

Evaluation of Sidestream Deammonification Process Enhancements for Treating High Strength Filtrate at the City of Raleigh's Neuse River Resource Recovery Facility

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ABSTRACT

This paper highlights findings and take aways from evaluation and LIFT SEE IT site visits of different side stream deammonification systems considered for the City of Raleigh's Bioenergy Recovery Project for treatment of high strength filtrate that will be generated from thermal hydrolysis pretreatment followed by mesophilic anaerobic digestion biosolids handling process. This paper reviews technology and process operation enhancement strategies considered to address challenges associated with treating high strength filtrates.

KEY WORDS

Sidestream treatment, Nitrogen removal, Deammonification, Thermal Hydrolysis Process (THP), High strength filtrate

INTRODUCTION

The City of Raleigh Public Utilities Department (CORPUD) owns and operates three advanced nutrient removal facilities in the service area, including the 60 million gallon per day (mgd) Neuse River Resource Recovery Facility (NRRRF), the 2.2 mgd Little Creek Wastewater Treatment Plant (WWTP), and the 3.0 mgd Smith Creek WWTP. The NRRRF treatment process, which is currently under the final phases of construction for expansion to 75 mgd, includes fine screening, forced vortex grit removal, influent pumping, primary treatment, enhanced biological nutrient removal (BNR) using a 4 or 5-stage activated sludge BNR process configuration, chemical phosphorus removal via alum addition, denitrification polishing filters, and UV disinfection. Figure 1 illustrates an existing process flow diagram for the NRRRF. The NRRRF produces a high-quality effluent that has achieved an average total nitrogen (TN) concentration of less than 3.0 mg/L since 2003.

As the largest of the CORPUD's treatment facilities, the NRRRF serves as a centralized biosolids processing facility for residuals generated at all three wastewater treatment plants. Residuals are currently processed using the following three different management options available at the Neuse River RRF: (1) a portion of the biological solids are aerobically digested on site using a two-step digestion process to produce a Class B liquid biosolids that are land applied as a fertilizer on permitted fields; (2) solids are dewatered onsite to a cake product and then lime stabilized to produce a Class A biosolids that is distributed for beneficial use as a liming agent to area farms; (3) solids are dewatered onsite and then trucked offsite for additional

processing at an offsite composting facility to produce a Class A product that is distributed by the compost facility for use as a fertilizer or trucked offsite for disposal at a landfill. The existing management options are illustrated on the existing process flow diagram in Figure 1.

In 2013, the City of Raleigh completed a Biosolids Master Plan Update to evaluate and identify sustainable long-term biosolids management for residuals generated from the City's three treatment facilities. The Master Plan Update compared continuing with the current biosolids management strategies to alternative strategies (CDM Smith, 2013). Based on findings and recommendations from the Biosolids Master Plan Update, the City of Raleigh plans to implement a Bioenergy Recovery Project in which the City will transition biosolids management at the 75-mgd NRRRF to an advanced anaerobic digestion process, which will utilize mesophilic anaerobic digestion (MAD) with a thermal hydrolysis pretreatment process (THP) (referred to hereafter as the THP + MAD process).

The THP+MAD process will allow the CORPUD to produce a Class A biosolids product while simultaneously moving toward energy neutrality and significantly reducing greenhouse gas emissions through recovery of biogas generated via anaerobic digestion. The biogas will be cleaned to renewable natural gas standards and the captured methane will be beneficially reused as a renewable natural gas. The City is working closely with a local natural gas utility to allow injection of the renewable natural gas into a new natural gas pipeline that is planned to be routed adjacent to the Bioenergy Recovery Project site. The ultimate goal is to utilize the renewable natural gas to offset fuel usage for the City's bus fleet.

Figure 2 illustrates the proposed process flow diagram for the proposed Bioenergy Recovery Project. Final design for this project is anticipated to be completed in August 2018 with construction anticipated to begin in late 2018. The biosolids handling systems will be initially sized to process biosolids from the 75 mgd NRRRF plant expansion including biosolids received from Smith Creek and Little Creek WWTPs. Major elements of the solids handling process include the following:

- WAS Gravity Belt Thickening
- Primary and Thickened WAS Blending
- Blended Sludge Screening
- Centrifuge Pre-Dewatering System
- Thermal Hydrolysis Process
- Post THP Cooling
- Mesophilic Anaerobic Digestion
- Final Dewatering Utilizing Belt Filter Presses and an Existing Centrifuge
- Sidestream Short-Cut Nitrogen Removal Treatment Process
- Alum Addition for Chemical Phosphorus Precipitation
- Digester Gas Storage, Cleaning and Utilization
- Steam Boilers for Steam Supply

