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Lessons Learned from 10 Years of ANITA Mox for Sidestream Treatment

Romain Lemaire [1] and Magnus Christensson [2,*]

[1] Veolia Business Support & Performance, 93300 Aubervilliers, France; romain.lemaire@veolia.com
[2] Veolia Water Technologies, AnoxKaldnes, 226 47 Lund, Sweden
* Correspondence: magnus.christensson@anoxkaldnes.com

Abstract: When a wastewater treatment plant (WWTP) uses anaerobic digestion (AD) on its sludge treatment line, the opportunity to install a sidestream deammonification process for the cost-effective removal of the N-rich reject water load generated by the sludge digester should be considered. In this context, the ANITA™ Mox process based on the moving bed biofilm reactor (MBBR) technology has been implemented at more than 30 full-scale facilities over the last 10 years to treat reject water from conventional AD or after thermal hydrolysis process (THP) to reduce the N-load and associated treatment costs on the WWTP. This paper reviews the lessons learned in the implementation of the ANITA™ Mox process at several WWTP in the US, Europe, and Australia.

Keywords: anammox; deammonification; IFAS; MBBR; nitrogen removal; return of experience; THP

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1. Introduction

As populations grow, it is important for municipal wastewater treatment plants (WWTPs) to identify cost-effective methods to manage total nitrogen (TN) levels and meet their environmental obligations. Untreated reject water from anaerobic digestion leads to 10–20% additional TN and ammonium load to the main treatment process in a WWTP. This leads to extra cost for (i) infrastructure (tank volume, equipment), (ii) chemicals such as external carbon source addition to increase denitrification capacity, and (iii) energy due to higher aeration capacity for nitrification [1]. With infrastructure delivery costs also increasing, there is also a focus on finding the lowest cost solutions for the greatest benefit.

In addition, many utilities are now looking beyond conventional anaerobic digestion (AD) to increase methane production and further reduce the volume of final biosolids and associated costs. Thermal Hydrolysis Process (THP) is one of the processes being considered to achieve these outcomes [2]. THP pre-treatment also allows reducing considerably the size of the downstream digester due to the lower viscosity of hydrolysed sludge. The downside of all these benefits, return sidestream from a THP + AD sludge treatment, can generate up to 30% additional N-load to the WWTP and produce intermediate inhibitory compounds [3,4]. Therefore, a sidestream treatment process installed today for the dedicated treatment of conventional anaerobic digester reject water should consider the possibility that THP may be installed in the future, leading to higher N-load to be treated and a specific process operation strategy to overcome the toxicity of THP.

Sidestream deammonification processes using anaerobic ammonium oxidation (Anammox) bacteria are now widely implemented to treat the N-load generated by the sludge treatment line in a very cost-effective manner. Due to the slow growth rate of anammox bacteria, long sludge ages have to be maintained, making biofilm systems a robust technology to perform deammonification. Ammonium Oxidising Bacteria (AOB) and anammox bacteria are maintained in a biofilm on moving carriers with no risk of biomass wash-out [5]. Moving bed biofilm reactor (MBBR) systems are less sensitive to high total suspended solids (TSS) level surges in the reject water inherent to the operation of dewatering units at all WWTPs, as incoming TSS can simply pass through the MBBR in most cases without impacting the anammox biomass safely retained on the biofilm carrier.

In this context, the ANITA™ Mox technology has been implemented at more than 30 full-scale facilities over the last 10 years to treat reject water from conventional AD or after THP. It is a one-stage MBBR deammonification process where partial nitrification to nitrite (i.e., nitritation) and autotrophic N-removal (i.e., anammox) occur simultaneously within the biofilm [6] (Figure 1). Aerobic and anoxic zones reside adjacent to each other due to the oxygen mass transfer limitation under limited and controlled bulk dissolved oxygen (DO) concentration. AOB oxidise ammonium (NH_4) to nitrite (NO_2) in the aerobic zone of the biofilm (i.e., outer part), while anammox bacteria located in the anoxic zone of the biofilm (i.e., inner part) consume NO_2 produced by AOB together with the residual NH_4 (Figure 1). The use of high-surface-area AnoxK^{TM}5 carrier material allows for compact design and simple process operation with maximal biomass retention security [7].

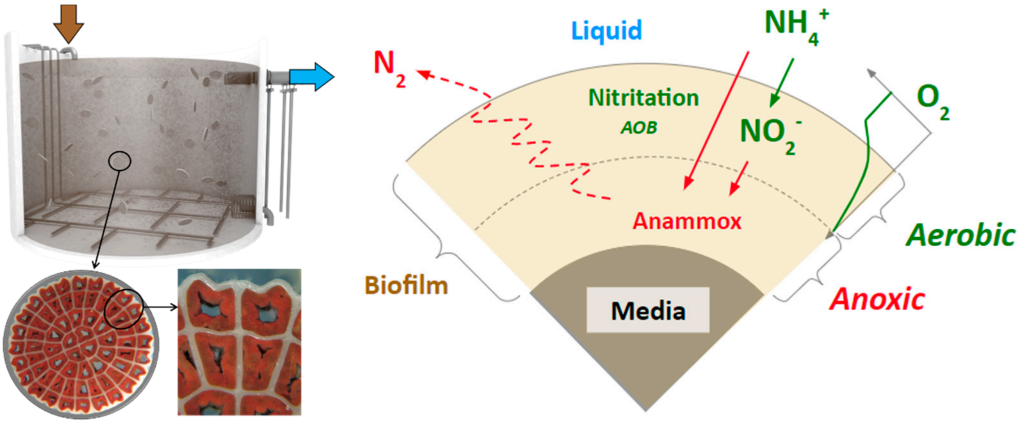

Figure 1. Biological mechanisms occurring in the biofilm of the AnoxK^{TM}5 carriers of the ANITA^{TM} Mox MBBR process.

