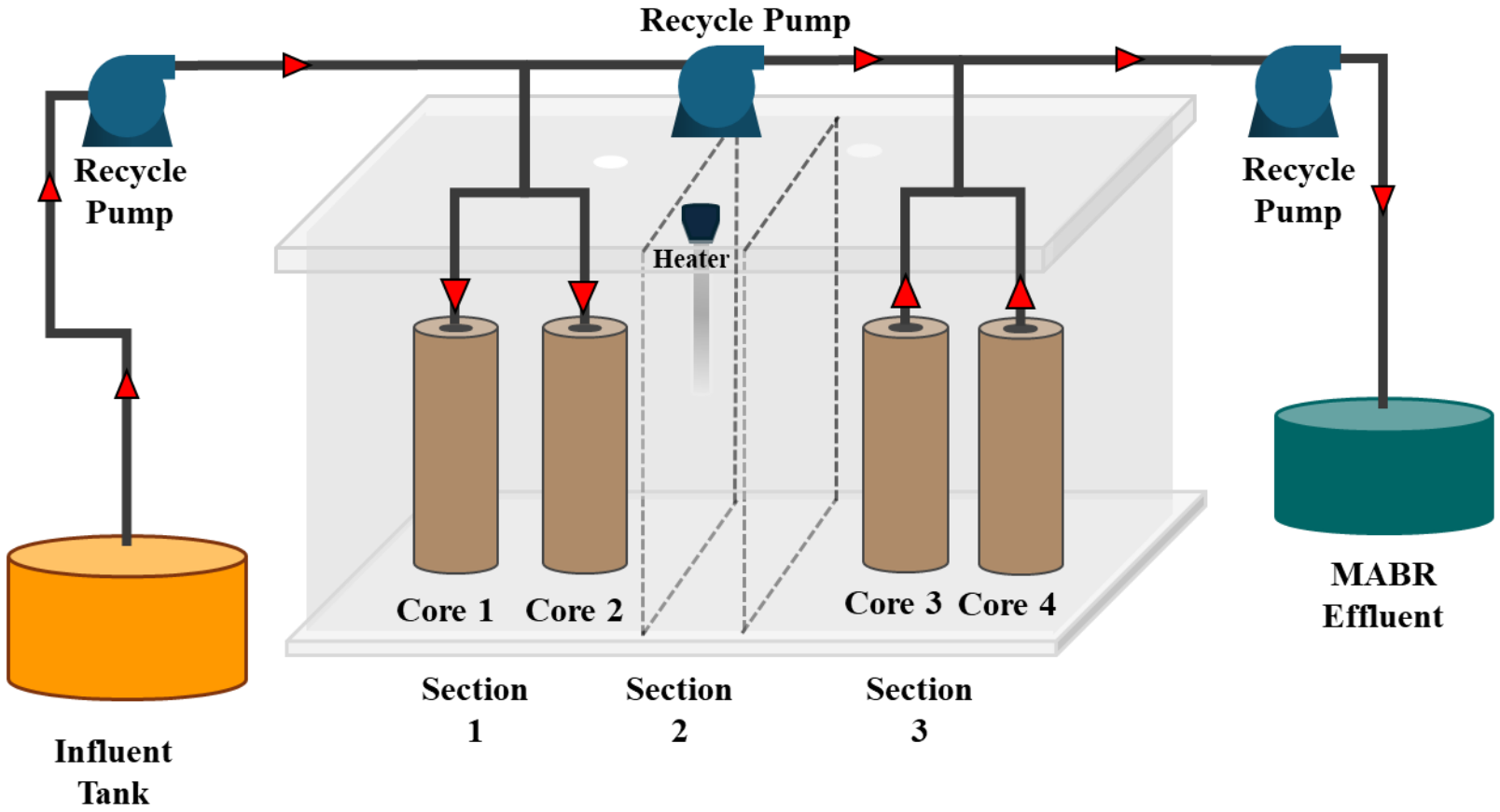
- Fed 2.1 L of urine + 300 mL of RO “flush water”

MAX

- Fed 2.0 L of MABR Corrected Effluent
- Analyzed increased loading
- Measured gas production using FTIR Gasmet Analyzer