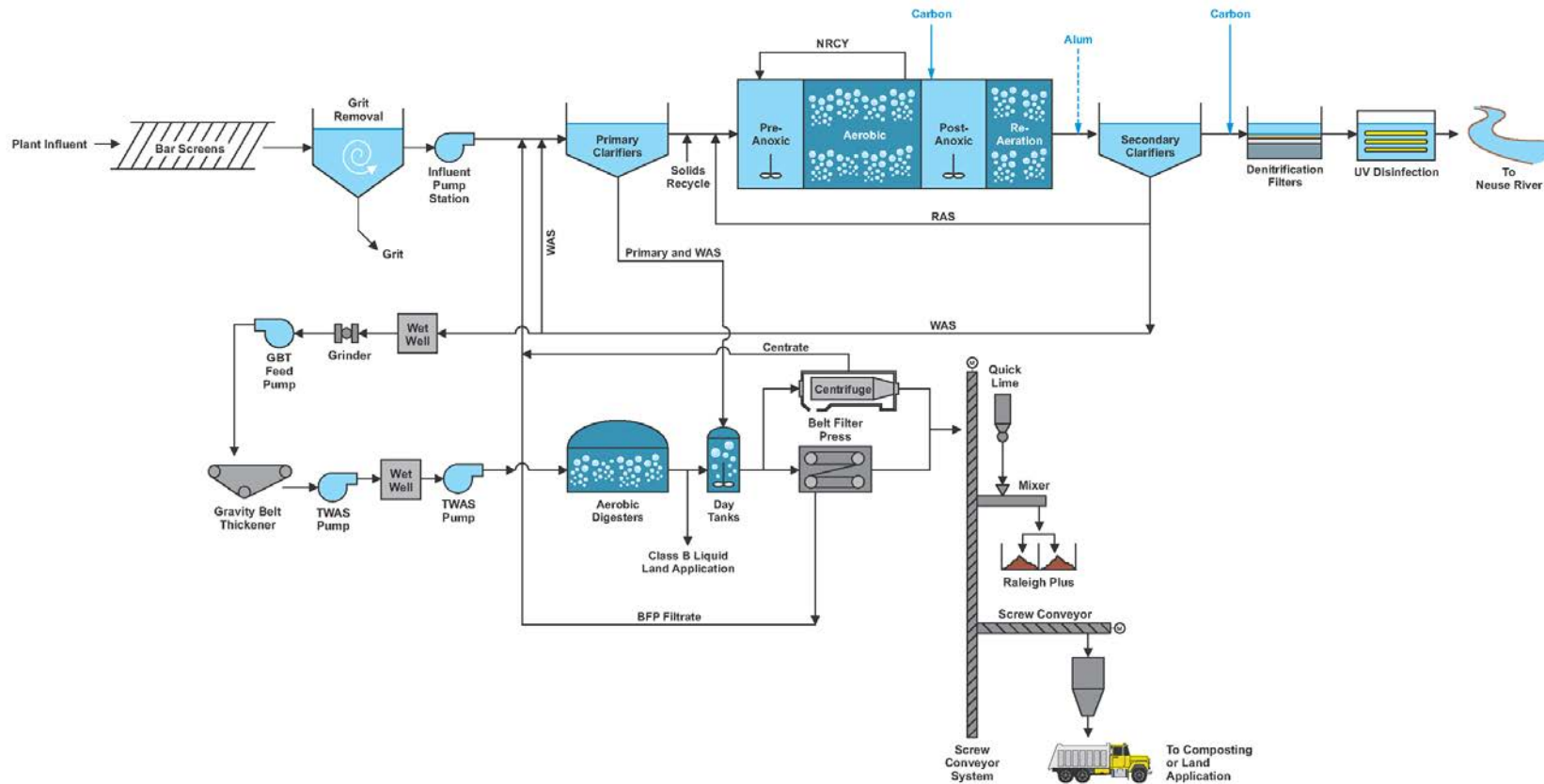


Figure 1. Existing Process Flow Diagram of Neuse River Resource Recovery Facility

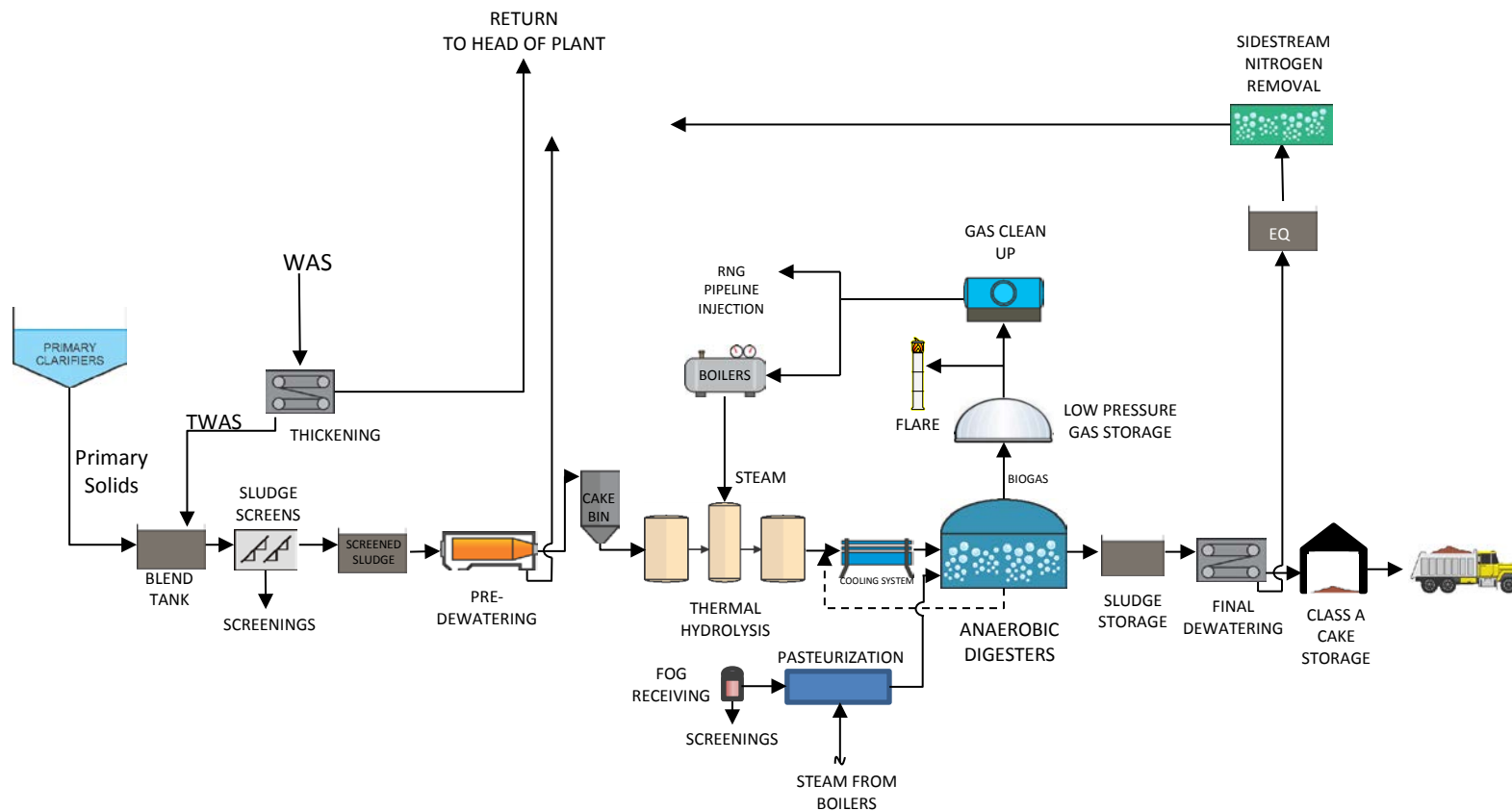


Figure 2. Proposed Biosolids Process Flow Diagram for Bioenergy Recovery Project at NRRRF.
(Note that FOG receiving will not be installed as part of initial construction phase).

One key component of the Bioenergy Recovery Project, which is the focus of this paper, is a sidestream short-cut nitrogen removal treatment process that will treat high strength nitrogen loads from the final dewatering process. The short-cut nitrogen removal process selected will utilize deammonification, in which approximately half of the ammonia is oxidized to nitrite via aerobic Ammonia Oxidizing Bacteria (AOBs) and additional ammonia is oxidized under anoxic conditions by anaerobic ammonia oxidizing bacteria (annamox bacteria). The deammonification process reduces nitrogen with significantly lower carbon, air, and alkalinity requirements in comparison to a conventional BNR process, providing opportunities for significant O&M cost savings.

With many full-scale installations, sidestream deammonification is considered a proven process for cost effective reduction of nitrogen loads in recycle streams from solids handling processes. However, there is considerably less experience with side stream deammonification treating high strength filtrates, such as encountered in solids handling processes incorporating THP + MAD. A THP+MAD filtrate has significantly higher concentrations and different fractions of organics and nitrogen compared to conventional anaerobic digester filtrate. Previous research has shown that the high strength filtrate is inhibitory to AOBs and also results in possible additional competition for the annamox bacteria (Figdore et al, 2011 and Zhang et al, 2016). Several different side stream process enhancement strategies have been implemented by different manufacturers to help to address these challenges. Example process improvements include: dilution of filtrate with process water to reduce AOB inhibition; higher operating DO set-points to address oxygen diffusion limitations; alternative annamox bacteria selection strategies; and more complex process configurations.

This paper highlights findings and take aways from evaluation and LIFT SEE IT site visits of different side stream deammonification systems considered for the City of Raleigh's Bioenergy Recovery Project for treatment of high strength filtrate that will be generated from thermal hydrolysis pretreatment followed by mesophilic anaerobic digestion biosolids handling process. This paper reviews technology and process operation enhancement strategies considered to address challenges associated with treating high strength filtrates.