This paper reviews the lessons learned in the implementation of the ANITA™ Mox process at several WWTP in the US and more recently in Australia for conventional AD sidestream treatment using MBBR configuration and in Europe for THP + AD application using the more adapted integrated fixed-film activated sludge (IFAS) configuration. Table 1 summarises the different ANITA Mox case studies that will be presented in more detail in this paper.

Table 1. ANITA Mox case studies treating conventional AD or THP + AD centrate presented in this paper.

Name	Flow WWTP (MLD)	Type of Centrate	Design Load (Kgn/D)	Design Flow (M^3/D)	Design NH_4 Level (Mgn/L)	ANITA Mox Config.	Start-Up Year
James River (US)	76	AD	250	280	900	MBBR	2014
South Durham (US)	20	AD	300	300	1000	MBBR	2015
Egan (US)	30	AD	940	860	1100	MBBR	2016
Denver (US)	850	AD	4000	3400	1200	MBBR	2017
Luggage Point (AU)	130	AD	975	1000	975	MBBR	2021
Växjö (SE)	20	THP + AD	430	300	1400	IFAS	2011
FiveFords (UK)	26	THP + AD *	850	425	2000	IFAS	2019
Toulouse (FR)	160	THP + AD	1800	1000	1800	IFAS	2020

* FiveFords THP + AD unit is designed to treat external sludge in addition to that produced by the plant itself.

2. Lessons Learned from Treating Conventional Reject Water

2.1. James River, VA: 1st ANITA Mox in the US

The Hampton Roads Sanitation District (HRSD) installed the 1st ANITA Mox in the US at its James River Wastewater Treatment Plant treating 76,000 m^3/d (76 MLD) in Newport News, VA. An existing pre-aeration tank was retrofitted to install the ANITA Mox process. Centrate design flow is 280 m^3/d with a NH_4 load of 250 kgN/d at a concentration of 900 mgN/L. The warm centrate temperature after anaerobic digester (30–35 °C based on buffer tank size and tank/pipe insulation) means that no heating device is usually required to keep the optimum design temperature of 30 °C in the ANITA Mox reactor. The process started in December 2013 with 10% of the total media volume supplied with pre-colonised biofilm from an established ANITA Mox located in Malmö, Sweden. This 1st ANITA Mox plant in Sweden was used as a "Biofarm" to provide seed media with pre-colonised Anammox biofilm to reduce the start-up time of new ANITA Mox plants (typically 5–15% of total media volume). Anammox activity was detected on the virgin media 3 months after seeding.

Ref. [8] reported that 4 months after seeding, the ANITA Mox reactor was achieving more than 85% NH_4 removal at design load condition (Figure 2). During the 1-month performance test done in May 2014, the maximum NH_4 load applied to the system was 375 kgN/d (50% more than design load) and the average NH_4 removal rate was 90% (83% TIN = NH_4 + NO_3 + NO_2 removal). The average NH_4 level in the outlet was 100 mgN/L.

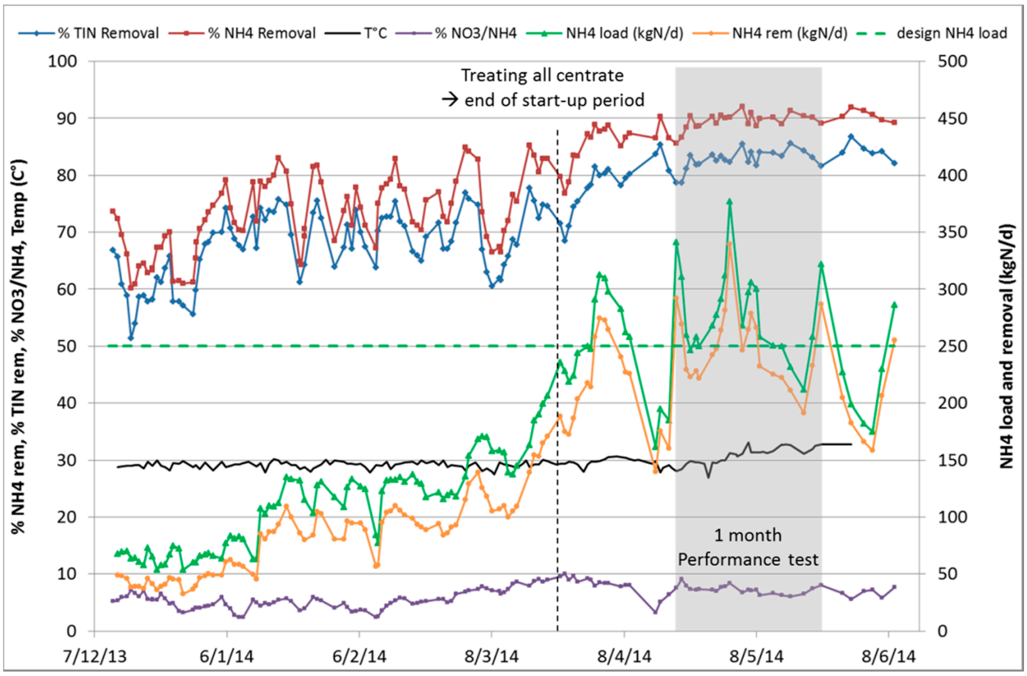

Figure 2. ANITA Mox start-up performance adapted from [8]. TIN (Total Inorganic Nitrogen) = NH_4 + NO_3 + NO_2.

