Process design to achieve mainstream deammonification in temperate climates

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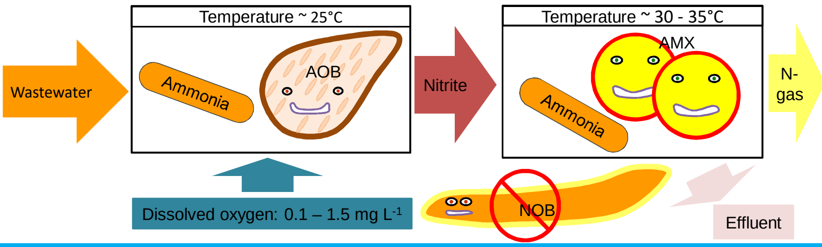
INTRODUCTION

The application of deammonification for nitrogen removal from wastewater for temperate climate (8 – 15°C) is still under investigation. The main challenge is to outcompete nitrite oxidizing bacteria (NOB) while providing sufficient production of nitrite by the AOBs [1]. The following bottlenecks have been identified:

- *Low temperature and seasonal change of wastewater.*
- *Different bacteria physiology of ammonia oxidizing bacteria (AOB), NOB and anammox.*
- *Separation of aerobic and anaerobic retention time.*



AIM:

The aim of the PhD is to investigate the application of deammonification at wastewater treatment plants. Part of it is to investigate the application of mainstream ammonia removal. This study is to design a process to remove ammonia from wastewater via deammonification for temperate climate such as the UK.

METHODS

Mainstream studies treating real wastewater at temperate climates were critically reviewed and summarised based on the characteristics in Table 1.

Table 1 – Summary of different mainstream deammonification reactors for temperate climates.

Process	Biomass	Configuration	Wastewater	Temperature range (°C)	Volume (m^3)	Volumetric nitrogen loading rates (kg N m^{-3} d^{-1})
Moving bed biofilm reactor	biofilm	one & two stage	synthetic, diluted filtrate	10 – 25	0.2	0.1 – 1.79
Sequencing batch reactor	granular	one stage	synthetic, municipal	7 – 18	0.01 – 0.6	0.07 – 0.4
Continuous stirred tank reactor	granular, suspended	two & multi stage	municipal	7 – 15	0.004 – 0.2	0.07 – 0.35
Plug flow reactor	granular, biofilm	one stage	municipal	10 – 25	0.02 – 4	0.02 – 0.22

Different processes were designed and weighted using the Kepner method and the following criteria in Table 2 (Kepner et al., 1988).

Table 2 – Weighting of decision criteria.

Criteria	Weighting
Effluent quality	4
Performance	4
Estimated cost	3
Operational robustness	4
Biomass supply chain	4
Retrofit ability to existing plants	5
Risk	2

A biological design and kinetic model based on ASM2 was built for the highest ranking process (Henze et al., 1999).

RESULTS

PROCESS SELECTION

The results of the process selection are presented in Table 3.

Table 3 – Summary of different mainstream deammonification reactors for temperate climates.

Process	Effluent quality	Performance	Estimated cost	Operational robustness	Biomass supply chain	Retrofit ability existing plants	Risk	Total
two-stage granular CSTR	16	20	12	28	24	25	10	135
two-stage media CSTR	20	24	9	28	32	25	12	150
granular PFR	8	20	18	12	24	40	16	138
media PFR	32	32	18	12	32	40	18	184
baffled granular PFR	20	20	15	40	24	40	12	171
baffled media PFR	20	24	24	40	32	45	10	195
granular SBR	20	20	15	20	24	15	14	128
MBR	20	20	6	16	36	40	12	150

A baffled plug flow media reactor was the highest ranking process. The influent ammonia concentration and sCOD to ammonia ratio was 40 mg/L and 1.5 respectively. The design hydraulic retention time was 14h. The dissolved oxygen concentration for zone 1 and zone 2 were 1.5 and 0.3 respectively.