OVERVIEW OF SIDESTREAM DEAMMONIFICATION PROCESS

Nitrogen is typically removed in wastewater treatment processes utilizing conventional nitrification and denitrification. In the conventional nitrogen cycle (Figure 3), ammonia is oxidized to nitrite and then to nitrate by aerobic ammonia oxidizing bacteria (AOB) and aerobic nitrite oxidizing bacteria (NOB) respectively. Nitrate is then denitrified to nitrogen gas under anoxic conditions using heterotrophic bacteria. This process requires 4.57 pounds of oxygen per pound of ammonia removed, 7.14 pounds of alkalinity per pound of ammonia removed, and 6 pounds of carbon as COD per pound of nitrate removed through heterotrophic denitrification (Metcalf, 2013).

An alternative approach for removing nitrogen in sidestream flows is the use of the deammonification process, as illustrated in Figure 4. The deammonification process requires conversion of approximately half of the influent ammonia into nitrite by AOB, followed by the

simultaneous removal of ammonia and nitrite by anammox bacteria. Under anoxic conditions, anammox have the ability to simultaneously reduce nitrite and ammonia to nitrogen gas.

Using this process, a 66.5% savings in aeration, 50% savings in alkalinity, and 100% savings in carbon is realized; this results in a substantial savings in energy and supplemental chemicals, as dewatering return does not typically contain sufficient inherent alkalinity and carbon for full nitrogen removal.

For deammonification processes to be successful, stable production of nitrite is needed, however the concentration must be minimal as it is also toxic to anammox bacteria. Further, since anammox bacteria have extremely low growth rates, deammonification processes must provide sufficiently long solids retention times (SRT) for anammox bacteria growth. In successful operation, the conversion of ammonia to nitrite is usually the limiting step, which ensures that the nitrite concentration remains small, as any nitrite produced is quickly utilized by the anammox bacteria, while ammonia concentrations can be present in larger amounts. (Wett, 2007)

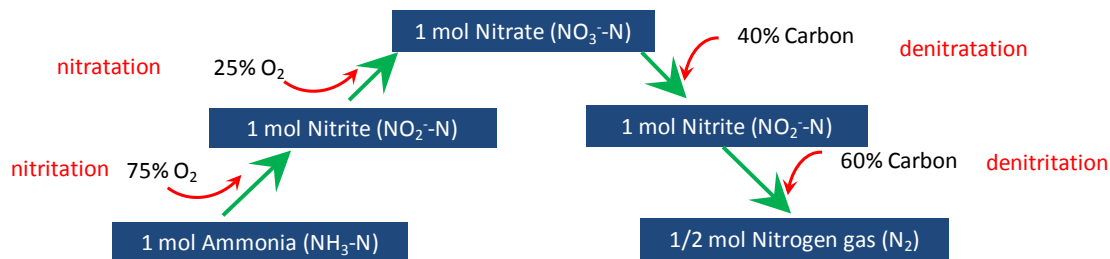


Figure 3: Conventional Nitrogen Removal Pathway

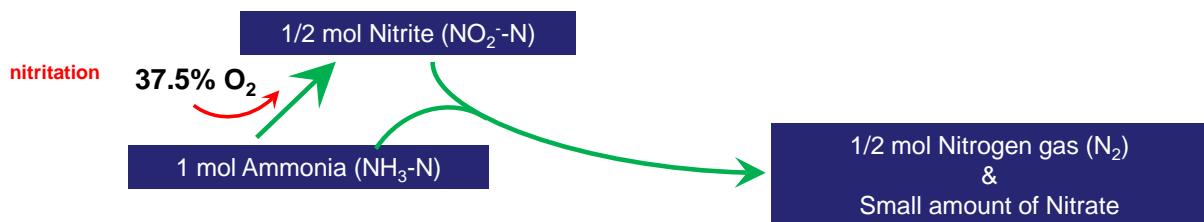


Figure 4: Overview of the Deammonification Process

Several sidestream deammonification treatment technologies are currently available. In each of these existing processes, nitrite production is achieved using patented approaches for repressing NOB using free ammonia and dissolved oxygen concentration gradients. The technology providers utilize seed anammox bacteria from operating facilities to start up a new installation.

Several different deammonification technologies were considered during the PER phase of the City's Bioenergy Recovery Project, including World Water Works DEMON® process and

Veolia's ANITA™Mox MBBR process, and Veolia's ANITA™Mox IFAs process. These technologies differ in operation and biomass retention/characteristic (suspended floc, granular and attached growth), as shown in Table 1. Each technology has proprietary equipment and process control software.

Table 1: Description of Vendor Deammonification Processes Considered to PER Phase of Bioenergy Recovery Project

	DEMON®	ANITA™ Mox MBBR	ANITA™ Mox IFAS
Reactor configuration	SBR	MBBR	IFAS
Biomass characteristic	Flocs and granules	Biofilm	Biofilm and flocs
Proprietary retention strategy	Hydrocyclone	Plastic carrier and screen	Plastic carrier, screen, and suspended phase wasting

FUTURE SIDESTREAM LOADS AND DRIVERS FOR SIDESTREAM TREATMENT

The current solids treatment process at the NRRRF does not include THP or anaerobic digestion and does not contribute significant quantities of nitrogen or phosphorus to the main stream process. However, with implementation of anaerobic digestion, and in particular, a high rate anaerobic digestion process that achieves high levels of volatile solids reduction (VSR), sidestream nutrient loads are expected to increase significantly at NRRRF.

Table 2 summarizes design flows and loads for the side stream deammonification system for NRRRF. Because the existing solids handling process does not incorporate THP or anaerobic digestion, existing sidestream data could not be used as the basis for estimating design loads for the final dewatering process. Therefore, sidestream loads were estimated using a combination of literature review of THP+MAD studies, data from other THP+MAD facilities, mass balances, and BioWin process modeling simulations of the future biosolids handling process. TKN and ammonia-N loads were estimated from BioWin modeling, mass balances, and literature. BOD, COD, and alkalinity values were estimated from literature and other facilities (Ahuja, et. al., 2015, Zhang, et al., 2015, and Figdore, 2011).

Table 2. Design Influent Flows and Loads for Side Stream Deammonification System at NRRRF (Initial design sizing is 50% of Ultimate).

Description	50% Ultimate²	Ultimate¹	Diluted Concentration (mg/L)
Sidestream Flow (mgd)	0.15	0.30	N/A
Dilution Water Flow (mgd)	0.15	0.30	N/A
TKN (lb N/day)	3,375	6,750	1,350
NH ₃ (lb N/day) (85% of TKN)	2,869	5,738	1,150
BOD (lb/day)	125-1,000	250-2,000	50 – 400
COD (lb/day)	7,874	15,748	3,150
CODs (lb/day)	6,750	13,500	2,700
TSS (lb/day)	1,751	3,503	700
Alkalinity (lb/day)	10,125	20,250	4,050
Side Stream TP Load with Chemical P Removal (lbs/day)	240	470	94
Side Stream TP Load with Biological P Removal (lbs/day)	710	1,420	284

¹Ultimate design based on 90 MGD Design Flow (2040) at NRRRF.