2.2. South Durham, NC: Most Cost-Effective Solution

The City of Durham, NC in the US completed a comprehensive wastewater master plan that evaluated different treatment techniques for meeting strict total nitrogen limits (TN < 3 mgN/L) at the South Durham Water Reclamation Facility (SDWRF). The city studied mainstream and sidestream treatment alternatives to meet its TN limits considering both capital and operating costs. ANITA Mox was estimated to cost $2.1/kg N-removed, while the most cost-effective mainstream biological nutrient removal (BNR) solution was estimated at $5.9/kg N-removed [9]. Thus, the city selected ANITA Mox to meet its strict effluent nitrogen limits using the most cost-effective solution.

The ANITA Mox design consists of two identical and parallel MBBR reactors that were retrofitted in sludge aeration basins that were no longer in use. Filtrate design flow is 300 m^3/d with a NH_4 load of 300 kgN/d at a concentration of 1000 mg/L. The minimum design temperature is 24 °C due to the lack of insulation and large buffer tank size. The process started in August 2015 with 7% of seed media coming from the James River plant (Figure 3). The system was treating the full centrate load by Nov 2015 and achieved greater than 80% NH_4 removal and 70% TN removal, both exceeding guaranteed values. Hollowed et al. 2018 describes a few imbalance process events that occurred at the plant such as short-term nitrate (NO_3) accumulation due to higher activity of Nitrite Oxidising Bacteria (NOB) or NH_4 accumulation from uneven feed flow between the two parallel tanks. Each time, these process disturbances were quickly fixed through better process control of the aeration and centrate feed flow to the reactors, demonstrating the robustness of the ANITA Mox system.

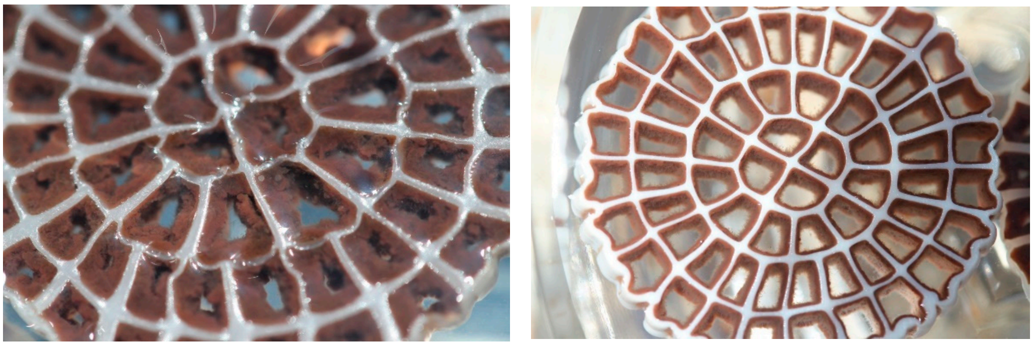

Figure 3. Photo of AnoxK^{TM}5 carriers 1 year after start-up (**left**: "seed" carrier, **right**: "virgin" carrier).

2.3. *Egan, IL: Robust Performance under Variable Flow*

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) installed the ANITA Mox system at its Egan Water Reclamation Plant in Schaumburg, IL. Existing, unused dissolved air flotation (DAF) thickening tanks were converted into one equalisation tank and four identical, parallel ANITA Mox reactors. Centrate design flow is 860 m^3/d with a NH_4 load of 940 kgN/d at a concentration of 1100 mg/L. The minimum design temperature is 27.5 °C without any heating device.

The process started in August 2016 with 10% of seed media coming from the James River plant. Experiences during the startup phase are summarised in [10] and include extended periods (10 months) of limited centrate availability due to maintenance/revamping work on the sludge line and alkalinity limitation. Egan reactors each receive similar flow through gravitational distribution via the weir box. Minor adjustments in aeration setpoints between the reactors are sufficient to keep them operating with similar performance.

As shown in Figure 4, after the 10 months of limited centrate availability, the ANITA Mox reached the design load in less than 3 months. A 90-day performance test was performed from April to June 2018. The average NH_4 load during that period was 75% of design load but with periods reaching 120% of design load based on centrate availability. The limited size of the centrate equalisation tank did not allow the process to be fed continuously during weekends when centrifuges were off, meaning that during the weekdays, the load and flow were often higher than design values [11]. Despite this large flow variation, average NH_4 and TIN removal efficiency were 89% and 81%, respectively with some fluctuation observed between the low load periods (higher removal efficiency >90%) and the high load periods often exceeding the design load (lower removal efficiency around 80%). Average NH_4 levels in the centrate and in the ANITA Mox outlet were 1230 mgN/L and 140 mgN/L, respectively.