Results - New Design

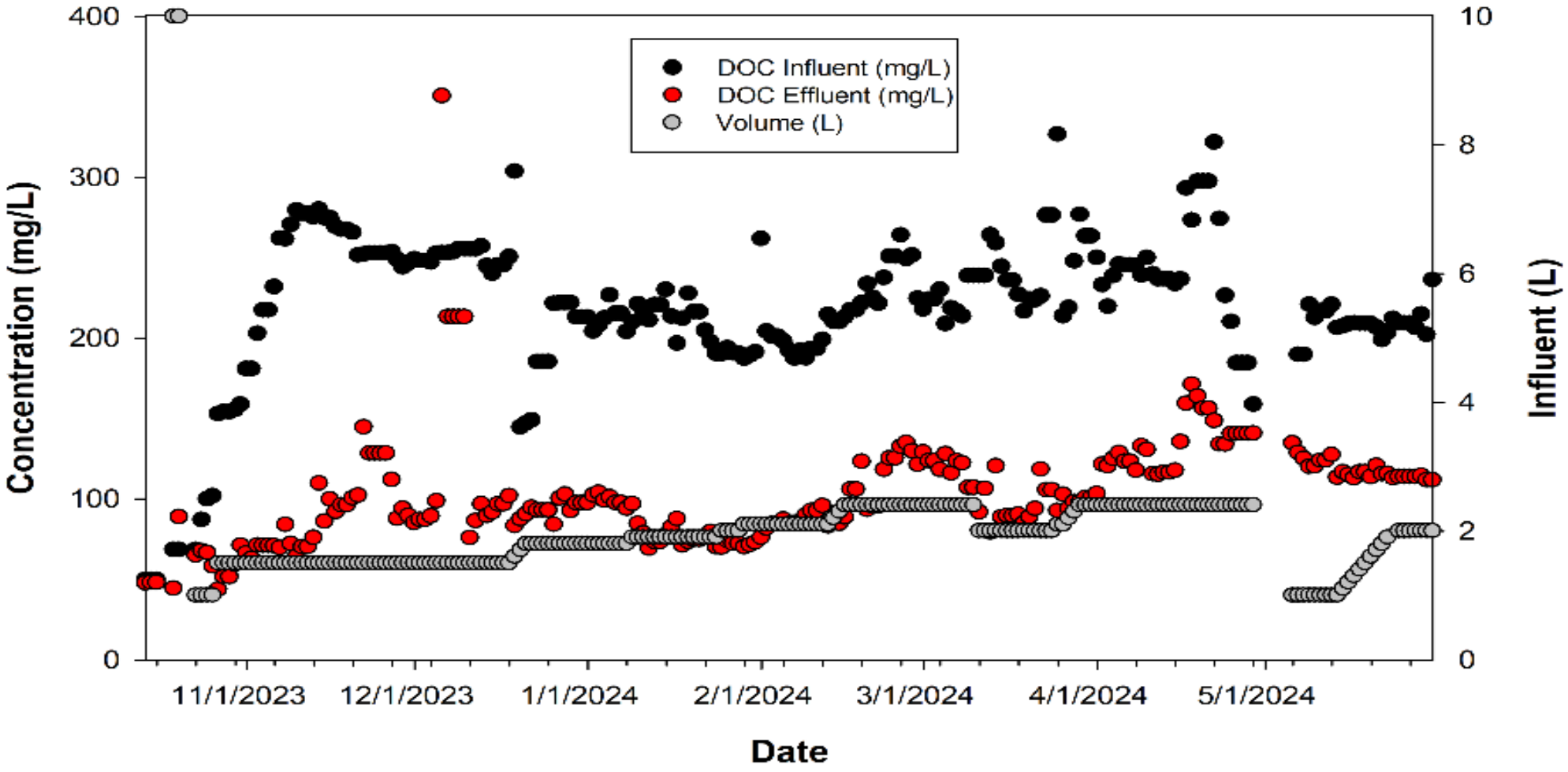
Second Stage – Mixed Anammox (MaX+)



- Simpler design aimed to improve flow and reduce gas trapping
- Inoculated with the same bacteria as PAX