²Sidestream treatment system will initially be sized to treat 50% of ultimate load.

A preliminary economic evaluation of both nitrogen and phosphorus sidestream nitrogen removal systems was conducted during the PER phase of the Bioenergy Recovery Project. The preliminary economic evaluation summary illustrated that each of the sidestream options had similar net present value and were significantly more cost effective than treating the additional nitrogen loads in the mainstream BNR process. Each sidestream nitrogen removal technology has a payback period of less than 12 years, which is typical for the technologies considered.

A similar preliminary economic evaluation was completed to compare phosphorus recovery systems to chemical phosphorus removal with alum. The phosphorus removal evaluation is dependent on whether the NRRRF is operating the anaerobic zone in the BNR basins for biological phosphorus removal. The economic evaluation indicates that generally it is less expensive over the 20-year planning horizon to remove phosphorus chemically with alum, particularly if the NRRRF continues to utilize chemical phosphorus removal in the mainstream BNR process as does not operated as a 5-stage BNR process. Based on this finding, it was recommended that implementation of struvite recovery for phosphorus removal be deferred until the THP+MAD facilities come online so that sidestream phosphorus loads can be determined and the economic evaluation refined. Provisions for a new alum storage and feed facility to control struvite formation will be implemented as part of the first phase of the Bioenergy Recovery Project.

OVERVIEW OF CHALLENGES & PROCESS ENHANCEMENT STRATEGIES FOR HIGH STRENGTH FILTRATES

As summarized in Table 2, THP+MAD filtrate has significantly higher concentrations and different fractions of organics and nitrogen compared to conventional anaerobic digester filtrate. Previous research has shown that the high COD is potentially inhibitory to AOBs and results in possible additional competition between annamox bacteria and heterotrophs (Figdore et al, 2011 and Zhang et al, 2016). In addition, high TKN concentrations has the potential to inhibit AOBs (Figdore et al, 2011). Higher strength filtrate also has the potential to create diffusion limitations, particularly in fixed film systems (Zhao et al, 2013). High ortho phosphorus concentrations in the filtrate has also been noted to cause issues with struvite formation (Bilyk et al, 2017) and the potential to bind with iron increasing risk for micronutrient deficiency. Other potential process challenges noted from the LIFT SEE IT site visits include potential for process upsets associated with poor filtrate quality, such as elevated TSS conditions, high COD concentrations, or excess polymer.

Several different sidestream process enhancement strategies have been implemented by different manufacturers to help to address the process challenges associated with treating high strength filtrate waste streams. Example process improvements that have been identified include the following:

- Dilute filtrate with process water at or greater to 1:1 dilution rate to reduce AOB inhibition to high ammonia and COD (Figdore et al, 2011).
- Utilize higher operating DO set-points to address oxygen diffusion limitations (Zhang et al, 2016)
- Use alternative annamox bacteria selection strategy to improve annamox retention (Zhang et al, 2016)
- Pretreat filtrate to reduce annamox competition (Remy et al, 2016), improve TIN removal, and reduce struvite potential.
- Utilize more complex process configurations (Zhao et al, 2013).

PROPOSED SIDESTREAM DEAMMONIFICATION SYSTEMS FOR NRRRF AND SITE VISITS OF SIMILAR SYSTEMS

Based on findings from the PER phase, two deammonification systems, World Water Works DEMON® process and Veolia's ANITA™Mox IFAS process, were recommended for further development during the detailed design phase of the Bioenergy Recovery Project. During the detailed design phase, World Water Works modified their DEMON process to the conDEA® process. There are currently no US installations of either of the proposed process configurations; however, both of these systems incorporate several of the referenced deammonification process enhancement strategies described above for treating high strength filtrates. The primary author visited representative installations of each technology in Europe in May 2017 as part of the LIFT SEE IT scholarship program to assist with evaluation of the different sidestream treatment systems proposed for NRRRF. Members of the design team also participated in the site visits. The following subsections describe the sidestream deammonification systems proposed during the detailed design phase for the Bioenergy Recovery Project and reports on findings from the site visits of similar systems completed as part of the LIFT SEE IT program. Site visit

summaries presented in the following sections are based on the author's LIFT SEE IT trip report (http://www.werf.org/lift/docs/LIFT_SEE_IT_2017.aspx).

The general process design for both systems evaluated, illustrated in Figure 5, includes influent equalization with mixing to provide two days of retention time to provide a consistent nitrogen load to the process, reuse water addition to provide a 1:1 dilution rate of filtrate to reclaimed water to address inhibition, steam addition as needed to maintain reactor temperatures at or above 25 °C, micronutrient addition, pumping to the deammonification reactor, and the proposed manufacturer's deammonification treatment process.

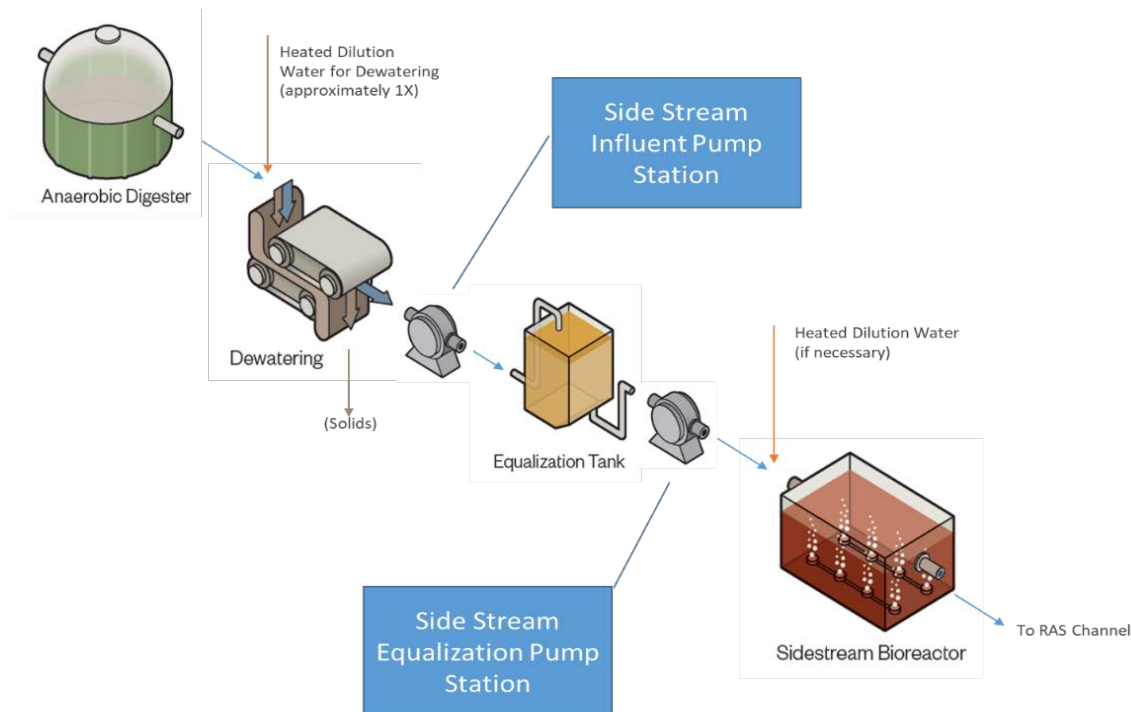


Figure 5. General Process Flow Diagram for Proposed Sidestream Nitrogen Removal System.