2.4. *Denver, CO: Largest ANITA Mox to Date*

The Metropolitan Water Reclamation District (MWRD) in Denver, CO USA, installed the largest ANITA Mox plant to date at its Robert W. Hite Water Reclamation Facility (850 MLD) by converting an existing return activated sludge (RAS) reaeration basin into two parallel ANITA Mox MBBR reactors (Figure 5). The centrate design flow is 3400 m^3/d with a NH_4 load of 4000 kgN/d at a concentration of 1200 mgN/L. The process started in August 2017 with 5% of seed media coming from US and Europe ANITA Mox plants. As seen in Figure 6, it took only 13 weeks to reach the full design load, while starting with only 5% of seed media.

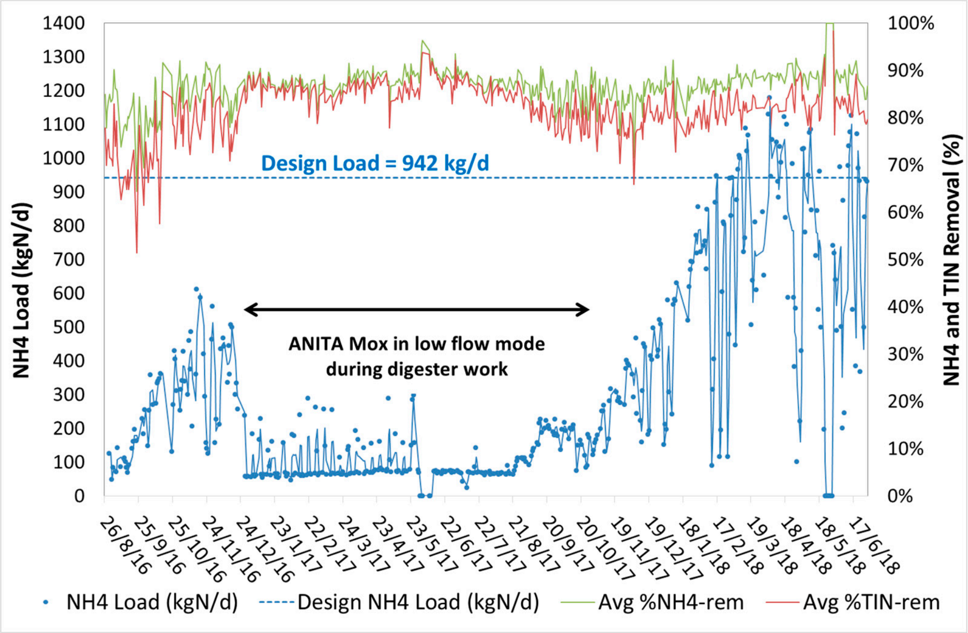

Figure 4. NH_4 load, NH_4, and TIN removal efficiency.

Figure 5. Photo of the ANITA Mox reactor in Denver retrofitted into an existing RAS reaeration tank.

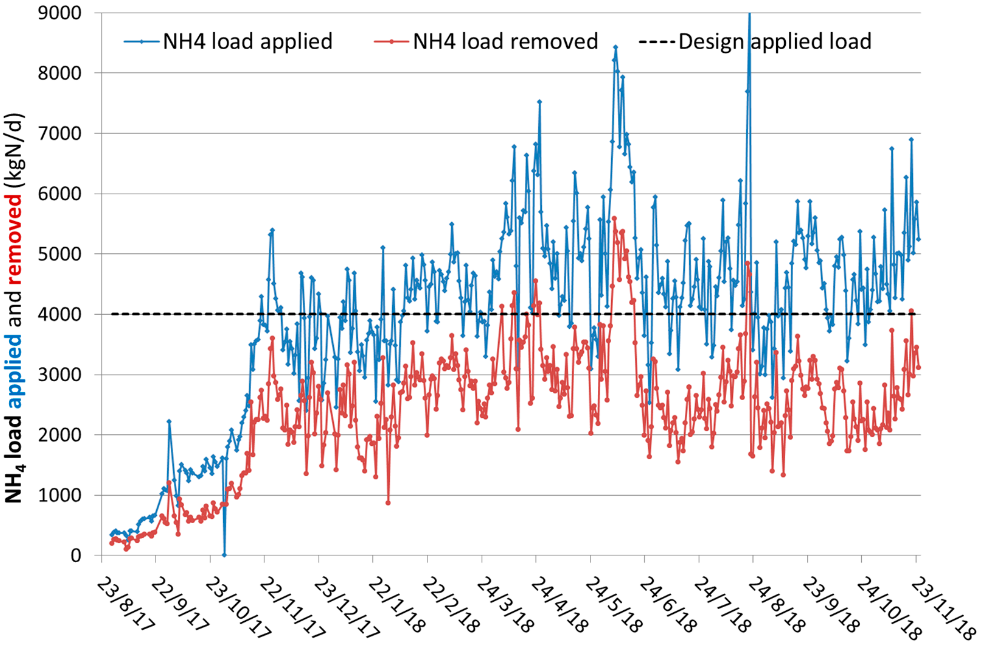

Figure 6. NH_4 load applied and removed (in kgN/d) at Denver since start-up of the ANITA Mox.

Experiences during this startup include instances of loading over design, variable flow, high polymer residual, and high TSS spikes. The ANITA Mox was very resilient to all of these disturbances thanks to the robustness of the MBBR system and its complete anammox biofilm retention feature. The goal of MWRD is to load the ANITA Mox to its maximum capacity (consistently above design load by 20–50%) targeting a residual NH_4 level between 200 and 300 mgN/L. It results in a lower NH_4 removal efficiency (65–75% instead of >85%) but allows them not to dose any extra alkalinity despite being limited in their centrate. Then, the ANITA Mox outlet is polished in remaining RAS reaeration basins.

