WRF 4973 Fact Sheet: ID 1801

Strategy: Chemical Savings

Overview of Chemical-Saving Strategies

Simultaneous Nitrification and Denitrification Can Achieve TN Reduction.
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Ammonia-Based Aeration Control.
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Chemical use can be a source of significant operational costs at nutrient removal water resource recovery facilities (WRRFs) for nitrogen (N) and/or phosphorus (P) removal. In addition to the costs associated with purchasing, handling, and adding chemicals to a WRRF process, most chemicals produce residuals (increase biomass production or chemical sludge production) that increase sludge management and disposal costs.

Chemicals are added to nutrient removal WRRFs for several reasons, including to (1) provide direct chemical precipitation of nutrients such as phosphorus, (2) supplement organics for biological denitrification or enhanced biological phosphorus removal (EBPR), (3) maintain the optimal environment for nutrient removal by, for example, adding alkalinity supplements to adjust/maintain pH, (4) maintain optimal treatment process performance, and/or (5) optimize solids capture. An example of chemicals commonly added to optimize solids capture is the addition of coagulant and polymer to secondary clarifiers, filters, or the dewatering process to improve the removal/capture of solids and increase cake production and quality.

This fact sheet series focuses on ways to optimize chemical use in general. Topics include identifying and selecting chemicals, application of chemicals, and strategies to reduce chemical usage. See the Additional Information section below for details about these approaches and the related fact sheets for more details.

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

Nutrient		Ammonia
	R	NOx
	R	TN
	R	Ortho-P
	R	TP

Scale (design flow)	R	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	PR	Optimize existing CNR
	R	Optimize existing TNR
	PR	NutRem in secondary plant

Process		Small
		Pond
	PR	Fixed film (secondary)
	PR	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	3	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	5	Technology ranking based (LIFT) see below*
Energy use	1	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	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	Reduce chemical usage to reduce operating cost
Description	Reduce cost for chemical addition through price reduction/competition, selecting the most effective chemical, automated dosing, and applying chemicals under optimal conditions
Application	Chemicals are added for several purposes: • Adding supplemental carbon for denitrification and/or biological P removal • Primary mechanism for P removal through chemical precipitation • Eliminate nuisance precipitation of struvite and other precipitants • Improve performance for solids separation processes • Add a second barrier or backup for interim use to maintain reliable performance • pH control
Constituents removed	Total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), nuisance precipitants
Development status*	LIFT TDL 5
O&M considerations	On top of the cost of the chemical(s) added, chemical addition requires operations and maintenance (O&M) activity for managing chemical deliveries, chemical dose, chemical storage, and instrumentation maintenance.
Benefits	Improve efficiency of treatment process performance and reliability. Could also be a primary unit process to meet permit requirements.
Limitations	Availability of chemicals and pricing is volatile at times. Chemical deliveries may not be neighbor-friendly.
Design considerations	Most chemicals are hazardous and require additional staff training.
Potential fatal flaws	None
Footprint requirements	Modest. Location is also important to keep distribution/dose delivery piping short.
Residuals	Some chemicals produce chemical sludge, some produce biomass, and some produce no residuals.
Cost considerations	Chemicals are typically competitively bid.
Past experience	City of Las Vegas, Nevada: ferric (odor control), alum (effluent P removal), alkalinity (process modified to denitrify and eliminated need for alkalinity addition). Clean Water Services, Portland, Oregon: alum for P removal converted to biological P removal. Alum for tertiary P removal (effluent permit 0.07 milligram per liter [mg/L] in 1990s, now 0.1 mg/L). Cities of Lacey, Olympia, and Tumwater and Thurston County (LOTT) Clean Water Alliance, Olympia, Washington: carbon dosing for N removal, nitrate analyzer was added to monitor chemical dose, which resulted in significant chemical use reduction.
Publications	ASTM. 2019. “ASTM D2035-19: Standard Practice for Coagulation-Flocculation Jar Test of Water.” American Society of Testing and Materials. AWWA. 2014. “Chapter 20: Jar Tests” In *Manual of Water Supply Practices M12: Simplified Procedures for Water Examination*. 171–178. 6th ed. Benisch, M., D. Clark, and J.B. Neethling. 2013. “Tertiary MBR for Nitrification and Low Level Phosphorus Removal.” Nutrient Removal and Recovery Conference. Vancouver, British Columbia: WEF/IWA. Bill, K., M. Benisch, H. Falconer, M-L. Pellegrin, H.S. Fredrickson, C. Fisher, B. Carleton, JB Neethling, and D. Clark. 2012. “Achieving ultralow phosphorus Concentrations Coeur d’Alene, Idaho, tests a tertiary membrane filter demonstration pilot system.” WWW.WEF.ORG/MAGAZINE l AUGUST 2012 l WE&T.

