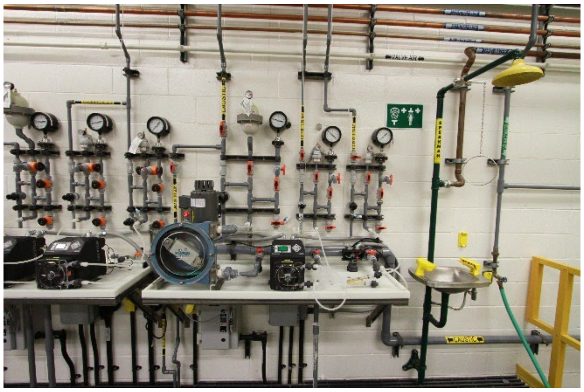
WRF 4973 Fact Sheet: ID 1301

Strategy: Chemical Addition

Use of Chemicals to Improve Nutrient Removal



Chemical Metering System.
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Ferric Injection Point.
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Chemicals can be used to improve both nitrogen (N) and phosphorus (P) removal to reduce effluent nutrients and to improve treatment reliability. Chemical treatment processes respond quickly to added chemicals and provide a way to optimize process performance and chemical costs. Chemical addition does have negative impacts such as increased residuals, increased operating cost, potentially hazardous chemical storage, and changing the chemical balance in the process (specifically alkalinity). Operators generally like the direct control and rapid feedback from chemical processes, but dislike handling the stock chemicals (most are dangerous and/or corrosive, and some are flammable). Generally, chemical addition is avoided when possible.

There are three major applications for chemicals:

- **Nitrogen removal:** Chemicals are also added to enhance N removal by providing carbon for denitrification or supplement alkalinity in nitrifying processes. Carbon is added to a biological nutrient removal (BNR) basin anoxic zone to enhance conventional nutrient removal (CNR) and tertiary nutrient removal (TNR) processes. The TNR process relies on chemical addition (carbon) for denitrification. Care is required not to add excess carbon because any remaining carbon will raise the effluent biochemical oxygen demand (BOD).
- **Phosphorus removal:** metal salts (alum and ferric) and other chemicals react with phosphorus to create a precipitant, which produces a chemical sludge. Chemical is often used to polish or as a backup to biological treatment. Chemical in the form of supplemental volatile fatty acid (VFA) addition may also improve enhanced biological phosphorus removal (EBPR). Overall, P removal includes chemicals that enhance biological P removal, chemically remove phosphorus, serve as external carbon sources, serve as alkalinity sources, and help with struvite control/recovery.
- **Clarifier performance enhancement with chemical addition:** Chemically enhanced primary treatment (CEPT) removes both BOD and phosphorus. Enhanced BOD removal diverts BOD away

from the secondary process to digestion and can increase gas/energy recovery and increase capacity in the secondary process (because of reduced organic load); however, it could negatively impact denitrification.

All of these factors should be considered when selecting a chemical to improve nutrient removal at the WRRF.