2.5. Brisbane: 1st Anammox Plant in Australia

The Anammox journey in Australia began in 2014 for Queensland Urban Utilities (QUU) and Veolia at QUU innovation centre located at Luggage Point WWTP in Brisbane. Starting with only 10 L of homegrown Anammox seed media provided by the University of Queensland, QUU and Veolia decided to carefully grow these precious bacteria, as biomass importation from overseas is not allowed to Australia, in order to have sufficient biomass to perform a 6 m^3 pilot trial. After several years of piloting, Urban Utilities decided to move to a full-scale sidestream anammox process for the Luggage point WWTP. The decision was based on the following required outcomes for Urban Utilities:

- Reduce OPEX cost associated with nitrogen removal in their WWTP (methanol to reach TN < 5 mg/L).
- Reduce the cost of delivery by retrofitting existing infrastructure.
- Be a leader in implementation of new technology in Australia with positive environmental outcomes.

ANITA™ Mox technology was selected as the media-based process, since it allowed easy retrofit into existing process tanks, and also, the process had proved itself to be very stable in extreme fluctuation of centrate feed conditions and quality during the pilot trial period: including power outage, feed stoppages, polymer overdose, high TSS in feed.

To proceed with this implementation at full scale, a larger amount of seed media was needed than available in the 6 m^3 pilot plant. To grow this seed media, QUU installed a small 12 m^3 biofarm tank at their innovation centre in 2017, and Veolia later installed a larger 50 m^3 biofarm tank in 2019 (Figure 7). The enrichment process took approximately 8 months to establish the seed required for the full-scale treatment process. In parallel, Urban Utilities and Veolia embarked on the process of upgrading four unused process tanks at the Luggage Point WWTP to accommodate the new full-scale sidestream deammonification process.

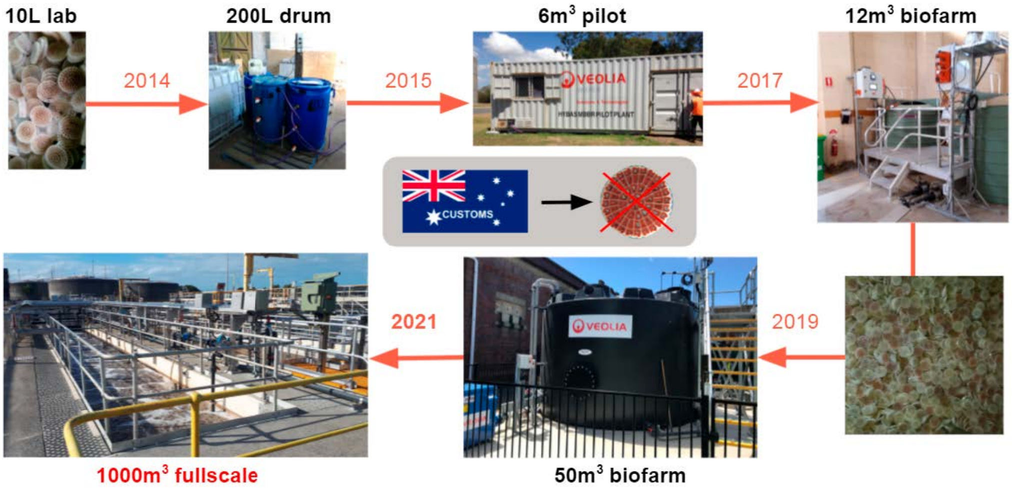

Figure 7. Scale-up journey to grow anammox bacteria locally for 1st ANITA Mox in Australia.

At the time of writing this paper (April 2021), the new sidestream tanks have been successfully retrofitted and commissioned with the seed media from the 50 m^3 biofarm, treating approximately 60% of the design flow. Once fully operational, the ANITA Mox sidestream process at Luggage point will be treating up to 1000 m^3/d of centrate with a design load of 975 kgN/d. Urban Utilities and Veolia will be operating these tanks as a biofarm as well as an integral part of the treatment process at Luggage Point. This means anammox seed in sufficient quantities will be easily available for other Australian Utilities considering ANITA Mox for their own WWTP upgrades.

3. Lessons Learned from Treating THP Centrate

When THP is introduced into the sludge treatment process, not only ammonia and soluble COD concentration increase, but also intermediate inhibitory compounds that typically require dilution of the centrate to maintain high removal performance. For this application, the IFAS configuration of ANITA™ Mox (Figure 8) has proven to be more robust than the MBBR configuration due to the buffering capacity of the heterotrophs and the increased amount of AOB in the mixed liquor suspended solids (MLSS), whereas the anammox bacteria are safely retained on the media [12,13]. Today, there are seven ANITA Mox units treating THP centrate: Växjö (Sweden), Grindsted (Denmark), FiveFords (UK), Toulouse (France) that are in operation, Osberstown (Ireland) under commissioning, and Ljubjlana (Slovenia) and Piscataway (US) that are under construction.