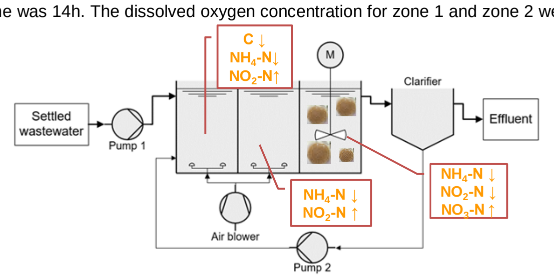


Figure 1 – Highest ranking flow chart, baffled granular plug flow reactor

DISCUSSION

One of the major challenges is the suppression of NOB during winter (<11 °C). The design provides a combination of the most favourable conditions for AOB including a separation of aerobic and anoxic retention times.

NOB suppression and AOB growth

Aeration plays a crucial part in the competition of AOB and NOB, a robust aeration control system is needed. NOB suppression at low temperatures was achieved by providing low dissolved oxygen concentrations of 0.1 to 1.5 mg/L (Cao et al., 2017).

Decoupling aerobic and anoxic solid retention times

Anammox biofilm media is used to decouple the aerobic sludge retention time from the anoxic. Short sludge retention times resulted in a washout of NOB's while maintaining sufficient AOB in the reactor (Han et al., 2016).

Process model for ammonia

Figure 2 shows the ammonia temperature model based on AOB kinetics. Ammonia is maintained at around 10 mg L^{-1} in zone 1 and 2 to provide sufficient ammonia and nitrite for AMX.

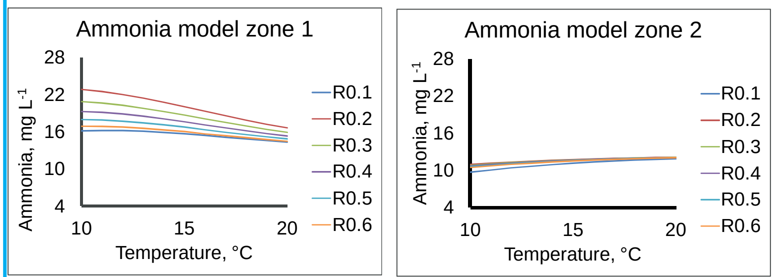


Figure 2 – Ammonia model for partial nitritation in zone 1 and zone 2 converting ammonia into nitrite for different sludge recycle ratios (R 0.1 to 0.6)

A combination of a three compartment baffled plug flow reactor, robust aeration strategy and separation of aerobic and anoxic sludge retention times is thought to play a key role in the successful application of mainstream deammonification for temperate climates. Future studies include the validation of the ammonia models using a baffled plug flow reactor in pilot scale.

CONCLUSIONS

- Baffled plug flow reactor physically separated partial nitritation and anammox.
- Dissolved oxygen concentration of 0.1 to 1.5 mg/L could suppress NOB.
- Decoupling aerobic and anoxic sludge retention times could help out-select specific bacteria.
- Short aerobic sludge retention times washout NOBs.
- A 20 m^3 mainstream deammonification pilot plant has been built.

Figure 2 – Mainstream deammonification pilot plat (3 chamber baffled plug flow reactor)

Rerferences: Further references upon request. Cao et al., (2017) Mainstream partial nitritation–anammox in municipal wastewater treatment: status, bottlenecks, and further studies, Applied Microbiology and Biotechnology; Henze, M; et al.; (1999) Activated Sludge Model No.2d, ASM2d. Water Sci. Technol; Kepner, J; and Robinson, D; (1988) Nonparametric methods for detecting treatment effects in repeated-measures designs, Journal of the American Statistical Association; Han, M; et al.; (2016) Uncoupling the solids retention times of flocs and granules in mainstream deammonification: A screen as effective out-selection tool for nitrite oxidizing bacteria, Bioresource Technology.

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