WRF 4973 Fact Sheet: ID 1620

Strategy: Reject Water Management

Sidestream Ammonia/TN Treatment and Control

Granular Anammox Organisms in a Reject Water Deammonification Process.
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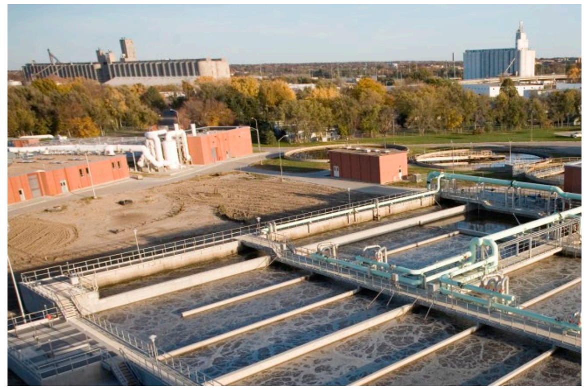

Pre-nitrification Zone (top zone) with Return RAS and to Nitrify Reject Water to BNR Basin.
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The unique composition of dewatering reject water (high concentrations, warm temperatures, and low alkalinity) creates unique treatment challenges and opportunities. Nitrification with conventional biological treatment does require alkalinity to achieve complete nitrification; partial nitrification may be acceptable for a reject water that is returned to the water resource recovery facility (WRRF). The nitrate and nitrite produced in the reject water nitrification process can be used beneficially for denitrification and odor control in the WRRF. Conventional sidestream nitrification or nitrogen (N) removal can reduce the mainstream minimum aerobic solids retention time (SRT) through bioaugmentation that is seeding the process with nitrifiers grown in the sidestream.

The deammonification process can remove nitrogen via partial conversion of ammonia (NH_3) to nitrite and simultaneously converting most of the remaining ammonia to N gas while using the oxygen in nitrite as an electron donor. Deammonification has proved effective and reliable to remove nitrogen from dewatering reject water. This process is most attractive when either carbon or alkalinity supplementation is required for N removal in the mainstream.

Another option to reduce the recycle NH_3 and N load is post-aerobic digestion where the anaerobically digested sludge is transferred into an aerobic digester. There, the residual ammonia can be nitrified. N removal can be achieved by controlling the dissolved oxygen (DO) in the digester to achieve simultaneous nitrification and denitrification (SND) through shortcut N removal, conventional N removal, or deammonification.

Ammonia in reject water from anaerobic digestion dewatering could be nitrified in a return activated sludge (RAS) nitrification zone within the mainstream activated sludge system. This approach is referred to as pre-nitrification, bioaugmentation regeneration (BAR), and other non-proprietary names.

Fact Sheet Application Checklist

R = fact sheet relevant to item
PR = fact sheet is potentially relevant to item depending on application, existing conditions, etc.

Category		
		Intensification
	PR	Chemical addition
	R	Carbon management
		I&C strategies
	R	Sidestream mgmt.
	PR	Energy savings
	PR	Chemical savings
	R	Operational savings
	R	Other means of NutRem

Nutrient		
	R	Ammonia
	R	NOx
	R	TN
		Ortho-P
		TP

Scale (design flow)		
	PR	Small (<1 mgd)
	R	Medium (1–10 mgd)
	R	Large (>10 mgd)

Goal		
	R	Improve reliability
	R	Reduce nutrient
	R	Reduce O&M cost

Group		
	R	Optimize existing CNR
	R	Optimize existing TNR
	R	NutRem in secondary plant

Process		
		Small
		Pond
	R	Fixed film (secondary)
	R	Conventional act. sludge (CAS)
	R	Nitrifying act. sludge (NAS)
	R	Conventional NutRem (CNR)
	R	Tertiary NutRem (TNR)
		Other

CAS = conventional activated sludge (BOD only)
NAS = nitrifying activated sludge (without denitrification)
CNR = conventional nutrient removal no chemical/no filter, etc.
TNR = tertiary nutrient removal with chemical, filter, etc.