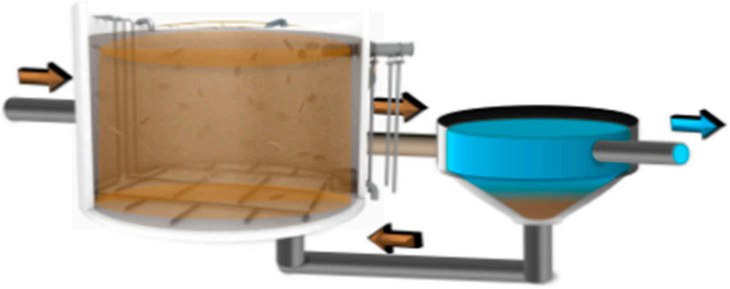

Figure 8. IFAS ANITA Mox configuration.

3.1. Växjö (Sweden): 1st Anammox THP Fullscale Plant

In 2011, Sundet WWTP located in Växjö, Sweden, installed the ANITA Mox process for sidestream management. The facility has a capacity of 95,000 population equivalent (PE) with an average daily flow of 20,000 m^3/d and discharges to nutrient-sensitive lakes around Växjö. At the time of initial startup, the system was processing filtrate from conventional anaerobically digested biosolids, native to the facility. The ANITA Mox system, operated in the MBBR configuration, was retrofitted within an existing SBR reactor. The existing fine bubble diffusers were retained in the reactor and the tank was filled with 45% of AnoxK™5 media.

In 2014–2015, the facility installed a THP upstream of the existing digesters in anticipation of an increasing solids load to the digesters in the form of source-separated household food waste and an increasing sludge volume from the existing plant. With the addition of THP, the plant is able to handle the increasing amounts of sludge and food waste using the existing digesters without the need for new digesters. In spite of higher strength filtrate, the ANITA Mox system was still able to treat all of the filtrate produced with the addition of dilution water; however, there were concerns regarding the stability of the process and the volume of dilution water being used why it was decided to upgrade to an IFAS configuration. An external stainless-steel settler was installed in May 2018, allowing the process to be operated as an IFAS. At design flows, the overflow velocity of the clarifier is 1.5 m/h. The ANITA Mox system was designed to treat an initial NH_4 load of 320 kgN/d, with the ability to treat up to 300 m^3/d of filtrate at 1400 mg N/L (corresponding to 430 kgN/d). The system should provide NH_4 and TN removal efficiency greater than 75% and 65% respectively.

Prior to THP, the MBBR ANITA Mox was receiving an average NH_4 load of 140 kgN/d and the performance of the system was, on average, 90% NH_4 and 83% TN removal. The ratio of NO_3 produced to NH_4 removed was typically less than 11% and averaged 8%, overall (Figure 9).

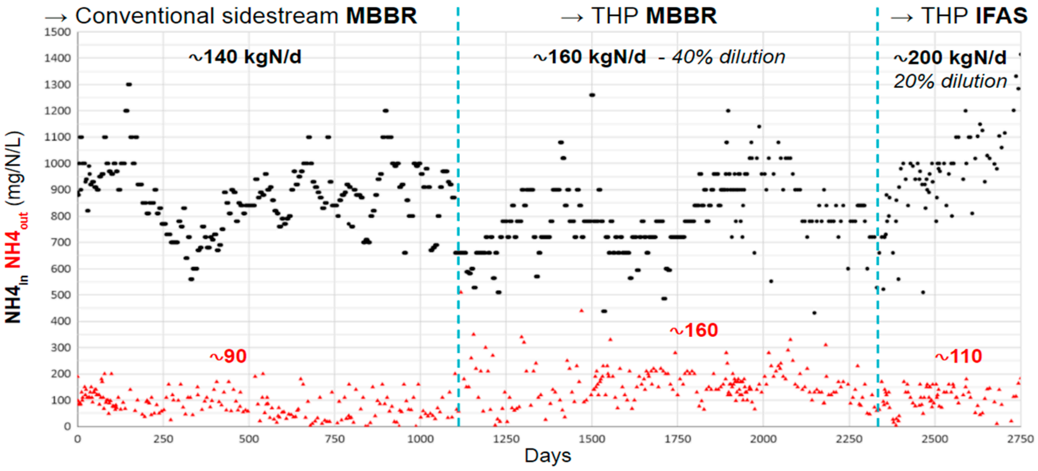

Figure 9. NH_4 concentration in the inlet and outlet of the ANITA Mox in Växjö.

After the installation of the THP process, and before the conversion of the ANITA Mox from MBBR to IFAS, the filtrate required dilution to minimise the inhibitory effects of recalcitrant COD and N compounds generated by the THP. The average ratio of dilution water to total flow during that period was 40%. The average influent NH_4 was 900 mgN/L and the NH_4 load was 160 kgN/d. The performance of the MBBR system was 85% NH_4 and 77% TN removal (Figure 9).

After converting the ANITA Mox to its IFAS configuration, the NH_4 load to the system increased to an average of 200 kgN/d, and the plant was able to treat the filtrate with less dilution water (20% on average), resulting in NH_4 concentration up to 1300 mgN/L. Results from operation in the IFAS configuration shows NH_4 and TN removal of 89% and 83%, with only 6% NO_3 production (Figure 9).

