AN INNOVATIVE APPROACH TO THE NITRIFICATION PROCESS: COMAMMOX

Department of Environmental Engineering
Marmara University
ENVE4198 Graduation Project

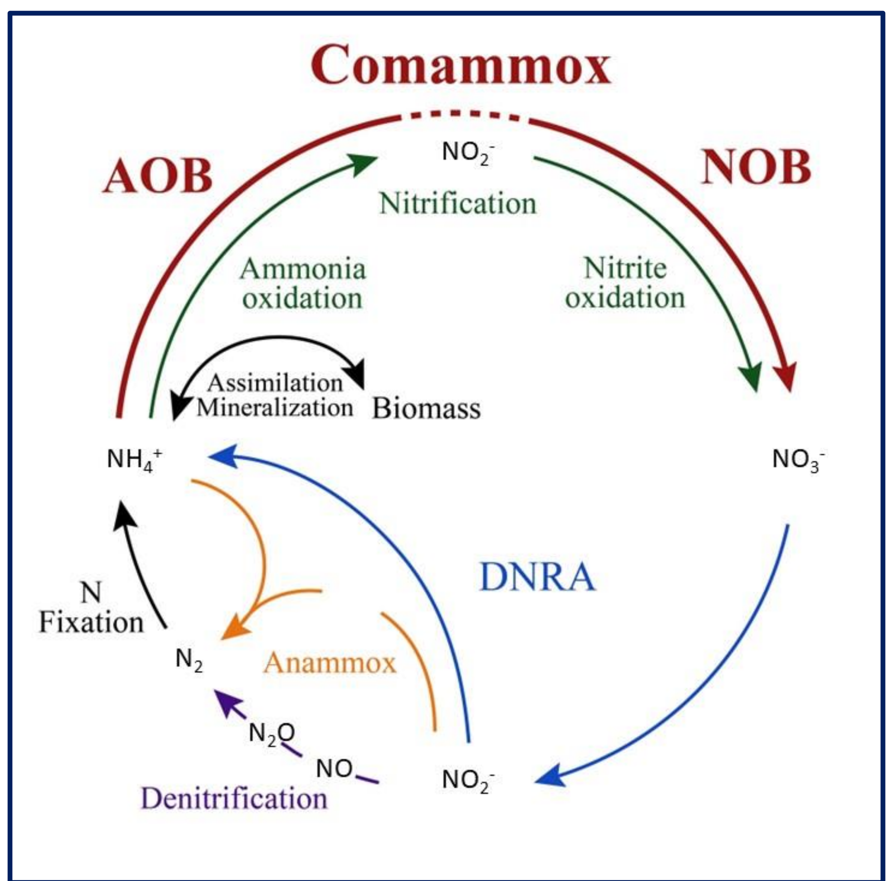
Uğur Kerem ÖZBEY[1]
Supervisor: Assoc. Prof. Bilge ALPASLAN KOCAMEMİ[2]

Contact: ugurkeremozbey@outlook.com[1], bilge.alpaslan@marmara.edu.tr[2]

THE AIM OF THE STUDY

This study aims to evaluate process efficiency and kinetics of innovative nitrification technology **COM**plete **AMM**onia **OX**idation (Comammox) process discovered in 2015 in a lab-scale SBR system started up with a mixture of seeds from different sources (from rapid sand filter from Ömerli WTP, paddy field soil from Edirne, sediment from Dalyan, paddy field soil and return activated sludge from Ambarlı WWTP) 495 days ago.

INTRODUCTION



Nitrification, which requires significant amount of oxygen (4.57 g O2/g NH_4^+-N) has traditionally been hypothesized to be a **two-step process** thought to be catalyzed by NO_2^- oxidation by AOA and AOB, as well as NOB. However, this long-standing assumption of the two functional groups was challenged by the discovery in year 2015 of the **Comammox** bacteria, complete NH_4^+ oxidizers with the ability to convert NH_4^+ to NO_3^- in a single organism **(Fig 1).**

Discovery of Comammox may appears as an alternative process for the achievement of nitrification under **low DO** concentration and an integration to novel nitrogen removal technologies (e.g. Anammox, DNRA).

MATERIALS AND METHODS

Start-Up :

- Two reactors, **blank** (**C_1**) and **Comammox** (**C_2**), were started to operate with a mixture of **seeds** from different sources; (a) rapid sand filter from Ömerli WTP, (b) paddy field soil from Edirne, (c) sediment from Dalyan, (d) paddy field soil, and (e) return activated sludge from Ambarlı WWTP in a previous study (Şenol, 2021) (**Fig 2**).