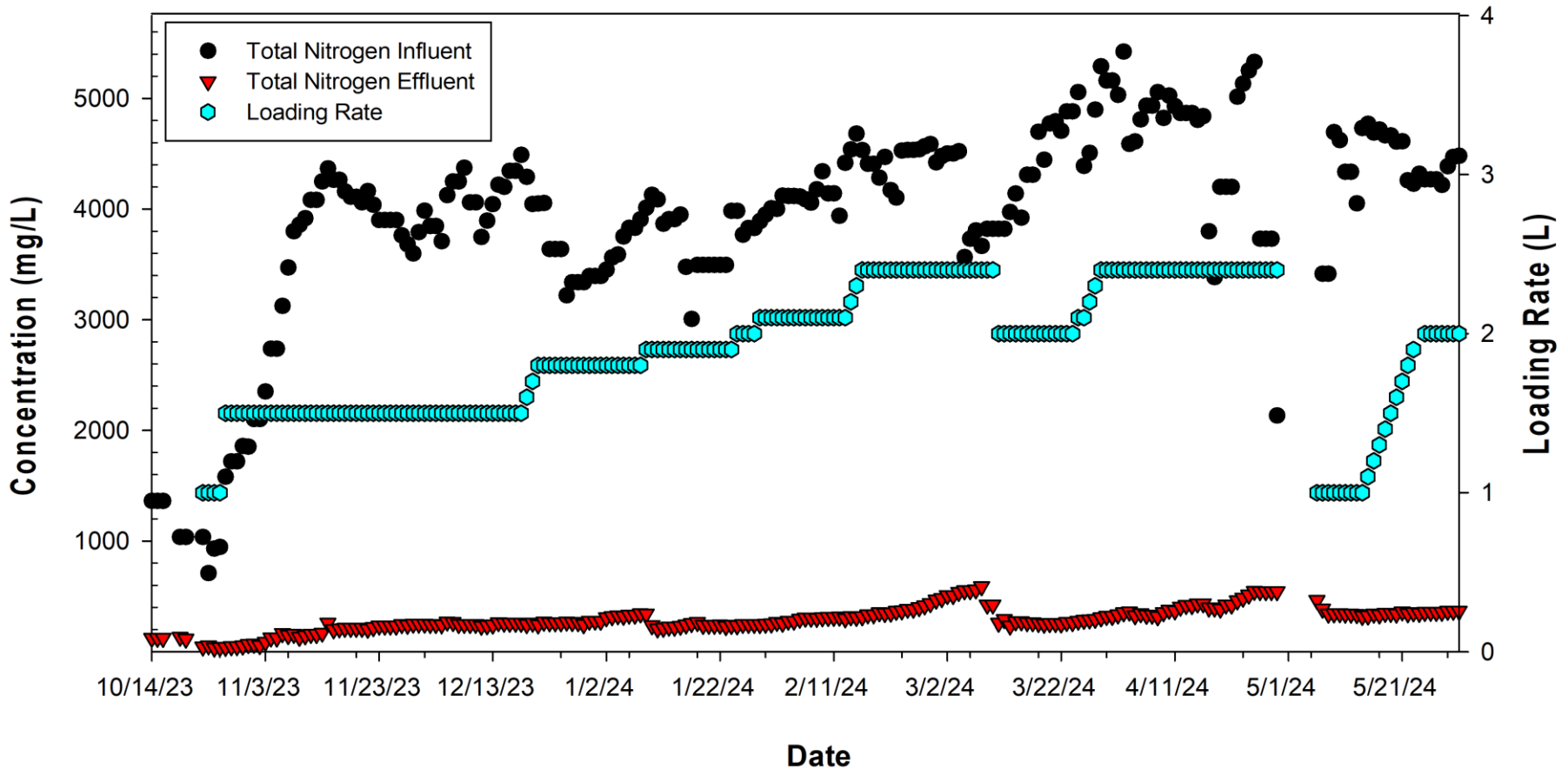
Dissolve Organic Carbon (DOC)

***90% reduction in DOC over 8 