Proposed DEMON® Process

During the detailed design phase of the Bioenergy Recovery Project, World Water Works proposed a flow through DEMON® process, referred to as the conDEA™ system with use of a new MicroScreen for retention of annamox granules. This was a major modification from the PER phase, during which an SBR configuration with hydrocyclones was proposed. The proposed changes were based on incorporating recent innovations and process enhancement strategies for effectively treated the MAD+THP filtrate.

Figure 6 illustrates a process schematic of the conDEA™ system. A 3D rendering of the general site layout of the proposed system for NRRRF from the 30-percent design phase is shown in Figure 7.

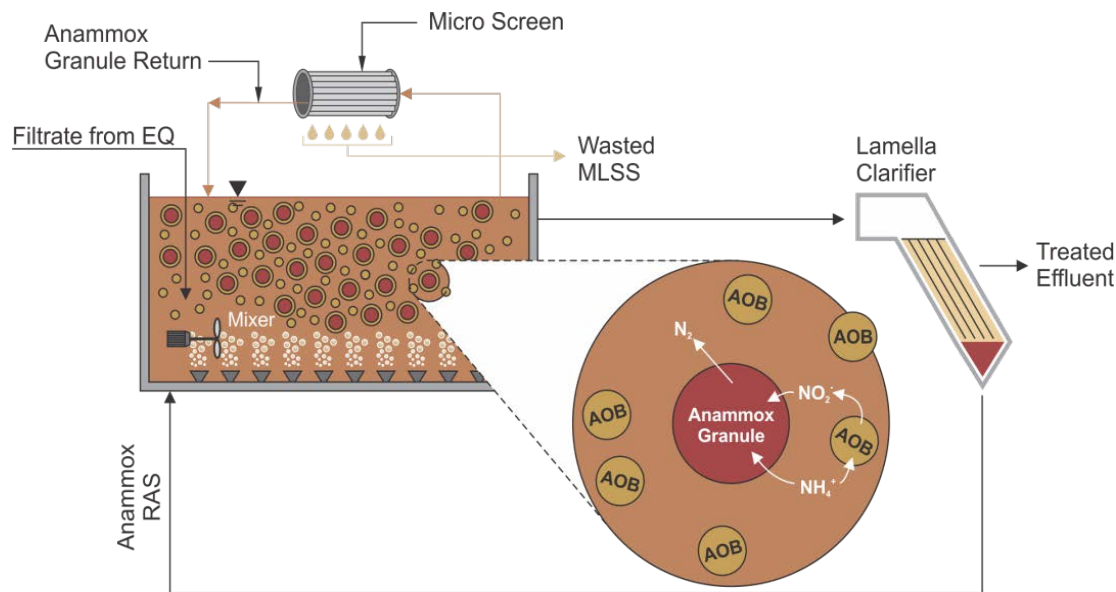


Figure 6. Process Schematic of World Water Works conDEA™ Process.

The conDEA™ system is a continuous flow-through activated sludge system that utilizes a lamella clarifier or internal clarification process for capture of settled biomass to return to the biological process. Anammox bacteria are part of the suspended solids but are granular in form. A separation device is utilized to capture and return the anammox granules to the biological reactor, allowing the anammox to stay in the system at a much longer SRT compared to the remainder of the suspended growth. The flow-through system provides capacity benefits compared to the SBR system by eliminating settling / decanting time and increasing the reaction time. At the time that the system was proposed, there were no US installations using the flow-through configuration.

The proposed conDEA™ system for NRRRF includes a separate internal pumping system with a sieve screen for capturing and retainment of granular anammox bacteria. The sieve screen was proposed as it has been shown to provide better capture of anammox bacteria in comparison to the cyclone system (Zang et al 2016). At the time that the system was proposed, Strass Australia was the only full-scale system using the new MicroScreen configuration.

The reactor is aerated using Messner panels. Submersible mixers are also used to maintain MLSS in suspension during non-aerated periods. On-line pH and DO analyzers are typically utilized to control blower and mixer operation to promote cycling of ammonia oxidation by AOBs and ammonia and nitrite reduction by anammox.

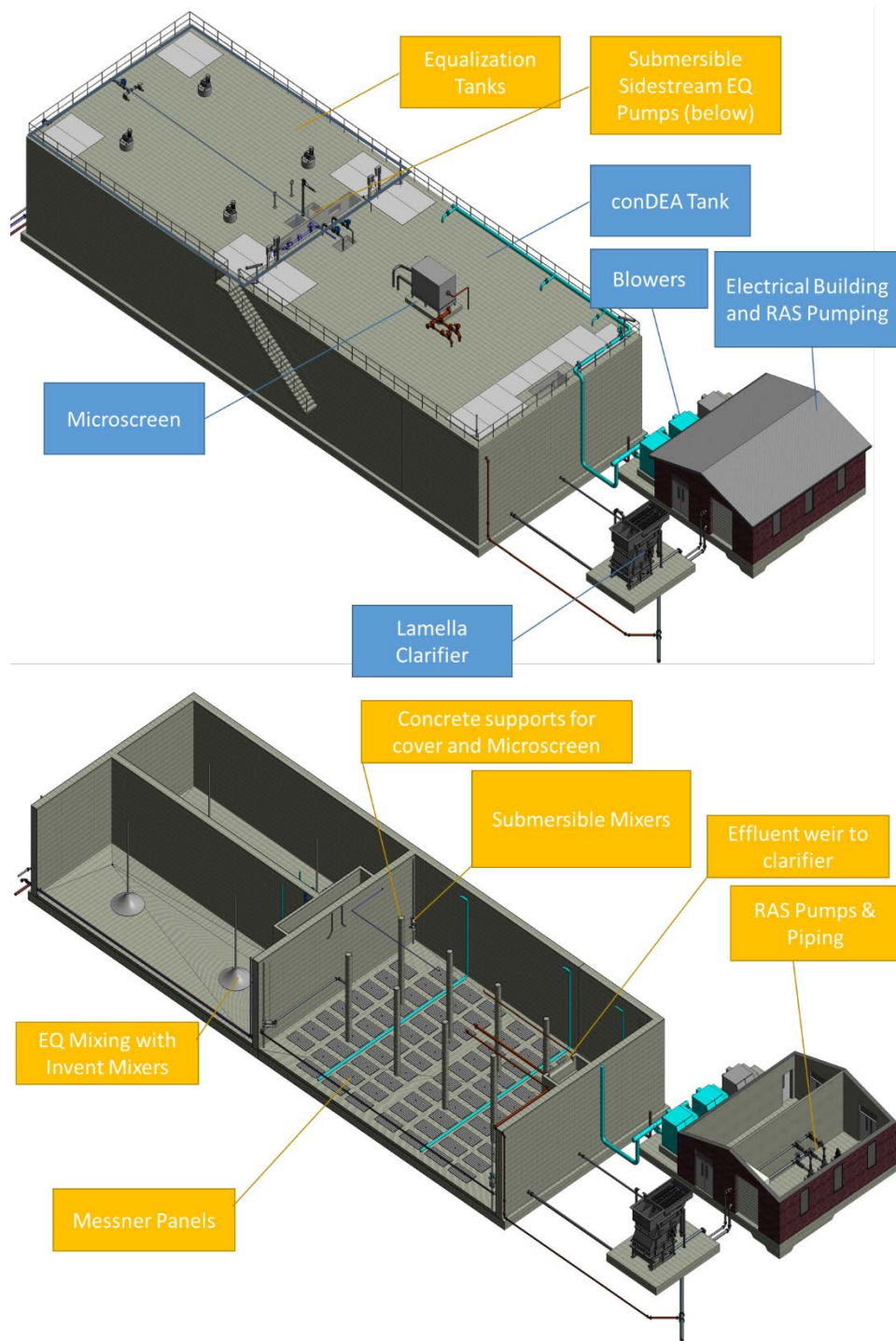


Figure 7. 3D Rendering of Proposed conDEA™ Layout for NRRRF.