Technology Summary Evaluation

Footprint	1	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	5	Technology ranking based (LIFT) see below*
Energy use	1–3	Scale 1–5: 1 = use much less; 3 = use similar to conventional; 5 = use much more
O&M cost	1–3	Scale 1–5: 1 = cost much less; 3 = cost similar to conventional; 5 = cost much more
Material/consumables	1–3	Scale 1–3: minimal = 1; some = 2; significant = 3 (e.g., UV lamps/membranes)
Chemical use	1–2	Scale 1–3: minimal/none = 1; some = 2; significant = 3 (e.g., chemical process)

* Technology ranking based on Leaders Innovation Forum for Technology (LIFT) Water Research Foundation (WRF) Technology Development Level (TDL) definitions:
1 = bench research and development
2 = small-scale pilot
3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional

Descriptions/Evaluation

Strategy	Reject water (sidestream) treatment for nitrogen
Description	This strategy is removal of ammonium-nitrogen (NH_4-N) in reject water streams that carry a high NH_3 concentration (> 200 milligrams per liter [mg/L]). The most common reject water source is from dewatering of anaerobically digested sludge. Other possible sources are digester decant and sludge storage lagoons. N removal technologies include conventional nitrification/denitrification activated sludge, nitrititation and denitritation, as well as deammonification. Reject water with high NH_3 concentration can be nitrified by mixing it with RAS in an aeration basin (several non-proprietary process arrangements exist, called pre-nitrification, BAR, centrate and RAS re-aeration basin [CaRRB], etc.). See description of technologies in Additional Information section below.
Application	WRRFs with anaerobic digesters and effluent NH_3 or total nitrogen (TN) limits. Secondary (biochemical oxygen demand [BOD]) WRRFs can reduce effluent N typically by 10%–30% by removing the nitrogen from the sidestream. In WRRFs that import organic waste or biosolids from other WRRFs, the effluent NH_3 reduction could be much higher. Sidestream treatment can achieve over 80% removal—higher TN removal, exceeding 90% in some cases.
Constituents removed	Ammonia and TN
Development status*	LIFT TDLs 2–5 Sidestream treatment technologies such as conventional nitrification/denitrification and deammonification are well established. New processes and innovations continue to emerge (i.e., membrane aerated bioreactor [MABR] for reject water treatment). N recovery processes such as ion exchange, stripping, etc. are emerging and are at LIFT TDLs 1–2.
O&M considerations	Most sidestream treatment technologies require online instrumentation for process control. These instruments must be maintained and calibrated on a regular basis. Sidestream treatment usually does not have redundant units. Shutdowns have to be planned accordingly. Once sidestream treatment is in place the mainstream process acclimates to the load changes. Sudden load changes could impact the mainstream performance and effluent quality. Sidestream flow equalization is highly recommended for all sidestream treatment processes
Benefits	Potential benefits may include: • Reduced BNR influent N load • Reduced energy consumption • Reduced chemical use (alkalinity, carbon) • Stable mainstream process • Increased mainstream capacity • Nitrate-rich water (from nitrified reject water) can be directed to the WRRF influent for odor control
Limitations	Dewatering reject from anaerobic digestion is warm but lacks sufficient alkalinity for complete nitrification and contains very little carbon for denitrification. Conventional nitrification will require alkalinity addition to completely nitrify the reject stream. Conventional denitrification would require a carbon source to be added under anoxic conditions. Some sidestream treatment technologies require a certain size WRRF to be economically viable. Sidestream treatment technologies require capital investment. Their operational savings and process improvements should be evaluated to determine the overall benefits.