months between MABR and MaX+ system**



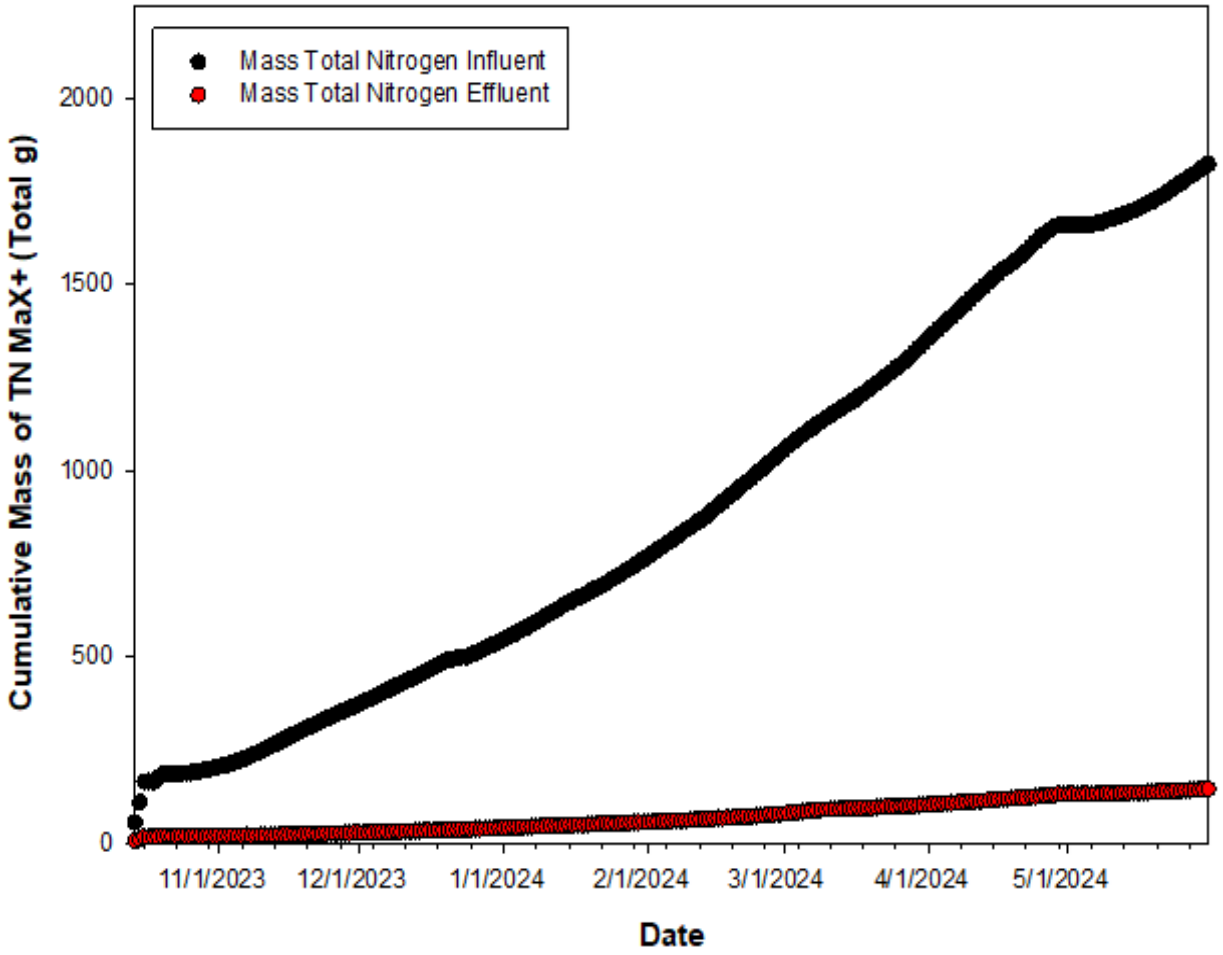
Total Nitrogen (TN)