Site Visit Summary of the conDEA™ system at the Amersfoort WWTP, Netherlands

Although there were no continuous flow through DEMON® process in the US at the time of this evaluation, there are several existing full-scale conDEA™ systems in operation in Europe with several years of operating history. The conDEA™ system at the Amersfoort WWTP, Netherlands, treats high strength filtrate from a THP+MAD process, and was visited as part of the LIFT SEE IT visits as a representative sidestream system for comparison to the proposed conDEA™ system for NRRRF.

The Amersfoort WWTP is designed to treat a population equivalent of 315,000 and has a biosolids processing capacity of 14,400 dry tons per year. The plant treats approximately 40% import solids.

Figure 8 shows several pictures from the site visit of the conDEA™ system at the Amersfoort WWTP. This system was originally installed in 2012 and is one of the earliest flow-through DEMON® systems. This system uses a hydrocyclone for annamox granule capture and retainment as the MicroScreen proposed for NRRRF is a newer equipment offering to the original hydrocyclone. The Amersfoort conDEA™ system includes a small “balance” tank (< 1 hour) upstream of the conDEA™ reactor, the conDEA™ reactor, which is contained with a single covered circular tank, a blower building which houses blowers, RAS, and WAS pumps, and on-line analyzers with associated control instrumentation for control of the blowers. The entire conDEA™ process is constructed with a single, circular tank shown in Figure 8. The activated sludge clarifier is in the center of the tank and the outer ring comprises the aerated biological reactor. A cyclone separation device is utilized to capture annamox granules from the mixed liquor prior to wasting and returns the granules to the biological reactor to retain the slower growing annamox. A SALSNESS filter is installed upstream of the reactor to reduce influent TSS to the process.

The sidestream process was originally installed prior to the plant installing THP. The system was originally designed for an ammonia-N loading rate of 0.6 kg/m³-day. The THP process, which uses a LysoTherm® process, was installed in 2015/2016. With installation of the THP system, the conDEA™ system is operating at a much higher ammonia loading than original design but still below 1 kg/m³-d, which is considered an acceptable loading rate for a flow-through DEMON® system without screens. The updated design conditions with THP are approximately 42 m³/hour (0.27 mgd) of flow and approximately 800 kg/day (1,760 lbs/day) of NH₃-N load (approximately 800 mg/L NH₃-N). The blowers were upgraded to accommodate higher ammonia loads associated with the THP+MAD filtrate.



Figure 8. conDEA™ system at the Amersfoort WWTP.
From left to right top to bottom: (1) conDEA™ Reactor; (2) Hydrocyclone with SALSENESS Filter in background; (3) Influent piping to reactor; (4) On-line instrumentation; (5) Center clarifier well; (6) Mixed liquor sample with annamox granules present.

The conDEA™ process treats both pre- and post-THP dewatering filtrate. A phosphorus recovery system, including a WASSTRIP® reactor and OSTARA® process, was also installed at the Amersfoort WWTP as part of the THP project. The WASSTRIP® reactor is used to release biologically bound phosphorus from the primary and WAS solids upstream of the anaerobic digestion process. Filtrate from pre- and post-THP dewatering processes are treated in a phosphorus recovery process using the OSTARA® process. The effluent from the OSTARA® process is directed to the conDEA™ reactor for removal of ammonia and nitrogen.

On-line pH, DO, nitrite / nitrate, and NH₃-N probes are installed in the conDEA™ reactor for on-line monitoring and control. The primary control system is pH / DO control based. pH settings are used for controlling when the blowers operate and DO is used to control the speed of the blower to maintain a target DO set point (typically 0.3 mg/L). The blowers were operated around a very narrow pH control band of 0.02 pH units. The control strategy was easy to follow on the SCADA system.

The facility was operating at lower temperatures in comparison to the proposed operating temperature for NRRRF, which is designed to be kept at or above 25 °C. Influent temperatures were reported to typically be 20 to 22 °C with a minimum of 18 °C. It was also noted that the system included minimal equalization volume and that no external micronutrients were being added.

The plant has experienced challenges with poor capture rates in the dewatering process. The filter was not operating during the site visit and the influent TSS was very high (> 3,000 mg/L). It was noted that the high influent TSS negatively affects process performance in the deammonification process. In addition, excess VFA production from WASSTRIP® process has resulted in increased COD loads and is reportedly challenging the downstream deammonification process.

Key take-aways from this site visit include the following:

- The flow-through configuration increases capacity and simplifies operation compared to an SBR.
- The all-in-one tank configuration eliminates the need for a separate clarification device outside of the aeration tank, minimizing footprint.
- It is very important to effectively manage filtrate quality going to the deammonification process. High VFA loads and high influent TSS were negatively impacting deammonification operations during the site visit.

Proposed ANITA™Mox IFAS system

For the Veolia ANITA™Mox system, an integrated fixed film (IFAS) system is proposed over the MBBR system for NRRRF. At the time that the system was proposed, there were no US installations using the IFAS configuration. The IFAS configuration is similar to the MBBR configuration except that it includes a clarifier with return activated sludge (RAS) and waste activated sludge (WAS) pumping. The IFAS system differs from the MBBR configuration in that a portion of the biological activity is suspended in addition to the fixed film on the media.

Figure 9 illustrates a process schematic of the ANITA™Mox IFAS system. A 3D rendering of the general site layout of the proposed system for NRRRF from the 30-percent design phase is shown in Figure 10.