Design considerations	Sidestream treatment is often implemented by using existing tankage that is no longer needed. General design considerations include: • Deammonification sidestream treatment technologies require upstream flow equalization. Conventional nitrification-denitrification (NDN) could be upsized to accommodate slug loadings. • Provide operators with the tools to handle shutdowns of sidestream treatment to limit shock loads on the mainstream process. • Conventional N removal will require aeration basins and anoxic zones (if denitrification is included) or cyclical aeration. Chemical (alkalinity for nitrification and carbon source for denitrification) would be needed.
Potential fatal flaws	Limitations of reject water treatment depends on the technology/process under consideration: • Intermittent flow and loads • Temperature: too hot for conventional nitrification; too cold for deammonification • Poor alkalinity: can be overcome with chemical addition
Footprint requirements	Reject water biological NH_3 removal processes require bioreactors. The space requirement is modest; it may require a footprint that is roughly 5%–20% of the digester complex.
Residuals	Conventional nitrification, NDN, or deammonification sidestream treatment may have nitrite and nitrate as well as biomass. The biomass can be used to seed the mainstream process (bioaugmentation). The nitrate can be redirected to denitrify in the mainstream biological nutrient removal (BNR) process or to the influent to reduce sulfide odors.
Cost considerations	New treatment basins are required to manage or treat sidestream. Unused or abandoned process tanks can often be used for sidestream treatment. Deammonification typically uses some proprietary process.
Past experience	DC Water Blue Plains Water Reclamation Facility (District of Columbia): deammonification (DEMON) Hampton Roads Sanitation District (HRSD) James River Water Reclamation Facility (Virginia): deammonification (Anitamox) Metro Denver R. Hite Water Reclamation Facility (Colorado): deammonification (Anitamox) Fond du Lac Water Reclamation Facility (Wisconsin): deammonification (AnamoPaque) Lincoln, Nebraska: RAS pre-nitrification Spokane County Water Reclamation Facility (Washington): post-aerobic digestion
Publications	Bailey, E., K. Bilyk, D. Wankmuller, and A. Hanna. 2018. “Evaluation of Sidestream Deammonification Process Enhancements for Treating High Strength Filtrate at the City of Raleigh’s Neuse River Resource Recovery Facility.” WEF’s 91st Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC. Bilyk, K., W. Khunjar, and R. Taylor, P. Pitt, and D. Wankmuller. 2012. “Economic Evaluation of Alternatives for Sidestream Nutrient Removal and Recovery.” WEF’s 85th Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC. Bowden, G., R. Tsuchihashi, and H.D. Stensel. 2015. “Technologies for Sidestream Nitrogen Removal.” WERF Nutrient Removal Challenge Report NUTR1R06w. Johnson, B.R, A. Mennetti, and S. Murthy. 2011. “Impacts of Post Aerobic Digestion on the Design of Nutrient Removal Facilities.” Nutrient Recovery and Management Conference. Miami, Florida: WEF/IWA. Mentzer, C., M. Drinkwater, and K. Pagilla. 2021. “Investigation of direct waste-activated sludge dewatering benefits and costs in a water resource recovery facility.” Water Environment Research. 1–13 DOI: 10.1002/wer.1651 WRF (The Water Research Foundation). 2019. “Deammonification from the Nutrient Removal Challenge.” https://www.waterrf.org/sites/default/files/file/2021-07/Deammonification.pdf.
Related fact sheets	1301: Use of Chemicals to Improve Nutrient Removal

	1601: Reject Water (Sidestream) Management Overview 1610: Sidestream Return Flow Management 1820: Chemical Testing and Selection 1901: Optimize Operation and Maintenance
Date updated	9/10/2022
Contributors	Mario Benisch, Adam Hendricks, JB Neethling, Anand Patel

Note

* Technology ranking based on LIFT WRF TDL definitions:
1 = bench research and development
2 = small-scale pilot
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4 = pioneer stage (production and implementation)
5 = conventional (https://www.waterrf.org/sites/default/files/file/2019-07/LIFT%20Scan%20Application-LIFT%20Link%2BHub_0.pdf: accessed September 2020)

Additional Information

The following tables and figures are included:

- Table 1 contains a list and short description of common sidestream reject water treatment processes.
- Figure 1 to Figure 4 contain simplified process diagrams of the commonly used processes:
  - Figure 1. Various Sidestream Activated Sludge Options: (1) Nitrification Only, (2) Nitrification and Denitrification, and (3) Sequencing Batch Reactor for Nitrification and Denitrification: various options for the activated sludge
  - Figure 2. Sidestream MMBR Process Schematic (nitrification and nitrification/denitrification)
  - Figure 3. Reject Water Deammonification Process Schematic
  - Figure 4. Example Schematic of a Closed-Loop Ammonia Air Stripping Unit

Table 1. Sidestream Nitrogen Removal Processes.