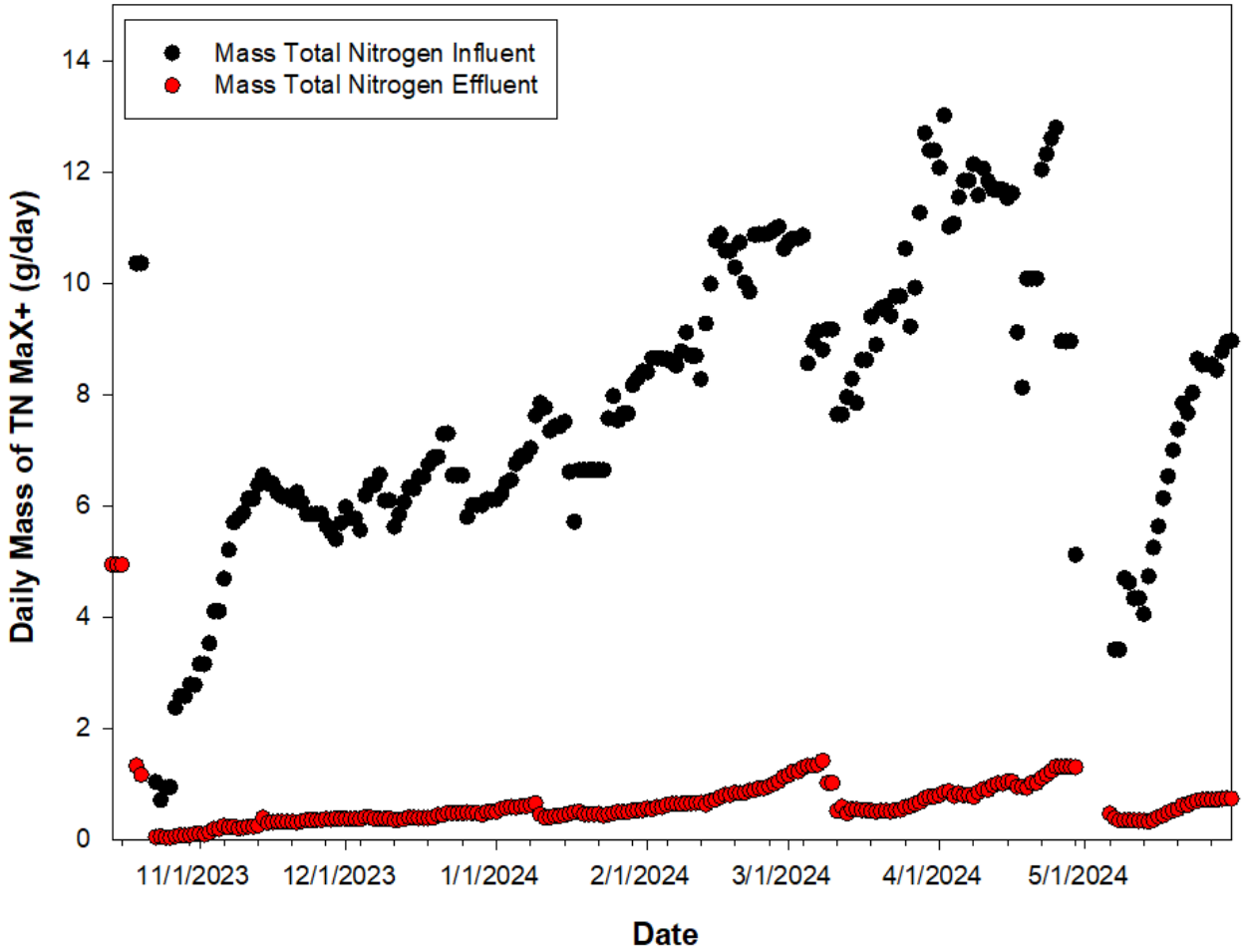
93% reduction in TN over 8 months *with an average reaction rate of 83.51 g/m^3-day