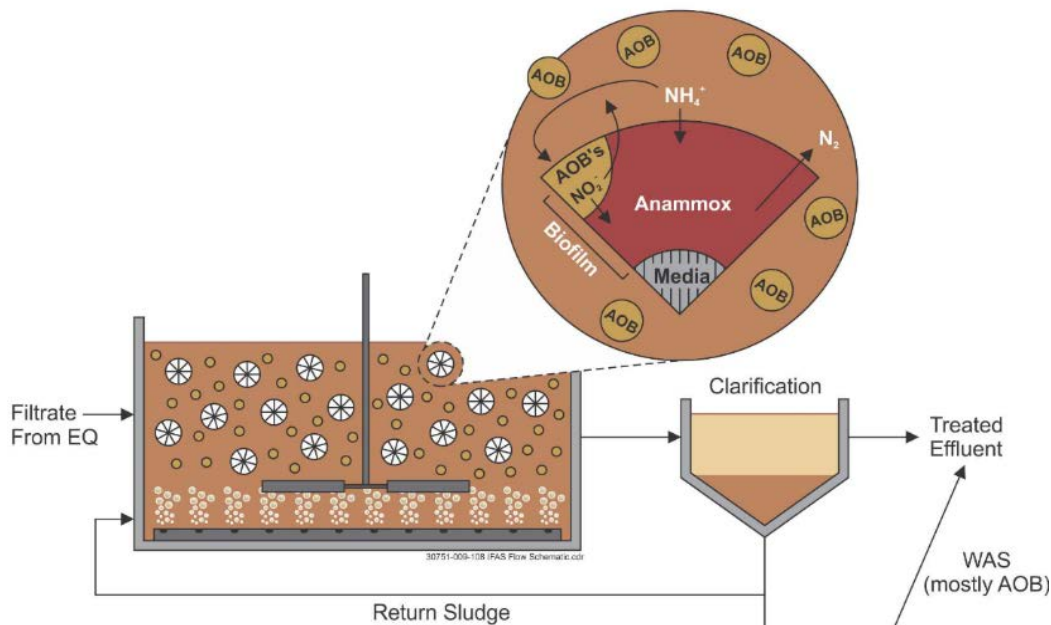


Figure 9. Process Schematic of Kruger ANITA™ Mox IFAS Process.

The ANITA™ Mox IFAS Process is a continuous flow through process that consists of a biological reactor followed by a secondary clarifier. Plastic media is installed in the biological reactor to allow a biological fixed film to stay in the reactor. The anammox bacteria colonize on the plastic media carriers. Media retention screens are installed along the exits to the reactor to retain the media in the reactor. Suspended growth in the biological reactor passes through the retention screens and settles in the downstream clarifier where it is then either returned to the biological reactor as RAS or wasted from the biological reactor as WAS. The biological reactors are equipped with mixers and diffusers. There are three different aeration control modes provide, but typically a combined pH / DO control mode is used to control operation of the blowers to cycling of nitrification by AOBs and ammonia oxidation and nitrite reduction by anammox.

The IFAS configuration is proposed over the MBBR configuration because a research study completed by Veolia illustrated that the IFAS configuration is preferable option to the MBBR configuration for treating high strength filtrates. Veolia completed a one-year demonstration study of the MBBR vs. IFAS deammonification configurations at their Malmo, Sweden Facility to compare performance of the two configurations. The IFAS system addresses oxygen diffusion

limitations for AOBs in treating high strength filtrates by maintaining the majority of the AOB in the MLSS suspension and allows the slower annamox bacteria to be retained in the system on the fixed media (Zhao et al, 2013).

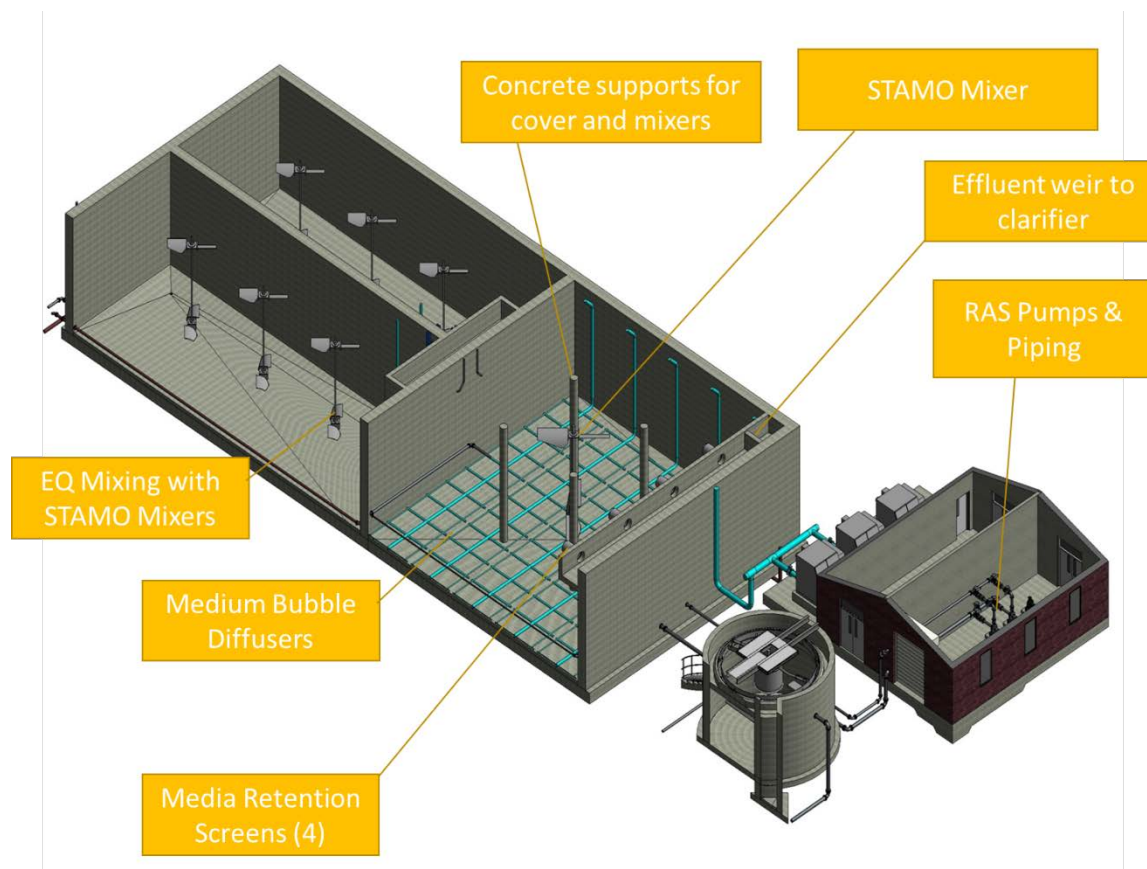


Figure 10. 3D Rendering of Proposed ANITA™Mox IFAS Layout for NRRRF.

Site Visit Summary of the ANITA™Mox IFAS installation at the Boras WWTP, Sweden

There are several ANITA™Mox MBBR installations in the US. At the time of this evaluation, Veolia had one ANITA™Mox system treating THP wastewater in Vjaxco, Sweden but it was designed in the MBBR configuration. However, the first ANITA™Mox installation using the IFAS configuration was under construction at a new wastewater treatment plant in Boras, Sweden. The system under construction at the Boras WWTP was visited as part of the LIFT SEE IT visits as a representative sidestream system for comparison to the proposed ANITA™Mox IFAS system for NRRRF. The sidestream treatment process at Boras will treat high strength filtrate from anaerobic digestion process and leachate from a neighboring landfill. Veolia has two other ANITA™Mox IFAS configurations that are planned to be installed to treat THP+MAD filtrate, but these projects were not yet started.

Because the Boras WWTP was still under construction, the site visit also included meeting with Veolia's process engineers that were familiar with the IFAS vs MBBR demonstration study as well as the Vjaxco, Sweden MBBR installation that is currently treating THP+MAD filtrate.

The meeting was helpful for understanding process design and controls, benefits and considerations for the IFAS configuration, and process challenges experienced in different ANITA™Mox installations.