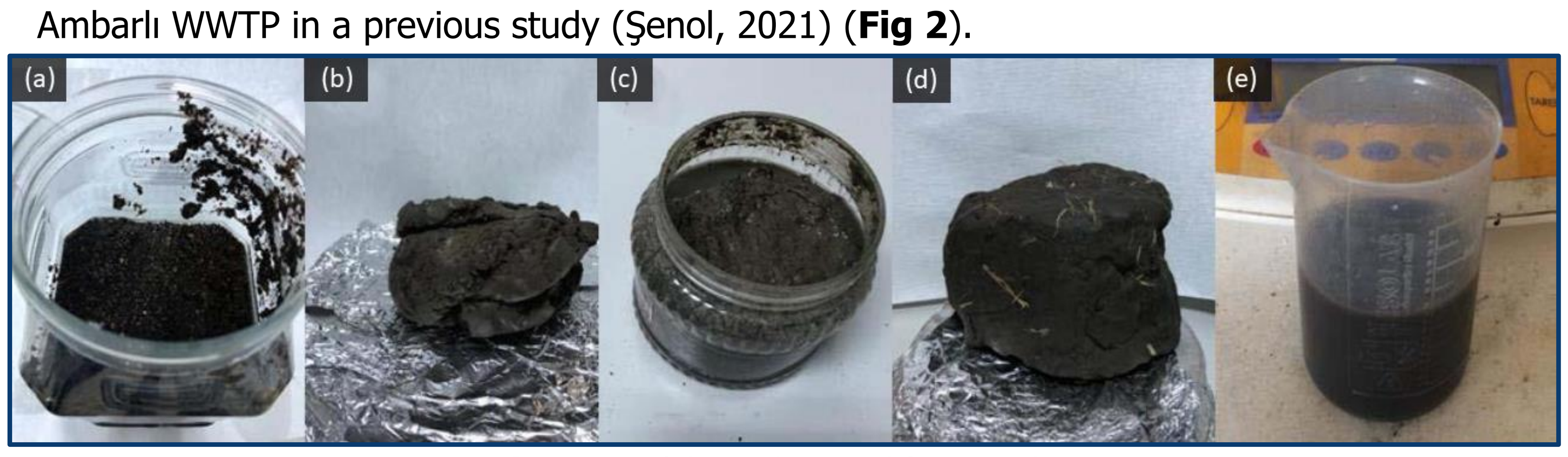


Figure 2 Solids used as seed for C_1 and C_2

Operation:

- Both C_1 (@DO>4 mg/L) and C_2 (@DO <0.5 mg/L) **(Fig 3)** were operated as **SBR (Fig 4)** for **365 days** under operational conditions shown in **Table 1.**
- Influent and effluent samples were analyzed for **NH_4^+-N, NO_2^--N and NO_3^-N** in order to calculate process efficiency.