3.2. Wrexham (UK): 1st IFAS ANITA Mox for THP

Welsh Water decided to install a sludge treatment platform next to their FiveFords WWTP in Wrexham, UK. This new THP + AD sludge platform receives sludge from all over the region. To reduce the NH_4 load returned to the nearby WWTP, an IFAS ANITA Mox was included in the overall sludge upgrade work by Mott MacDonald Bentley (MMB). The sludge platform is designed to treat 53 tDS/d producing a NH_4 load in the final centrate of 850 kgN/d with a design flow of 425 m^3/d and a concentration of 2000 mgN/L. The ANITA Mox IFAS system at Wrexham was the 1st deammonification plant built by MMB (Figure 10). The process was initially supposed to be started up using existing conventional AD centrate while the new THP unit was getting constructed and then gradually increase the THP fraction in the centrate. Due to a change of construction planning, the ANITA Mox was started after the THP upgrade works using full-strength THP centrate straight from the beginning. Therefore, the quantity of seed media was increased from 10% originally to a total of 25% with a second addition occurring 3 months after the first one. This was necessary as the change in commissioning plan resulted in the centrate design load being available more rapidly than foreseen initially.

Figure 10. New IFAS ANITA Mox reactor at Wrexham (**left**: IFAS tank, **right**: clarifier).

After adjusting the IFAS operation to balance the high AOB activity in the MLSS to the growing but limited Anammox activity on the media, it was observed that the alkalinity of the centrate was often limiting, resulting in unstable and more challenging operation. Therefore, it was decided to better control the NH_4 removed and final NH_4 concentration in the outlet to avoid being alkalinity limited. The instrumentation for NH_4 on-line measurement was changed from ISE sensor to an analyser after filtration (FILTRAX and AMTAX units from HACH) to improve the accuracy of the measurement in this challenging THP matrix. Then, aeration of the ANITA Mox was controlled based on a target NH_4 value in the outlet to prevent alkalinity limitation and stabilise the operation. The drops in NH_4 removal efficiency from 85% to 80% around Day 380 and then to 75% on Day 440 observed in Figure 11 were the results of action taken to operate at a higher NH_4 level in the IFAS to save on alkalinity and avoid dosing caustic to the system.

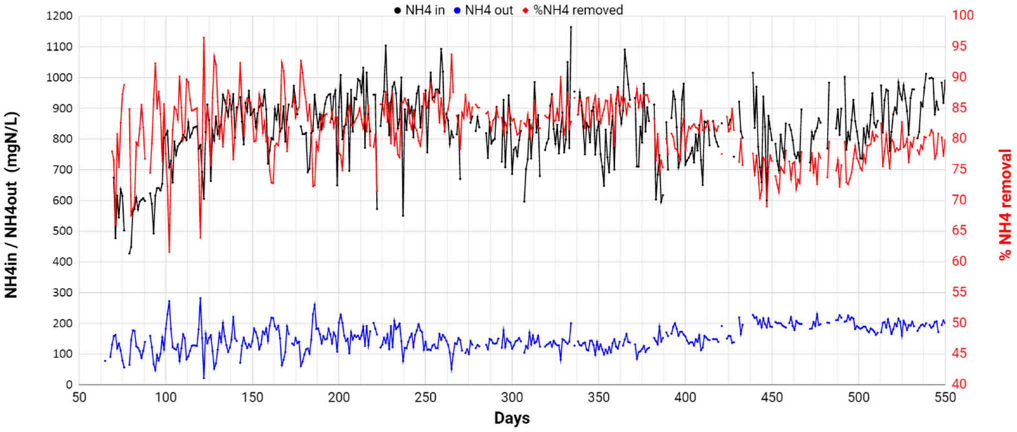

Figure 11. NH_4 level in the inlet and outlet of the ANITA Mox at Wrexham and percentage of NH_4 removed.

Despite a longer start-up time to reach full design load, the IFAS ANITA Mox at Wrexham is successfully treating all the THP centrate produced by the new sludge platform (Figure 12). The anammox activity on both the seed and initial virgin media has been monitored during the entire period through ex situ laboratory batch test and microbial analysis (quantitative polymerase chain reaction—qPCR) by Veolia Research and Innovation team in Paris and AnoxKaldnes process experts in Sweden providing robust evidence that the biofilm colonisation by Anammox in the IFAS ANITA Mox process at Wrexham was always progressing in the right direction. This comprehensive technical and scientific support was key to overcome some of the challenges encountered during the start-up.

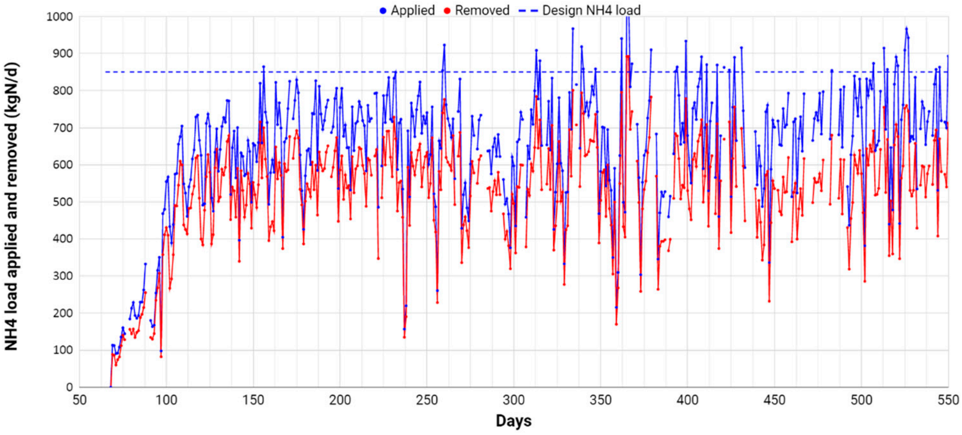

Figure 12. NH_4 load applied and removed (kgN/d) at the ANITA Mox in FiveFords.