Cumulative vs Daily TN

***Only ~144 grams of TN were not transformed out of a total of 1,823 grams which were fed to the reactor**

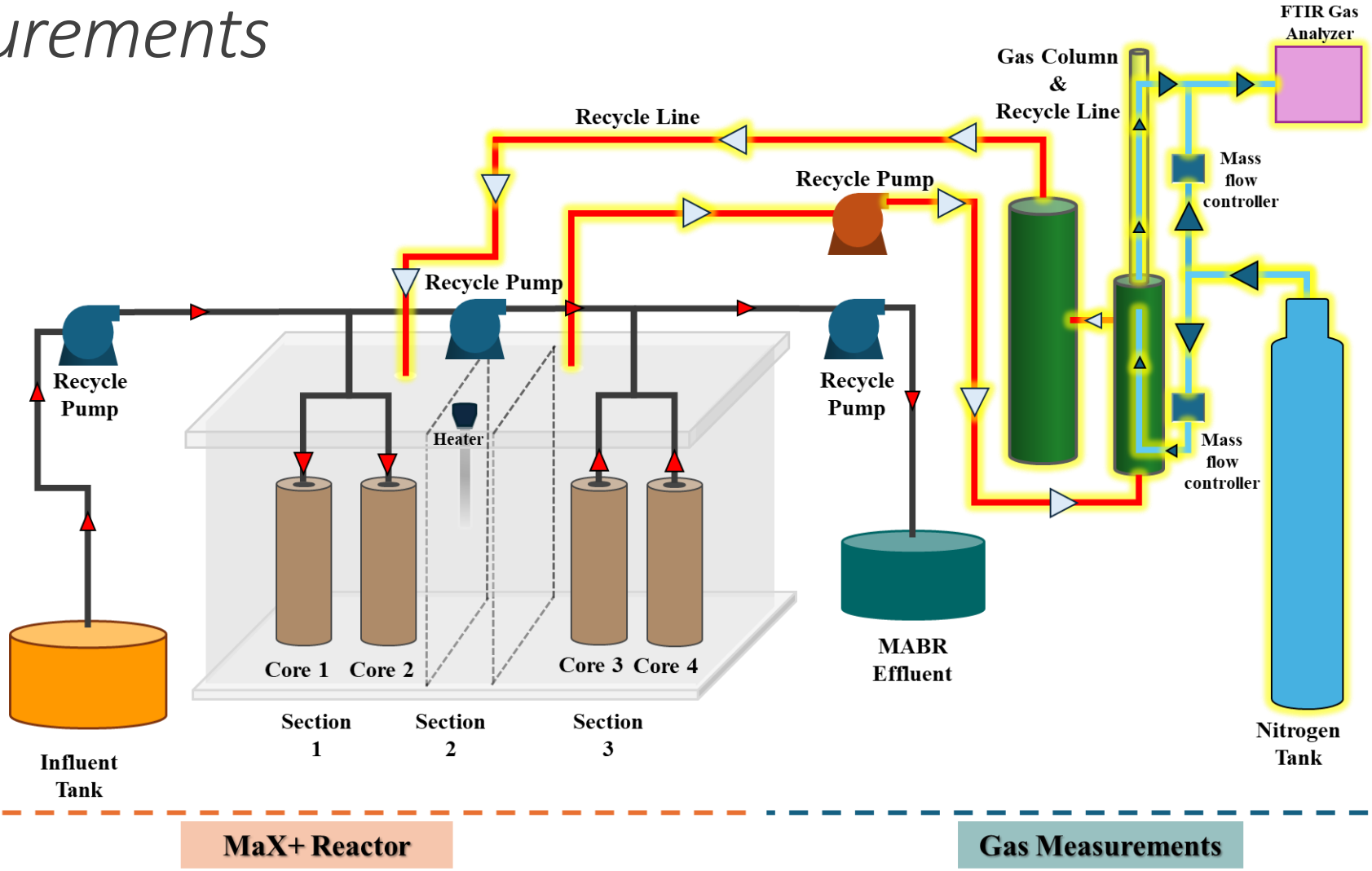




Methods

Second Stage – Mixed Anammox (MaX+)