	Gu, A.Z. and A. Onnis-Hayden. 2010. “Protocol to Evaluate Alternative External Carbon Sources for Denitrification at Full-Scale Wastewater Treatment Plants.” WERF Nutrient Removal Challenge Report NUTR1R06b. Maher, C., J.B. Neethling, and K.R. Pagilla. 2014. “Solids Role in Tertiary Chemical Phosphorus Removal by Alum.” WERF Nutrient Removal Challenge Report NUTR1R06t. Rohrbacher, J., Bilyk, K., Bruton, T., Pitt, P., and Latimer, R. 2009. “Evaluation of Alternative Supplemental Carbon Sources at Four BNR Facilities.” WEF’s 82nd Annual Technical Exhibition and Conference. Orlando, Florida: WEFTEC 2009. Selock, K., C. Bott, and J.B. Neethling. 2008. “Achieving Limit of Technology for Effluent Total-Nitrogen and Effluent Total-Phosphorous at WSSC’s Parkway Wastewater Treatment Plant.” Presented in Workshop W101 at WEF’s 81st Annual Technical Exhibition and Conference. Chicago, Illinois: WEFTEC. Szabó, A., I. Takács, S. Murthy, G.T. Daigger, I. Licskó, and D.S. Smith. 2008. “The Significance of Design and Operational Variables in Chemical Phosphorus Removal.” Water Environment Research, 80(5), 407–416.
Related fact sheets	1301: Overview of Chemical Addition 1310: External Carbon Sources 1320: Chemical Phosphorus Removal 1820: Chemical Testing and Selection 1850: Reuse Chemical Sludge
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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

Strategies to reduce chemical cost can be grouped into two broad categories. The first group of strategies reduces the cost of the chemical supply (Table 1), while the second group improves the application efficiency of the chemicals (Table 2).

Table 1. Chemical Supply Source Strategies.

Strategy	Approach	Comment
Obtain competitive bids from chemical suppliers	Obtain the lowest cost for chemicals.	Include financial and reliability considerations in evaluation.
Evaluate alternative chemicals or proprietary chemical solutions	Compare the efficiency of various chemicals. Conduct jar tests (ASTM 2019) or biological denitrification evaluations to find the most cost-effective chemical.	New proprietary chemical solutions may have additional characteristics or chemical mixtures to enhance treatment. For example, polyaluminum chloride (PACl) preparations do not impact alkalinity.

Strategy	Approach	Comment
Consider industrial waste products	Some industrial waste streams (brewery, cola bottling, food processing, etc.) contain high concentrations of readily biodegradable organics that can be used as a carbon supplement. Waste from metal plating industry (pickle liquor) can supply ferric chloride.	Using industrial waste organics can be a win-win solution for the industry and the WRRF. WRRFs should consider the purity and stability of supply from industrial sources.

Table 2. Reduce Chemical Dosage Applied.

Strategy	Approach	Comment
Find optimal chemical dose	Conduct jar tests to evaluate chemical dose.	Jar test conditions should simulate application conditions.
Improve mixing and flocculation	Implement good mixing at the dose point to disperse added chemical.	Some applications require rapid dispersion only; other applications also require flocculation to improve particle removal in solids separation processes.
Use chemical sludge from water treatment	Waste sludge from aluminum- or iron-based water treatment has significant P removal capacity.	When released to the sewer aluminum and iron sludge will sequester orthophosphate (PO_4-P) through adsorption and complexation. Note that discharge of waste with activated carbon will remove soluble chemical oxygen demand (sCOD) through adsorption and therefore can be detrimental to biological nutrient removal (BNR).
Use instrumentation and controls (I&C) for online control chemical dose	Add online monitoring and control logic to pace chemical dose. Feed-forward and feedback controls strategies have been used for biological or chemical process applications.	Controls should be tuned to maintain stable operation.
Establish KPIs to track chemical dosage	Set KPIs based on past performance and challenge operations team to improve dosage while meeting permit requirements.	Comparison with similar WRRFs could be a helpful benchmark to guide KPIs.
Increase denitrification to recover alkalinity	Denitrification adds alkalinity to the biological process and can be a cost-effective way to reduce or eliminate alkalinity addition.	Denitrification will also reduce aeration requirements and improve settleability of biomass in the BNR process.
Reuse metal hydroxides in waste chemical sludge	Aluminum and iron addition produce hydrous metal oxide (HMO) precipitants. HMOs from filter backwash or HMOs from water treatment plants can be recycled to provide additional P removal.	Reusing HMOs can reduce the chemical dose and also provide a buffer to improve process reliability.

Abbreviations

BNR	Biological nutrient removal
BOD	Biochemical oxygen demand
CAS	Conventional activated sludge: BOD removal only
CNR	Conventional nutrient removal
EBPR	Enhanced biological phosphorus removal
HMO	Hydrous metal oxide
I&C	Instrumentation and controls
L	Liter(s)
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
LOTT	Cities of Lacey, Olympia, and Tumwater and Thurston County (Clean Water Alliance)
mg	Milligram(s)
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
PACl	Polyaluminum chloride
PO_4-P	Orthophosphate
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
sCOD	Soluble chemical oxygen demand
TDL	Technology Development Level
TN	Total nitrogen
TNR	Tertiary nutrient removal
TP	Total phosphorus
TSS	Total suspended solids
UV	Ultraviolet
WRF	The Water Research Foundation
WRRF	Water resource recovery facility