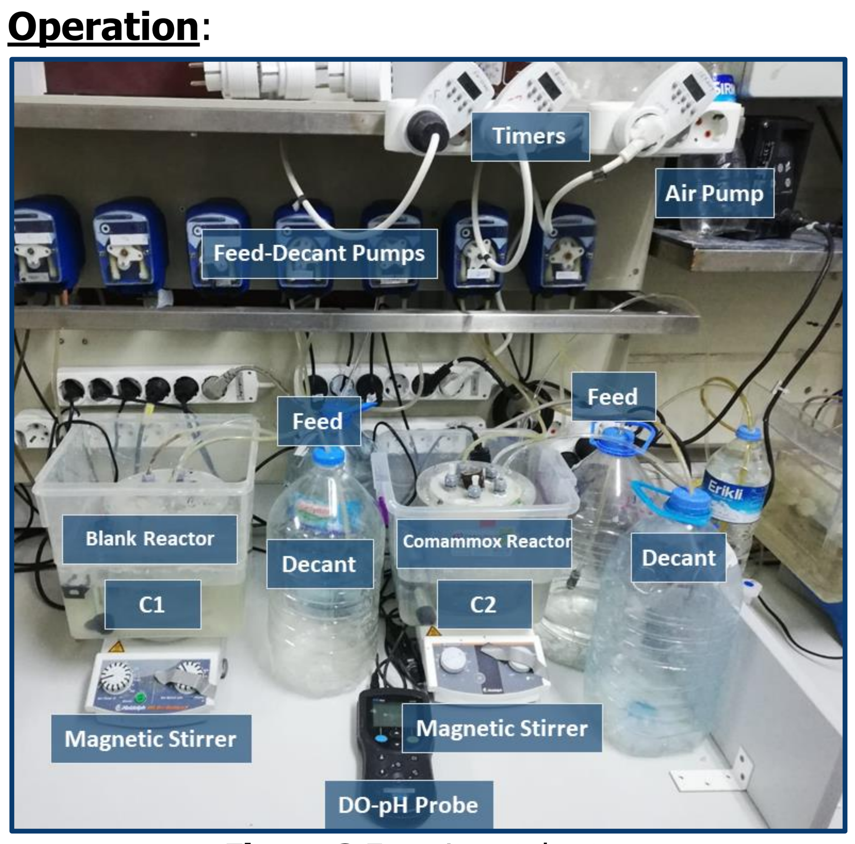


Figure 3 Experimental set-up

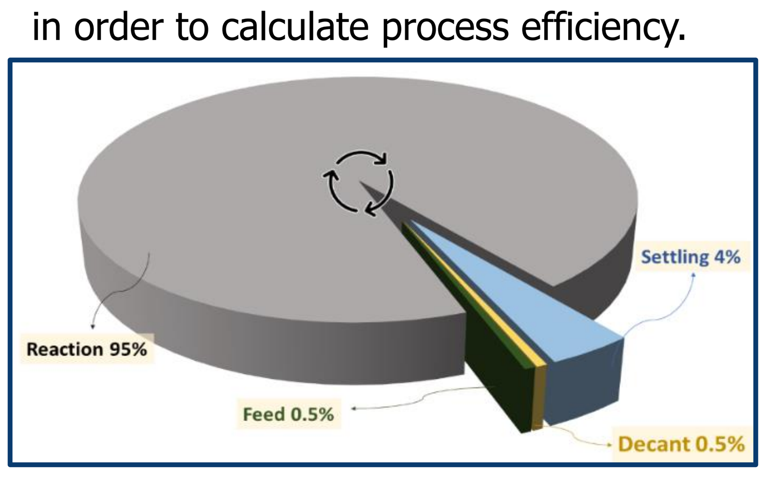


Figure 4 SBR cycle of the system

Table 1 Operational conditions of C_1 and C_2

Phase	Operational Day	HRT (day)	DO (mg/L)		pH		Temperature (°C)		Influent NH_4^+-N (mg/L)	
			C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
I	1-161	2	8.1 ± 0.2	0.45 ± 0.1	7.3 ± 0.1	7.2 ± 0.1	24 ± 1.6	24 ± 1.6	45 ± 10.1	44.3 ± 11.0
II	162-221	2	8.3 ± 0.2	0.4 ± 0.1	7.3 ± 0.1	7.3 ± 0.1	21 ± 0.8	21 ± 0.8	60 ± 10.1	60 ± 11.0
III	222-245	2	8.2 ± 0.5	0.4 ± 0.1	7.3 ± 1.4	7.2 ± 0.1	21 ± 1.4	21 ± 1.5	41 ± 2.7	37 ± 6.8
IV	246-365	2	8.2 ± 0.3	0.4 ± 0.1	7.3 ± 0.4	7.1 ± 0.4	22 ± 1.2	22 ± 1.2	46 ± 13.7	44 ± 11.6

OUR and qNH_4^+-N Kinetic Experiments :

S_0/X_0 = 0.25 – 0.30
pH: 7.2 Temperature: 24°C

Measurement of Oxygen Uptake Rate (Fig 5)
@DO= 7 mg/L
Initial NH_4^+-N: 50 – 80 mg/L

Measurement of Substrate Utilization Rate (Fig 6)
@DO> 4 mg/L
Initial NH_4^+-N: 50 mg/L