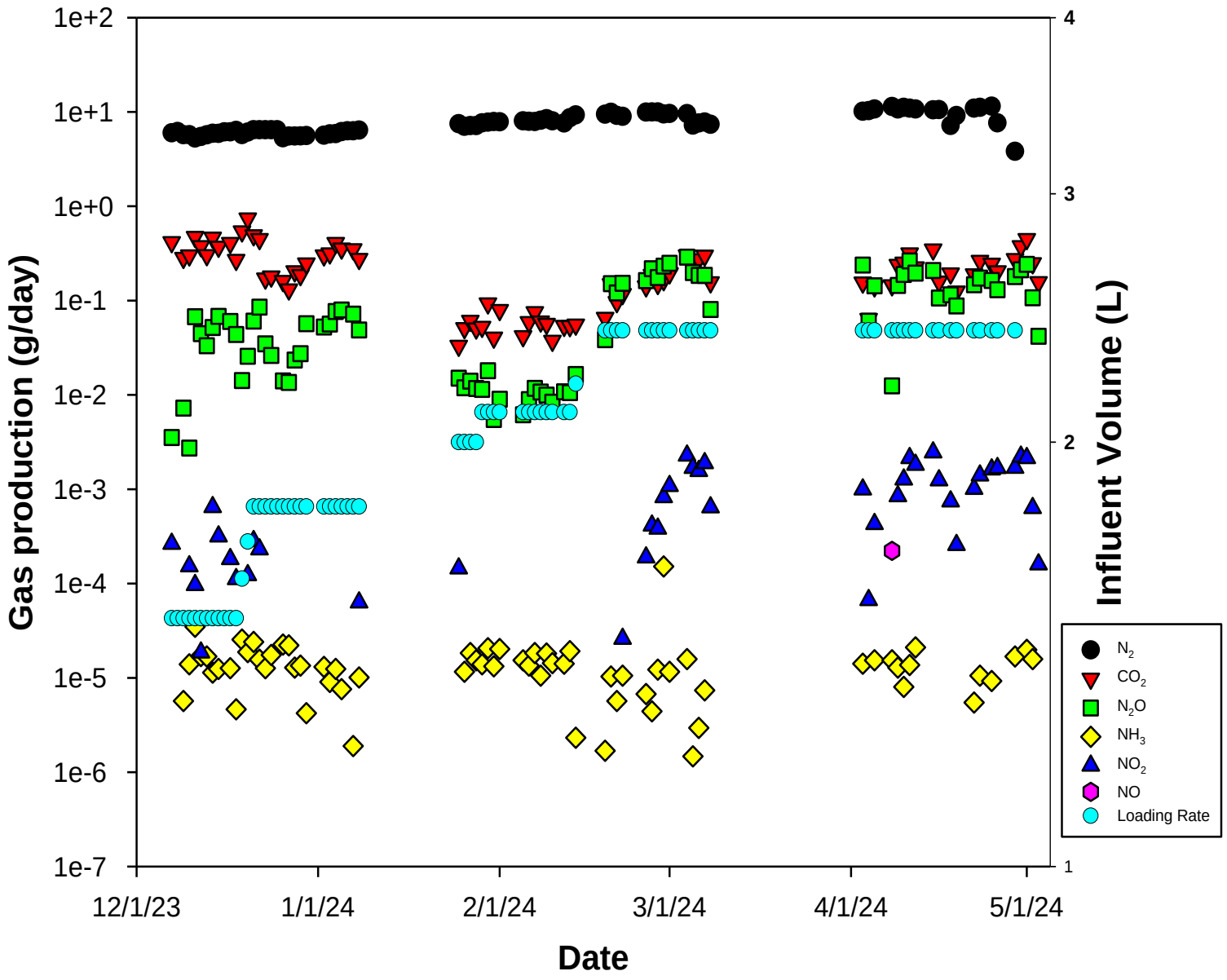
Gas Measurements



Gas Production Rates

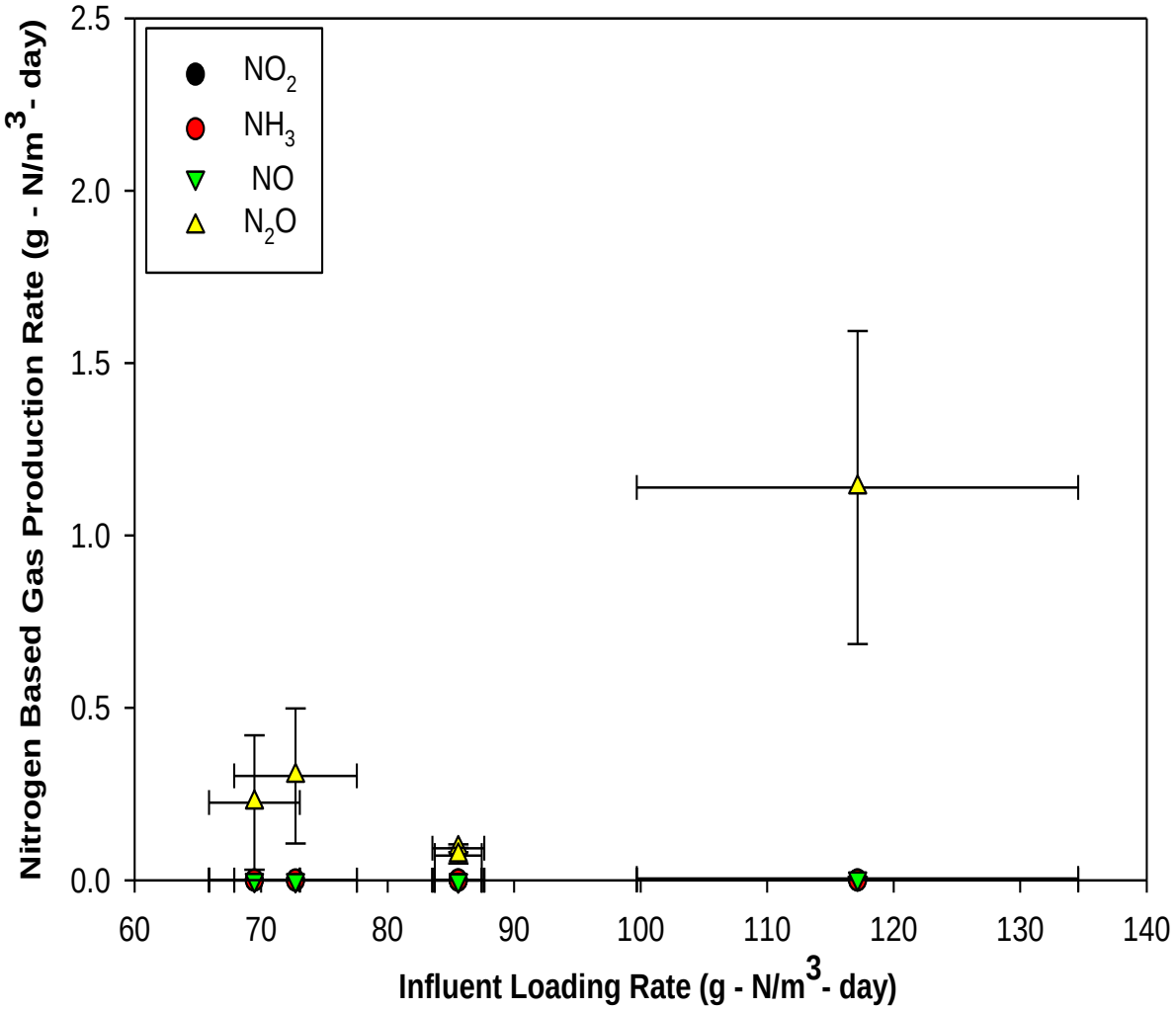
System averaged *91.55% conversion of influent Total Nitrogen to N_2 gas