The Boras WWTP is designed to treat an average flow of 15.5 mgd and a peak flow of 36 mgd through the secondary treatment process. The plant is a greenfield construction.

Figure 11 shows several pictures from the site visit of the ANITA™Mox IFAS system at the Boras WWTP. The sidestream system is designed to treat an average flow of 1,400 m³/day (0.37 mgd) and a maximum flow of 2,232 m³/day (0.59 mgd). The design nitrogen load to the reactor is 838 kg/day (600 mg/L N), which is lower in comparison to THP systems. The filtrate will be diluted at a 1:1 ratio prior to treatment in the side stream reactor to reduce inhibitory impacts of the high strength filtrate. The system was sized for a design operating temperature of 30°C.

The ANITA™Mox IFAS construction was nearly complete at the time of the site visit but flow was not available to start-up the process. It is expected that the system will start-up in later 2018. Since there was no flow yet, the IFAS equipment was accessible for viewing during the site visits. The system does not include an equalization tank. The IFAS reactor includes three medium bubble air grids, a single dual-impeller Stamo mixer with baffles, four air lifts for foam, and two media retention screens with air spargers. The IFAS media will be added during start-up. The system will be started up in an MBBR configuration and then switched over to an IFAS operation. A separate small circular clarifier will be used to settle the floc and return as RAS to the biological reactor.

On-line pH, DO, nitrite / nitrate, and ammonia probes will be installed in the reactor for on-line monitoring and control. The primary control system will be pH based. The pH control band is approximately 0.2 pH units typically. During start-up, a much broader pH setting range would be used (pH 6.8 – 7.6). The DO set point in an IFAS configuration is much lower in comparison to the MBBR configuration (0.2 – 0.5 mg/L vs. 0.5 – 1.5 mg/L).

Key take-aways from this site visit include the following:

- The IFAS version of the ANITA™Mox™ system looks very similar to the MBBR configuration, apart from the added clarifier and RAS / WAS pumping.
- The IFAS system is more complex to operate, but provides some additional process controls relative to an MBBR system, such as ability to maintain an SRT for suspended growth and allowing operation at a lower operating dissolved oxygen concentration.
- It is very important to effectively manage filtrate quality going to the deammonification process. High loads (i.e., COD, TSS) have negatively process performance in other ANITA™Mox MBBR installations.



Figure 11. ANITA™Mox IFAS system at the Boras WWTP.

From left to right top to bottom: (1) IFAS Reactor and clarifier; (2) IFAS clarifier; (3) Medium bubble diffuser in reactors; (4) Media retention screens in reactor; (5) Stamo mixer with foam air lifts in background along wall.

Site Visit of Ovivo-Paques AnammoPAQ™ at Olburgen WWTP, Netherlands

The AnammoPAQ™ process is a relatively new side stream short-cut nitrogen removal treatment process in the United States, but it has many overseas installations. It was not one of the side stream processes recommended during the Preliminary Engineering Phase for the City's Bioenergy Recovery Project. However, there was an installation located in Olburgen, NL, that could be viewed following the site visit at Amersfoort, NL, so this site visit was added to the original LIFT SEE IT scholarship itinerary to assist with determining if this is another side stream short-cut nitrogen removal system that should be considered for the Bioenergy Recovery Project. Pictures were not allowed to be taken of the treatment process during this site visit.

The AnammoPAQ™ is a completely granular system that operates as a single pass operation. The annamox and ammonia oxidizing bacteria (AOB) co-exist on the granules with the AOBs located at the outer part of the granules and the annamox located within the inner portion of the

granules. The granules, typically 1 - 5 mm in diameter, are much larger in size in comparison to the granules observed in the DEMON® process.

The Olburgen WWTP includes a municipal treatment facility and a separate industrial / side stream treatment facility that is privately operated. The industrial / side stream treatment facility receives potato processing waste which is pretreated in an upflow anaerobic sludge blanket (UASB) reactor. The UASB effluent and reject from the main municipal treatment facility is treated in a side stream treatment process. The sidestream treatment process includes a Phospaq™ reactor which achieves phosphorus recovery via struvite precipitation through addition of magnesium oxide followed by an AnammoPAQ™ process for deammonification. This facility is Paques' second oldest annamox installation and has been in operation since 2006.

The system is designed to treat approximately 3,360 m³/day of flow (0.89 mgd) and 1,250 kg/day of TKN (~ 400 mg/L TKN). The system typically achieves between 92 - 95% NH₃-N removal. Effluent NO₃-N is typically 32 mg/L (5 – 10% of NH₃-N removed). The original design NH₃-N loading rate is 2 kg/m³-day. Actual loading rates fluctuate between 1.2 and 2.5 kg/m³-day. The ammonia loading rates are significantly higher than the other two deammonification systems visits. However, it is noted that the Phosphaq™ reactor significantly reduces loads, particularly organic loads to the AnammoPAQ. The Phosphaq™ reactor was noted to achieve approximately 50% soluble COD and 5 to 10% NH₃-N reduction.

The system included a small “balance” tank (< 1-2 hour) upstream of the side stream process. The entire AnammoPAQ™ process occurs within a single, aerated rectangular tank. The blowers and operating DO in the reactor is controlled through a site-specific algorithm using a combination of NH₃-N, NO₂-N, pH, and DO sensors. A proprietary separation device is located within the reactor. The density of the granules are such that the majority of the granules are retained in reactor while suspended solids and non-granulated bacteria are washed out of the system through the overflow weir of the separation device. Excess granules are occasionally wasted or “sluiced” from the reactor to maintain the granule inventory.

Key take-aways from this site visit include the following:

- The AnammoPAQ™ is a relatively simple system (less equipment, no moving parts, all granules, single pass system).
- It was unclear how the process is controlled (how are granules formed/maintained), but the observed granules were numerous and large in size.
- The AnammoPAQ™ control system is set up differently for each application (no standardized control system).
- Phosphorus pretreatment achieves significant sCOD reduction, which likely plays into the ability for the system to achieve higher NH₃-N loading rates.

Following the site visit, the AnammoPAQ™ process was further evaluated and considered but ultimately was not carried forward as a recommended sidestream option for the NRRRF. One of the primary reasons for this decision was the need to implement a phosphorus pretreatment step as part of the initial phase of the Bioenergy Recovery Project, which as explained previously, was not recommended to be included as part of the initial Bioenergy Recovery Project.

EVALUATION OF PROPOSED SIDESTREAM PROCESSES FOR NRRRF

Following completion of the site visits, a detailed evaluation was completed at the 60-percent design phase to compare the proposed deammonification systems proposed for NRRRF. Both economic and non-economic criteria were utilized to evaluate the proposed systems. Findings and take-aways from the site visits were used to help to establish some of the non-economic criteria used in the evaluation. Overall, findings from the site visits and design evaluation illustrated that both of the proposed deammonification systems are viable processes for treating high strength filtrates. The net present worth for the two systems were similar, so non-cost criteria were important in assisting with identifying a preferred system. In addition, a key lesson learned from the site visits is that effective management of filtrate quality is critical for successful operation of the deammonification process. Based on this finding, flexibility will be incorporated in the design to assist with filtrate management, including the potential to utilize the equalization basin for pretreating filtrate, if required.

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