Figure 5 Experiment setting for OUR

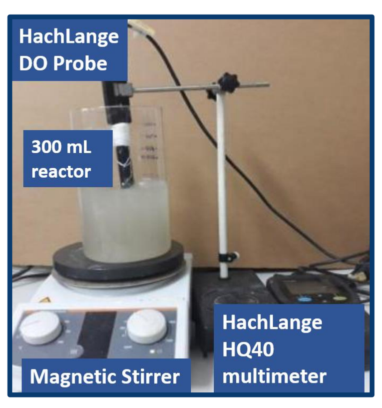
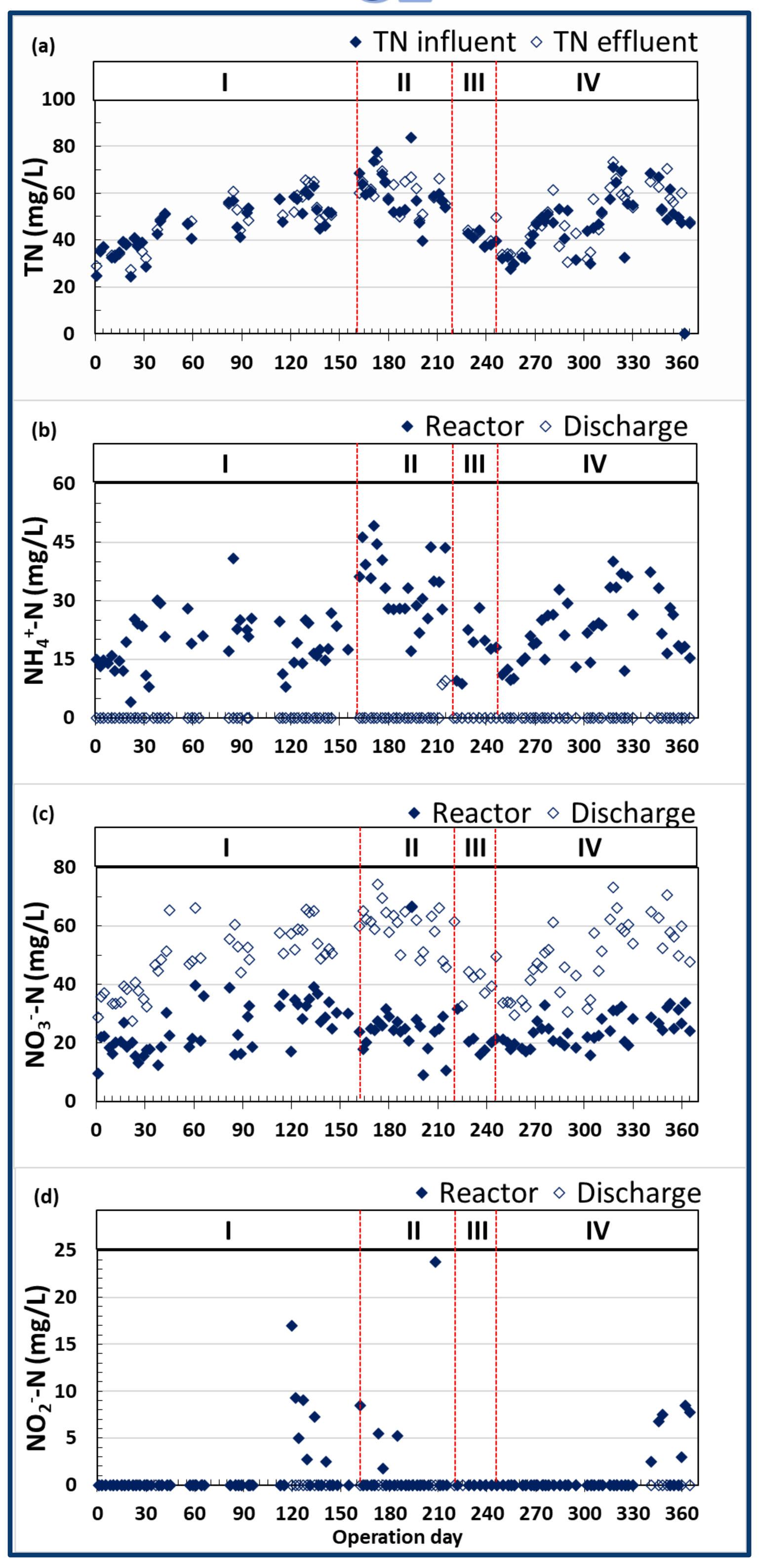


Figure 6 Experiment setting for SUR

→ **$V_{max,DO}$, K_{DO}, $V_{max,NH4+N}$, K_{NH4+N}** values were found with NLSR analysis using the Monod Model by 'CurveExpert Professional' program and statistical analysis.

