WRF 4973 Fact Sheet: ID 1450

Strategy: Carbon Management

DO Control to Increase Denitrification

Simultaneous Nitrification and Denitrification Can Achieve TN Reduction.
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Unintended Aeration by Liquid from Aerobic Zone Returning into Unaerated Anoxic Zone.
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This strategy is based on balancing two objectives: (1) maintain just sufficient dissolved oxygen (DO) to provide stable operation and optimize denitrification and (2) avoid biochemical oxygen demand (BOD) oxidation from unintentionally introducing DO into anaerobic and anoxic zones.

Adjusting the operating DO can improve efficiency and reduce blower power demand by increasing the oxygen transfer efficiency. At the same time, a lower DO has proved to be more efficient to achieve simultaneous nitrification and denitrification (SND). Ammonia-based aeration control (ABAC) is another strategy that not only reduces energy demand but can also improve denitrification and reduce the total nitrogen (N) in the effluent. See Fact Sheets 1501, 1510, and 1560 for more information about instrumentation and controls (I&C) strategies.

The biological nutrient removal (BNR) process configuration and process design can be optimized to maximize the use of available carbon for denitrification and enhanced biological phosphorus removal (EBPR) by limiting the direct oxidation of chemical oxygen demand (COD) with DO. The efficiency of the anoxic zone (for denitrification) and anaerobic zone (for EBPR) is reduced when DO in the feed streams is high.

See the Additional Information section below for some examples of unintended aeration introducing DO into an unaerated zone.

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
		Chemical addition
	R	Carbon management
	R	I&C strategies
		Sidestream mgmt.
	R	Energy savings
	R	Chemical savings
	R	Operational savings
		Other means of NutRem
Nutrient		Ammonia
	R	NOx
		TN
		Ortho-P
		TP
Scale (Design flow)	R	Small (<1 mgd)
	R	Medium (1–10 mgd)
	R	Large (>10 mgd)

Goal		Improve reliability
	R	Reduce nutrient
	R	Reduce O&M cost
Group	R	Optimize existing CNR
	R	Optimize existing TNR
		NutRem in secondary plant
Process		Small
		Pond
		Fixed film (secondary)
		Conventional act. sludge (CAS)
		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*	4–5	Technology ranking based (LIFT) see below*
Energy use	2	Scale 1–5: 1 = use much less; 3 = use similar to conventional; 5 = use much more
O&M cost	2	Scale 1–5: 1 = cost much less; 3 = cost similar to conventional; 5 = cost much more
Material/consumables	1	Scale 1–3: minimal = 1; some = 2; significant = 3 (e.g., UV lamps/membranes)
Chemical use	1	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	Blower and DO control to reduce operating cost and/or improve nitrogen removal
Description	This strategy is based on balancing two objectives: (1) reducing energy and carbon use by reducing DO to provide stable operation and at the same time optimize denitrification and (2) avoiding unintentional aeration of unaerated zones to maximize carbon use for denitrification and EBPR.
Application	Any system with diffused aeration-based oxygen supply can benefit from DO control by better matching demand and supply, maintaining lower DO set points to increase transfer efficiency, decreasing oxygen recycle from aerobic to anoxic zones, and/or reducing the oxygen demand by promoting shortcut N removal via anaerobic ammonia oxidation (anammox).
Constituents removed	Nitrate, nitrite, and phosphorus
Development status*	LIFT TDLs 4–5
O&M considerations	Some strategies such as low DO operation require no special equipment. Additional I&C is needed for more sophisticated aeration and nutrient control of DO and N-species (e.g., ABAC or ammonia vs. NOx [AvN]). Low-DO operation may require mechanical mixing in aerated zones as the air demand can drop below the minimum required for mixing.
Benefits	Denitrification improvement: reduce energy use; lower effluent TN EBPR improvement: improves process stability, lower effluent TP
Limitations	Some strategies will require advanced I&C. Some vendor-supplied systems are available. Limiting DO entrainment control strategies depends on the local situation. Unintended DO recycles can sometimes be managed with baffles and flow routing. Deoxygenation zones can be used to limit DO return with RAS and internal recycle streams.
Design considerations	Advanced I&C requires adjustments to obtain stable operation. Aeration control valves need to be sized to optimal operation under large operation range. Some suppliers can provide control packages for ABAC and other controls.
Potential fatal flaws	None
Footprint requirements	Small. Mainly space for control systems.
Residuals	None
Cost considerations	Low for low DO operation; lower cost can be expected
Past experience	Gale Road Environmental Control Facility, Ohio Glendale Water Reclamation Plant, California Henrico County Water Reclamation Facility, Virginia North Durham Water Reclamation Facility, North Carolina
Publications	Brischke, K., W. Anderson, G. Budzynski, M. Alvis, I. Myers, and L. Rieger. 2018. “Taking Ammonia Based Aeration Control to the Next Level: Real World Experience and Lessons Learned.” WEF’s 91st Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC. Klaus, S. and C.B. Bott. 2020. “Comparison of Sensor Driven Aeration Control Strategies for Improved Understanding of Simultaneous Nitrification/Denitrification.” Water Environment Research. 92(5) DOI:10.1002/wer.1359. Klaus, S., M. Kinyua, K. Chandran, B. Wett, S. Murthy, and C. Bott. 2016. “Comparison of ABAC and AVN aeration control strategies for efficient nitrogen removal.” WEF’s 89th Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC.