3.3. Toulouse (France): Largest IFAS ANITA Mox

Toulouse Metropole decided to upgrade the sludge treatment line at the Ginestous WWTP (1M PE). The new sludge line is composed of BioThelys^{TM} THP, two large anaerobic digesters of 6000 m^3 each, and a MemGas^{TM} biomethane purification unit to produce 56 GWh/year that will be reinjected into the city natural gas grid. For the cost-effective removal of the NH_4 load returned to the WWTP, an IFAS ANITA Mox is treating all the centrate generated by the THP and AD. Figure 13 shows a 3D illustration of the new sludge treatment line with the IFAS ANITA Mox highlighted in red. The new sludge line is still under the final commissioning stage but is already treating all the sludge produced by the plant today, approximately 45 tDS/d for a design load of 73 tDS/d in 2035. The IFAS ANITA Mox is designed to treat a NH_4 load of 1800 kgN/d with a centrate flow of 1000 m^3/d in 2035. Today, it is already treating all the centrate produced by the THP + digester (approximately 900 m^3/d corresponding to 800–1000 kgN/d) despite having been seeded with only 8% of pre-colonised Anammox media.

Figure 13. Three-dimensional (3D) drawing of the THP + AD sludge treatment extension project in Toulouse and photo of the IFAS ANITA Mox unit.

4. Lessons Learned with Operation Control Strategy

Experiences show that the deammonification systems have some challenges during their start-up phase and their operation. Reported challenges are mainly due to the slow growth rate of the anammox bacteria, the complex interactions between different groups of microorganisms, and these microorganisms being sensitive to inhibition [14]. There is a need for a safe operation strategy to overcome such challenges. Known operation strategies require reliable on-line sensors and acute attention from the operator. When the operation strategy mostly relies on the operator's attention, it is very likely to have disturbances in operation during the absence of a dedicated operator. Considering the entire operation period and the long start-up phase of such processes, a lot of man-hours are needed for process control.

The control strategy of the ANITA Mox was developed to have not only safe but also optimised operation in a less operator-dependent way. Veolia's digital offering Hubgrade Performance Plant provides process optimisation and long-term stability in operation. The Hubgrade Performance Plant is a cloud-based holistic service for real-time optimisation of the process performance. This digital solution calculates set points for blowers and feed pumps using operational data from the on-line sensors and algorithms built in the features. This allows adjustment of aeration flow into the reactor and feed flow rate to optimal levels, thus providing a state-of-the-art autopilot to optimize the whole treatment process.

Overall, the ANITA Mox operation with Hubgrade Performance Plant provides an automated real-time performance optimisation, remote monitoring of operation via a user interface, stable optimal conditions 24/7 and maximal utilisation of all the ANITA Mox benefits.

Nitrous oxide (N_2O) emissions from sidestream deammonification processes have been often linked to specific operation control strategies employed by the different technologies such as feeding regime (continuous vs. batch), aeration control (continuous vs. intermittent), and substrate concentration gradient in the reactor [15,16]. Ref. [15] reported N_2O emission from a full-scale granular sequencing batch reactor (SBR) deammonification unit at Ejby Mølle WWTP in Denmark in the range of 4–8% of incoming N-load under standard intermittent aeration control. The N_2O emission was divided by half (2–4% of N-load) when the granular SBR was operated under a new continuous aeration strategy. Similar observation was made by [16] comparing N_2O emission of a full-scale sidestream SBR operated in nitrification/denitrification (N/DN) mode at Slottshagen WWTP in Sweden to that of a deammonification MBBR unit replacing the existing SBR for reject water treatment. While the N_2O emission of the N/DN SBR was averaging 10% of incoming N-load, it was reduced to an average of 0.1–0.7% of incoming N-load for the deammonification MBBR operated under continuous feed and continuous aeration. The N_2O emission measurement campaign at the ANITA Mox MBBR at Växjö was performed in 2012 [6], and average N_2O emissions of 0.2–0.8% of incoming N-load were reported with very low N_2O emission during stable operation (0.04–0.16%) and higher emission (up to 1%) when the centrate feed was not continuous, triggering the aeration to stop in the reactor until centrate was made available again at the plant. Therefore, N_2O emission from MBBR-based ANITA Mox is significantly lower than from other sidestream deammonication systems due to its continuous feed and continuous aeration feature. Operation with the Hubgrade Performance Plant system provides further optimisation of the N_2O emission by offering more stable operation in term of feed regime and aeration control.

5. Conclusions

With more than 30 references installed over the last ten years, the Veolia experience with Anammox has been a positive and passionate journey. With consistent good performance for NH_4 and TN removal at WWTPs combined with the added benefits of reduced OPEX for the overall WWTP, ANITA Mox has proven itself as a viable, robust, and sustainable process that can be considered for the treatment of reject water from conventional AD or after THP. With biofarms now available in Europe, the US, and Australia, this unique and exciting process can be easily installed at other WWTPs. Daily operation of such anammox systems can be improved through the use of digital advanced control system providing continuous process optimisation and stability during start-up and long-term operation.

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