RESULTS AND DISCUSSIONS

C1



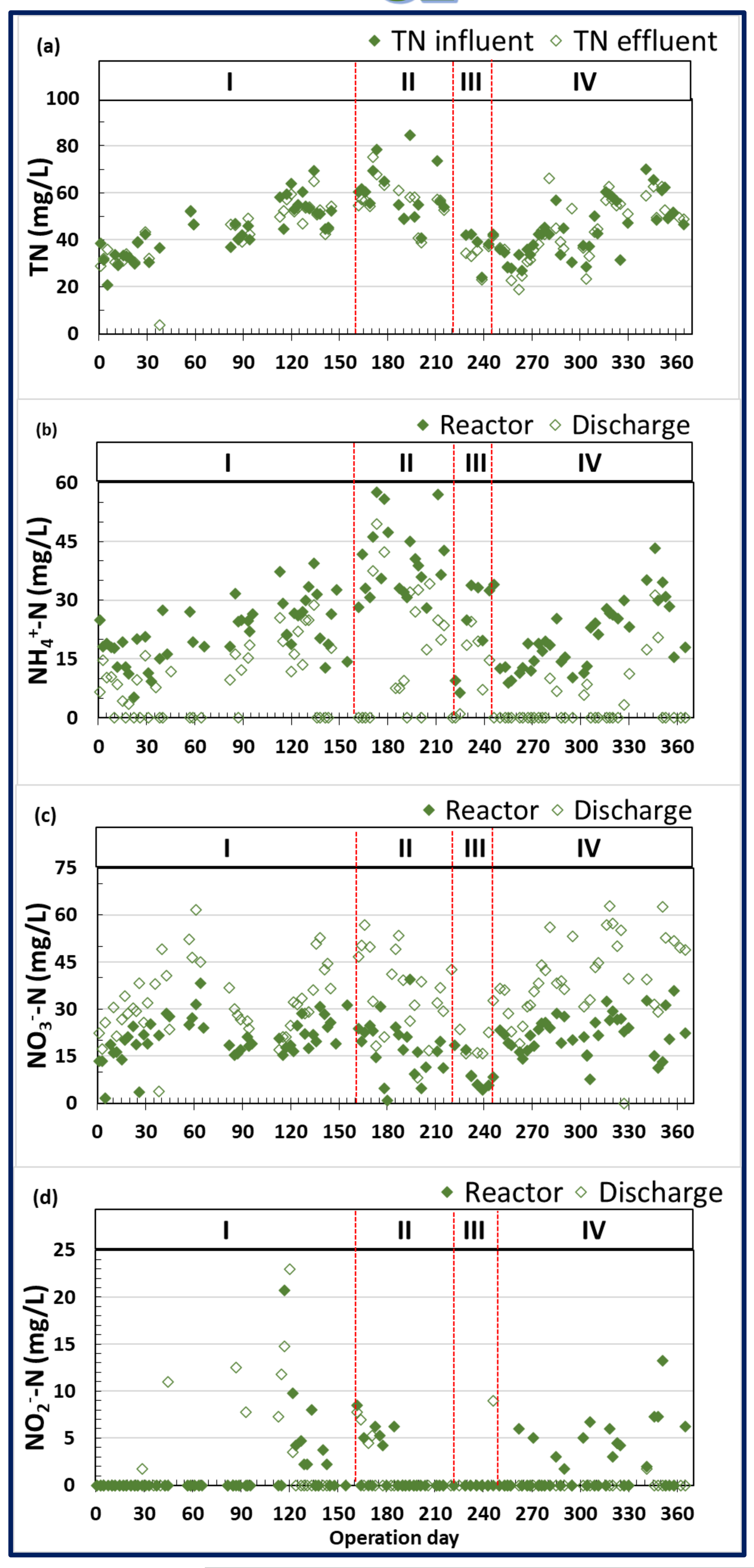
C1

- No TN removal (no denitrification and Anammox activity)
- NH_4^+-N removal eff. (97.7-100%)
- No NO_2^--N acc. Complete NO_3^--N prod.

C2

- Slight TN removal (5.5-11.4%)
- NH_4^+-N removal eff. 56.8-87.7%
- Slight NO_2^--N acc. Complete NO_3^--N prod.