Process	**Requirements**
Sidestream activated sludge	Requires alkalinity and carbon supplementation (for denitrifying processes) for maximum N removal
MBBR (Figure 2)	Requires alkalinity and carbon supplementation for maximum N removal
Deammonification (Figure 3)	Some pretreatment may be required. Examples of pretreatment are: • Flow equalization • Strainer, belt, or drum screen to remove debris • Chemical addition for trace nutrients Consult subject matter expert for specific requirements.
Stripping (Figure 4)	Requires pretreatment to prevent plugging of stripping tower

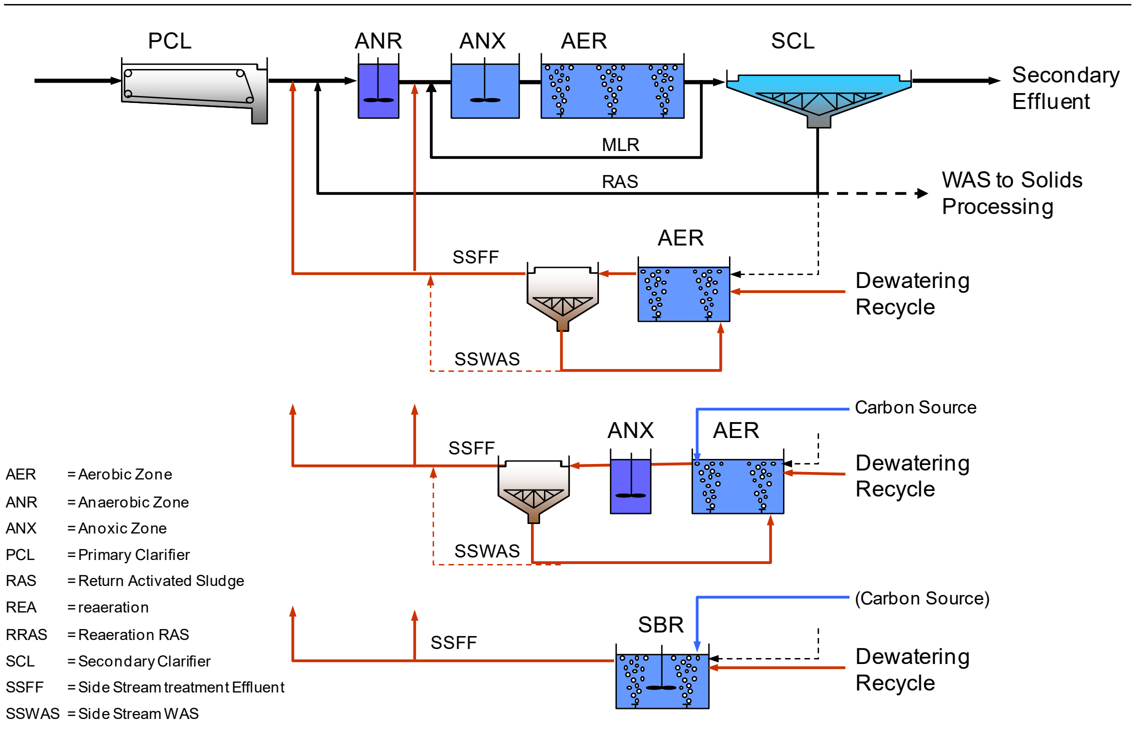

Figure 1. Various Sidestream Activated Sludge Options: (1) Nitrification Only, (2) Nitrification and Denitrification, and (3) Sequencing Batch Reactor for Nitrification and Denitrification.
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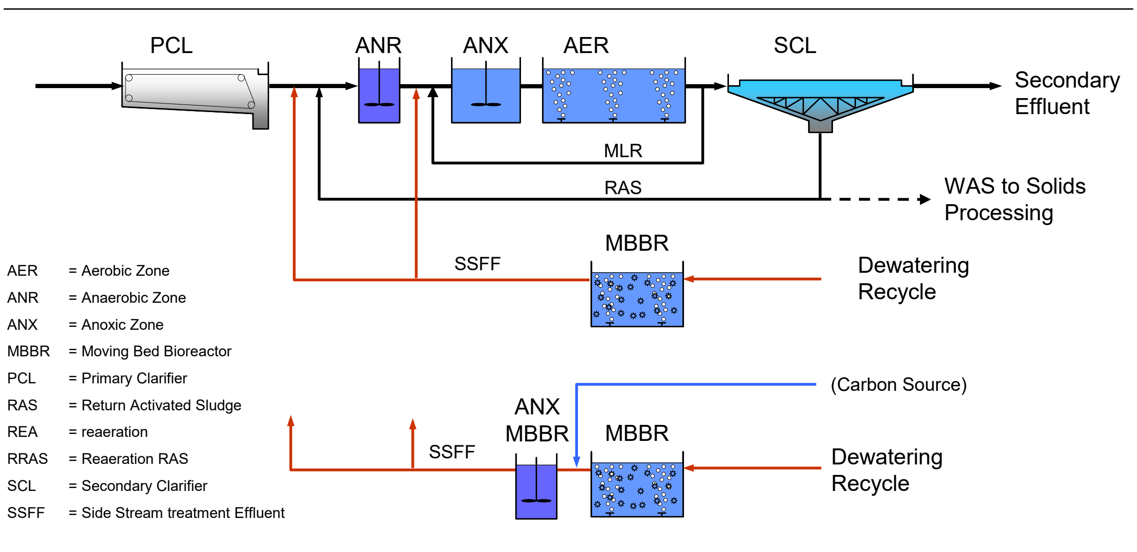

Figure 2. Sidestream MMBR Process Schematic (nitrification and nitrification/denitrification).
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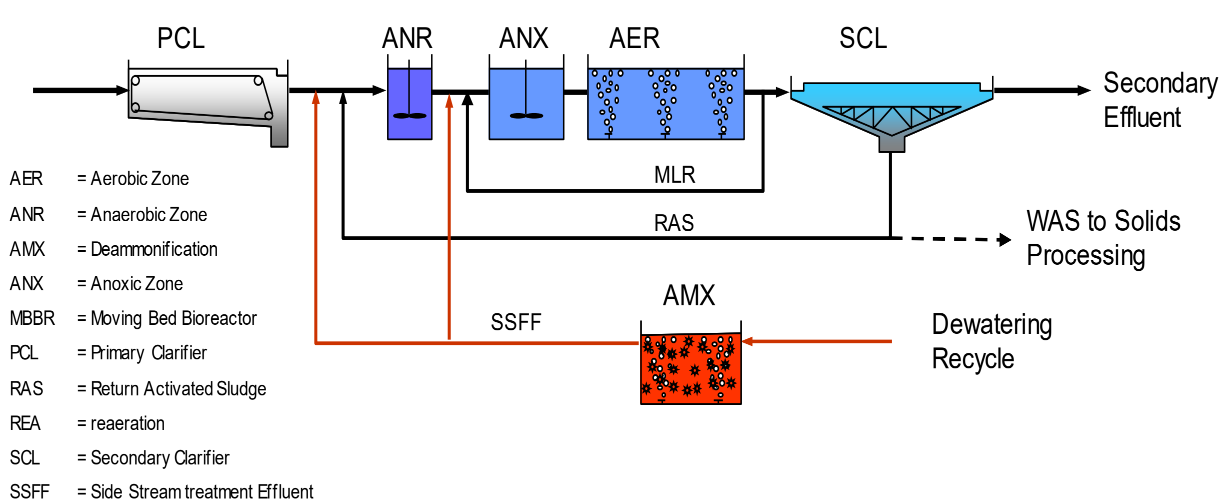