	Regmi, P., K. Chandran, and J. Jimenez. 2017. "Full-Scale Evaluation of Carbon and Energy Efficient Combined Nitrogen and Phosphorus Removal with Advanced Aeration and Settleability Control." WEF's 90th Annual Technical Exhibition and Conference. Chicago, Illinois: WEFTEC. Smith, R., J. VanDommelen, and J. Holton. 2018. "Optimization of Aeration Control for Nitrogen Removal in an Oxidation Ditch Using Online Ammonium and Nitrate Sensors." WEF's 91st Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC. Wankmuller, D., K. Bilyk, P. Pitt, D. Fredericks, R. Latimer, J. Grandstaff, P. Greene, J. Irby, and J. Sparks. 2017. "Saving Carbon with SND Using Ammonia Based Aeration Control." Nutrient Symposium. Fort Lauderdale Florida: WEF. Wood, P. and N. Nakashima. 2017. "Full-scale Implementation of Simultaneous Nitrification/Denitrification in an AO Process Configuration with Simple Aeration Control." Nutrient Symposium. Fort Lauderdale Florida: WEF.
Related fact sheets	1310: External Carbon Sources 1401: Optimize Carbon Use for Nutrient Removal 1410: Fermentation 1501: Overview of Instrumentation and Control Strategies 1510: Improve Control, Stability, and Efficiency 1560: Sensors and Instrumentation
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Note

* Technology ranking based on LIFT WRF TDL definitions:
1 = bench research and development
2 = small-scale pilot
3 = full-scale pilot (demonstration)
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

Unintentional aeration of anoxic and anaerobic zones comes in many forms:

- Creating a "waterfall" across a baffle between zones in the BNR basin. Influent into a zone dropping over a weir at a flow split structure or baffle wall.
- Backflow from aerated to unaerated zone.
- RAS carrying nitrate and DO into an anaerobic zone will provide denitrification but reduces the carbon available for EBPR and inhibits phosphorus (P) release by conventional polyphosphate-accumulating organisms (PAOs).
- Internal mixed liquor recycle (IMLR) from aerobic to anoxic returning DO from the aerobic zone.
- Excessive mixing with oversized mixers.
- Coarse-bubble aeration used for mixing anoxic or anaerobic zones.
  Examples of these forms of unintentional aeration can be found in Case Study 6010: Improve Process Hydraulics.

Abbreviations

ABAC	Ammonia-based aeration control
AvN	Ammonia vs. NO_X (aeration control)
BNR	Biological nutrient removal
BOD	Biochemical oxygen demand
CAS	Conventional activated sludge: BOD removal only
CNR	Conventional nutrient removal
COD	Chemical oxygen demand
DO	Dissolved oxygen
EBPR	Enhanced biological phosphorus removal
I&C	Instrumentation and controls
IMLR	Internal mixed liquor recycle
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
mgd	Million gallons per day
N	Nitrogen
NAS	Nitrifying activated sludge
NO_x	Oxidized nitrogen (nitrate + nitrite)
NutRem	Nutrient removal
O&M	Operations and maintenance
P	Phosphorus
PAO	Polyphosphate-accumulating organism
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
SND	Simultaneous nitrification and denitrification
TDL	Technology Development Level
TN	Total nitrogen
TNR	Tertiary nutrient removal
TP	Total phosphorus
UV	Ultraviolet
WRF	The Water Research Foundation
WWTP	Wastewater treatment plant