C2



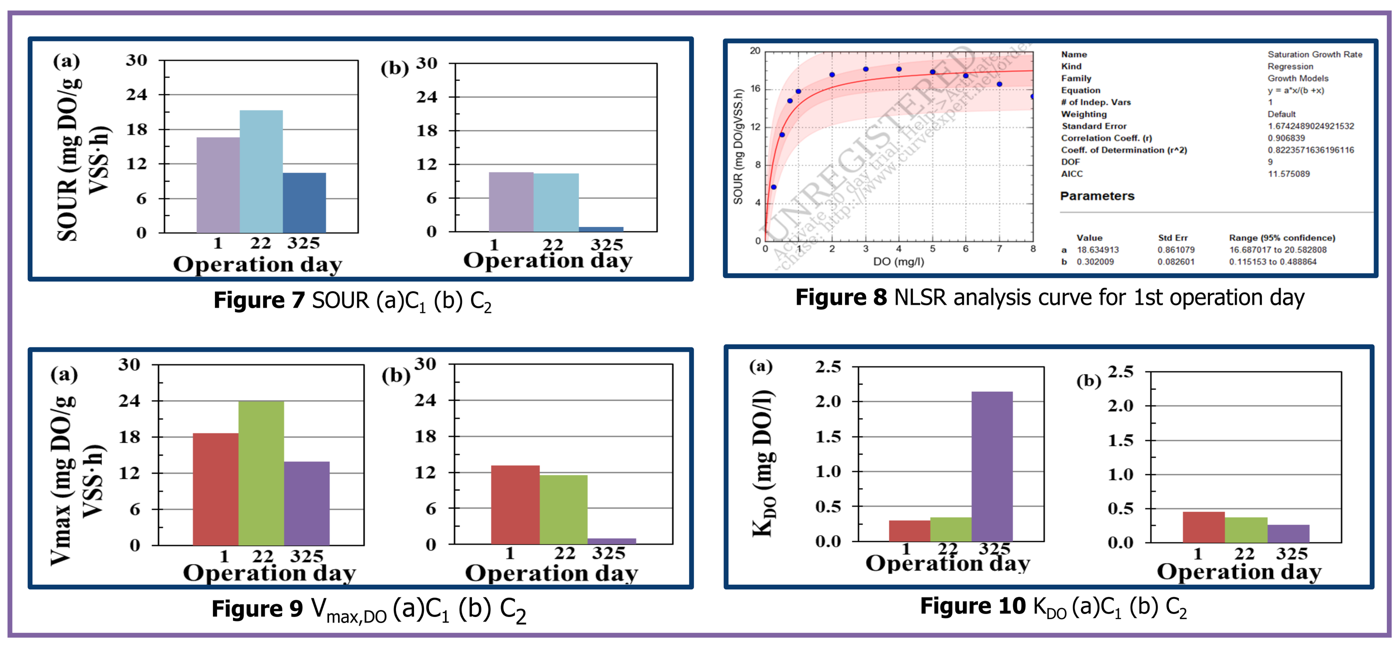


Figure 7 SOUR (a)C_1 (b) C_2

Figure 8 NLSR analysis curve for 1st operation day

Figure 9 $V_{max,DO}$ (a)C_1 (b) C_2

Figure 10 K_{DO} (a)C_1 (b) C_2

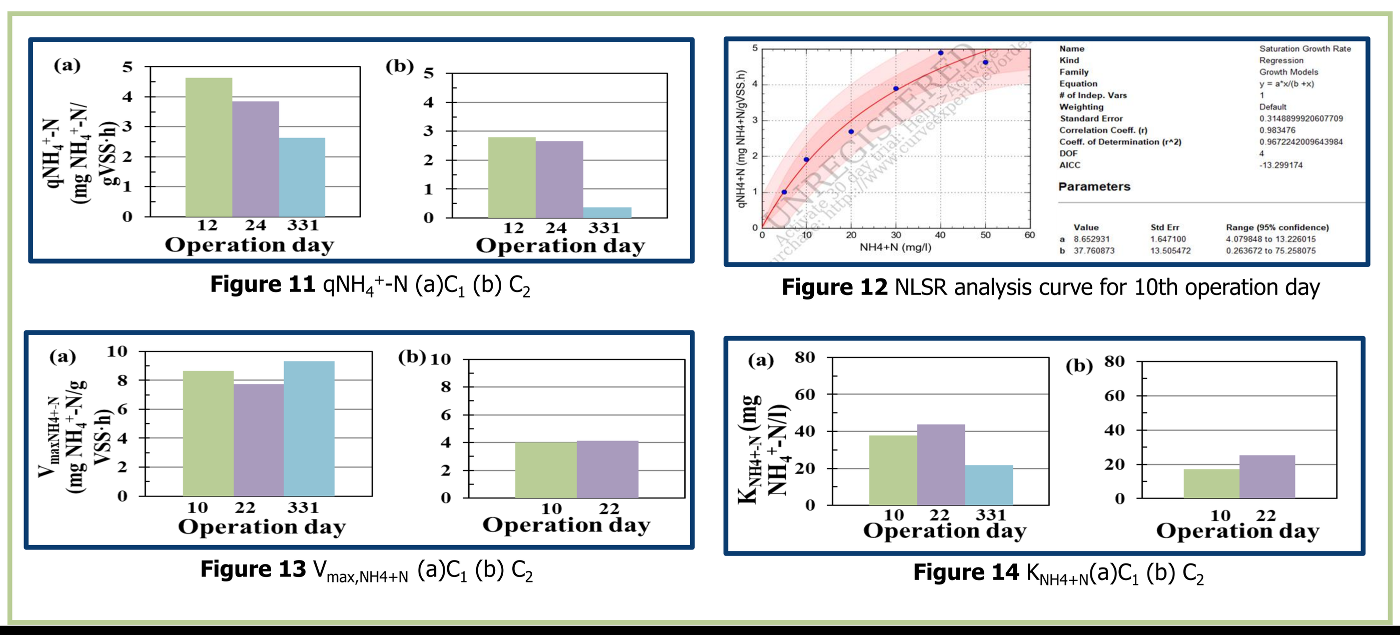


Figure 11 qNH_4^+-N (a)C_1 (b) C_2

Figure 12 NLSR analysis curve for 10th operation day

Figure 13 $V_{max,NH4+N}$ (a)C_1 (b) C_2

Figure 14 K_{NH4+N}(a)C_1 (b) C_2

Canonical nitrifiers		Comammox species
OUR 16.1 ± 4.4 mg DO/g VSS·h	> 54%	OUR 7.3 ± 4.6 mg DO/g VSS·h
qNH_4^+-N 3.7 ± 0.8 mg NH_4^+N/g VSS·h	> 49%	qNH_4^+-N 1.9 ± 1.1 mg NH_4^+N/g VSS·h
$V_{max,NH4+-N}$ 8.6 ± 0.6 mg NH_4^+-N/g VSS·h	> 52%	$V_{max,NH4+-N}$ 4.1 ± 0.1 mg NH_4^+-N/g VSS·h
K_{NH4+-N} 34.4 ± 9.3 mg NH_4^+-N/L	> 38%	K_{NH4+-N} 21.2 ± 3.9 mg NH_4^+-N/L
$V_{max,DO}$ 18.8 ± 4.1 mg DO/gVSS·h	> 55%	$V_{max,DO}$ 8.5 ± 5.4 mg DO/gVSS·h
K_{DO} 0.9 ± 0.6 mg DO/L	> 55%	K_{DO} 0.4 ± 0.1 mg DO/L

CONCLUSIONS

In this study, the performances of canonical nitrification and Comammox processes were observed for 365 days under synthetic feeding and room temperature conditions at DO>4 mg/L (C_1) DO<0.5 mg/L (C_2).

Nitrification efficiency comparison

- Nitrification efficiency of Comammox system was observed lower (10-40%) with respect to the nitrification efficiency under non-limited oxygen condition.
- Slightly nitrite accumulation was observed in Comammox system.
- Slighty TN removal was observed in Comammox system. It might be related with Anammox process because of low DO (<0.5 mg/L) conditions, or denitrification process because of the small amount of organic carbon coming from the decay of microorganisms.
- Removal performance of Comammox reactor is more severely affected than the canonical nitrification system due to the major operational changes.

From batch experiments it has been observed that;

- Both oxygen utilization and substrate degradation rate of Comammox species were observed lower than canonical nitrifiers.
- Oxygen affinity of Comammox species found higher than canonical nitrifiers.
- Ammonium affinity of Comammox species were found higher than canonical nitrifiers.

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Reference:

Şenol, A. (2021). Complete Ammonium Oxidation (Comammox) in Nitrification and Partial Nitritation – Anammox (Deammonification) Systems. Master Thesis, Marmara University Instutue of Pure and Applied Sciences, Istanbul, Turkey.