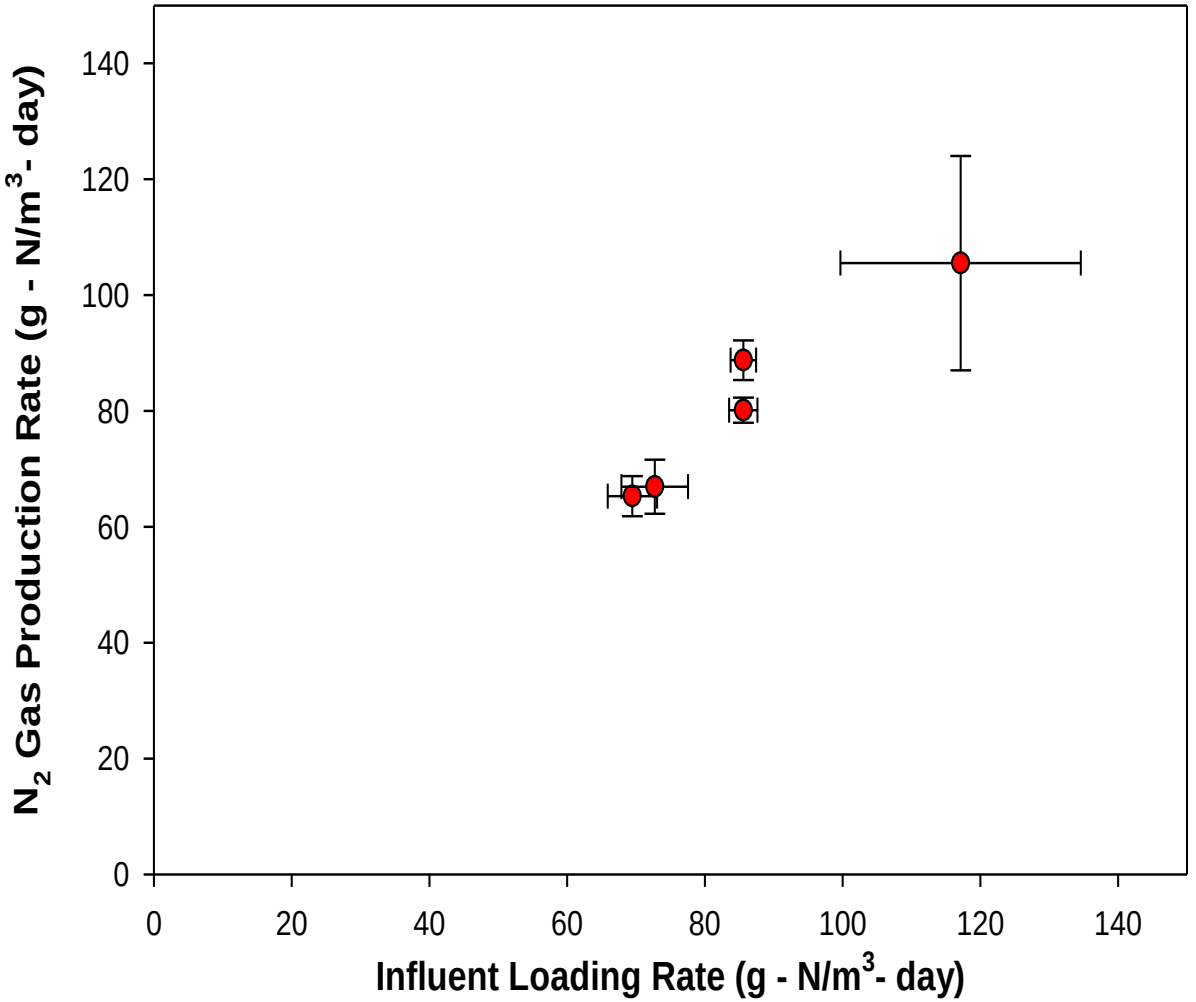
***Maximum loading rate of MaX+ was 14.46 g-N/m^3-day**
***Daily N_2 gas production rate ranged from 60-120 g-N/m^3-day**
***Total NOx production over 8 months was 4.92 g-N/m^3**



Gas Production Rates

***Approximately 91.55 % of the total N was converted to N_2 gas, the equivalent of 7.7 g-N/crew-day**





Conclusion

- Proportional relationship between N_2 gas production & influent nitrogen loading rate
- Produced effluent more stable for down stream processing
  - No solids management
- Predicted N_2 production rate for a crew of 4 for a year:
  - **~2,810.5 g-N/crew**
  - More gas recycled due to simpler design

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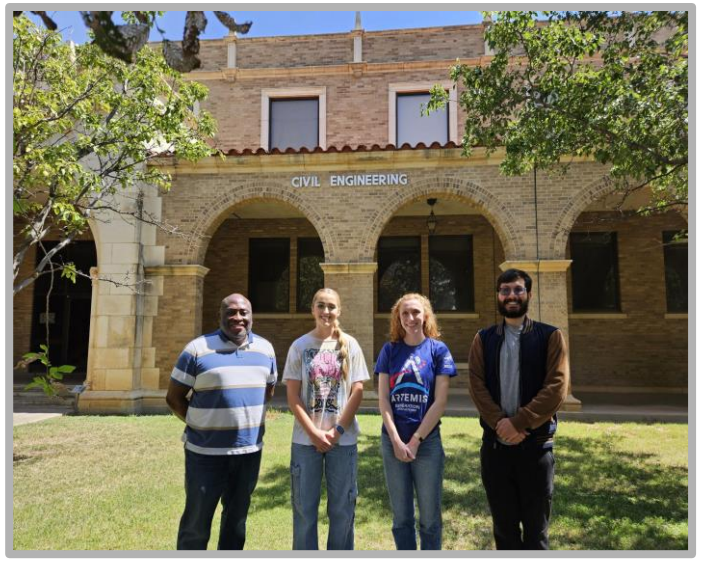

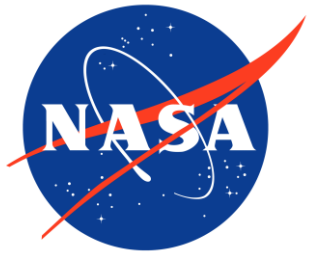

Questions?

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