Figure 3. Reject Water Deammonification Process Schematic.
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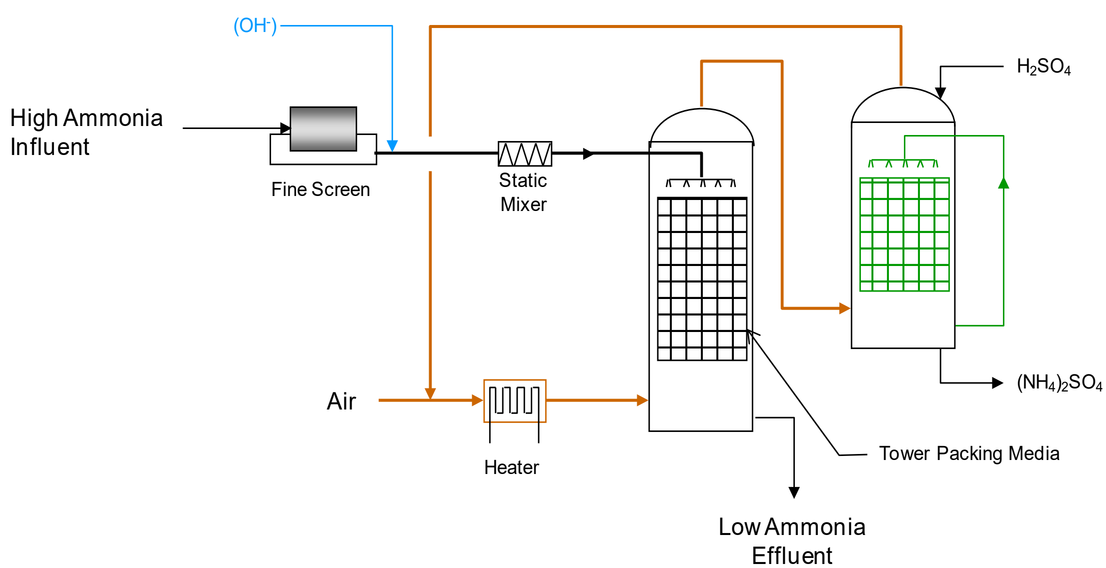

Figure 4. Example Schematic of a Closed-Loop Ammonia Air Stripping Unit.
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Table 2. Example of Deammonification Processes.
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	Schwing - NuResys	Multiform Harvest	Ovivo - Phospaqu	CNP AirPrex	CNP CalPrex	Ostara Pearl 2000
						
Number of Installations					none	
US Installations	none	≥ 2	none	none	pilot	
Capital Cost	high	high	low	moderate	high	high
Complexity	moderate	high	low	moderate	high	high
Recovery Rate	30% – 40%	30% – 40%	30% – 40%	10% - 15%	40% - 50%	30% – 40%
Product Quality	medium	medium	low	low	high	very high
						
Product Value	low	low	low	low	unknown	high
Take off agreement	no	yes	no	no	no	yes
O&M Requirements	medium	high	low	low	high	high

Abbreviations

BAR	Bioaugmentation regeneration (process)
BNR	Biological nutrient removal
BOD	Biochemical oxygen demand
CaRRB	Centrate and RAS re-aeration basin
CAS	Conventional activated sludge: BOD removal only
CNR	Conventional nutrient removal
DO	Dissolved oxygen
HRSD	Hampton Roads Sanitation District
I&C	Instrumentation and controls
L	Liter(s)
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
MABR	Membrane aerated bioreactor
mg	Milligram(s)
mgd	Million gallons per day
N	Nitrogen
NAS	Nitrifying activated sludge
NDN	Nitrification-denitrification
NH_3	Ammonia
NH_4-N	Ammonium-nitrogen
NO_x	Oxidized nitrogen (nitrate + nitrite)
NutRem	Nutrient removal
O&M	Operations and maintenance
RAS	Return activated sludge
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
SRT	Solids retention time
TDL	Technology Development Level
TN	Total nitrogen
TNR	Tertiary nutrient removal
TP	Total phosphorus
UV	Ultraviolet
VFA	Volatile fatty acids
WRF	The Water Research Foundation
WRRF	Water resource recovery facility