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
	R	Carbon management
		I&C strategies
		Sidestream mgmt.
		Energy savings
	R	Chemical savings
		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
		Reduce O&M cost
Group	R	Optimize existing CNR
	R	Optimize existing TNR
	R	NutRem in secondary plant
Process	R	Small
	R	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	3	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	5	Technology ranking based (LIFT) see below*
Energy efficiency	3–5	Scale 1–5: 1 = use much less; 3 = use similar to conventional; 5 = use much more
O&M impact	3–5	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	3	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	Chemicals used to remove nitrogen or phosphorus
Description	Chemicals are typically fed in a treatment process as a liquid or dry chemical, although liquid feeds are more commonly used in water resource recovery facilities (WRRFs). These chemical feed systems consist of a chemical storage tank and metering pumps. Chemical is applied to the process in a well-mixed or highly turbulent location to disperse through the liquid. Chemical addition is a relatively simple process to implement and control. Most chemicals used at WRRFs are hazardous (toxic and/or flammable) and require proper handling.
Application	Chemicals for N removal include alkalinity addition to maintain the pH and help stabilize nitrification and/or carbon addition to improve denitrification. Metal salts like ferric and alum are typically used for chemical P removal. Chemicals such as polyaluminum hydroxide formulations, lime, cesium chloride, and others can also be used. Biological P removal can be enhanced by the addition of suitable carbon sources, such as VFAs, glycerol, suitable industrial wastes, or commercially available carbon formulations. Chemical addition to primary clarifiers can improve solids capture and reduce the organic loading to the secondary process. Such a reduction in organic load can result in reduced aeration requirements and biomass yield and thereby increase the available biological treatment capacity. Nuisance precipitants, such as struvite formation, can be controlled with metal salt addition. See Table 1 for a list of the common chemicals used at WRRFs and their applications.
Constituents removed	Nitrogen and/or phosphorus
Development status*	Chemical addition is a well-established process (LIFT TDL 5). New chemicals or proprietary chemicals, such as cerium or polyaluminum chloride (PACl) for P removal (and others), can be evaluated in jar tests to determine their specific dose requirements and performance.
O&M considerations	Chemical feed adds operation cost because of chemical purchases and the required operations and maintenance (O&M) time. Chemical doses can be optimized with online monitoring and automatic chemical dose control. Most chemicals used for nutrient removal are hazardous, flammable, and dangerous to handle. O&M staff will need the appropriate training and safety gear for these chemicals. Implementing chemical solids recycle could reduce chemical dose requirements in the long run. Many coagulants used for P sequestration consume alkalinity (e.g., ferric, alum).
Benefits	Increased treatment reliability by overcoming variability associated with influent water quality variations Maintain biological processes (denitrification) by adding controlled carbon dose. Ferric addition will also reduce odor.
Limitations	Some chemicals consume alkalinity. Chemical precipitants will slightly increase solids production. Many chemicals are hazardous to handle.

Design considerations	• Chemical feed pumps need to be interlocked with the pipe flow pumps to ensure that there is flow in the pipe. • Include flow indicator at discharge end when pipes are not visible. • Injection quills should allow safe removal (i.e., no overhead installation). • Design chemical feed system compatible with multiple chemicals that can be used for the same purpose (e.g., ferric, ferrous, alum, PACl). • Evaluate feasibility of provisions for multiple dosing points. • Some carbon sources like methanol are highly flammable. • Use online dose control to reliably meet nutrient targets. • Chemical sludge generated by many coagulants (ferric, alum) has signifying residual P sequestration capacity. This chemical sludge: o Can be used to lower chemical doses required to remove P o Sequester P and make it unavailable for P recovery
Potential fatal flaws	Only in rare applications. Industrial waste as chemical additive requires special treatment and handling.
Footprint requirements	Minimal—requires storage tanks and containment areas
Residuals	Carbon addition increases biomass production, thus increasing the required waste activated sludge (WAS) wasting rate. Chemical P removal with metal salts produces chemical precipitants (chemical sludge), which increases the total dissolved solids (TDS).
Cost considerations	Initial chemical feed costs are modest. The main cost component is ongoing chemical purchase. The second cost is chemical handling and dose control.
Past experience	Many (most) WRRFs have chemical feed facilities.
Publications	See material safety data sheets for individual chemicals.
Related fact sheets	1310: External Carbon Sources 1320: Chemical Phosphorus Removal 1401: Optimize Carbon Use for Nutrient Removal 1510: Instrumentation and Control—Improve Control, Stability, and Efficiency
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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)

Common Chemicals Used for Nutrient Removal

Table 1 contains some chemical applications and objectives along with a list of the common chemicals used. Other chemicals and new proprietary formulations continue to emerge. See related fact sheets for approaches to evaluate chemical alternatives for effectiveness and application.

Table 1. Common Chemicals Used in Nutrient Removal WRRFs.

Application	Objective	Common Chemicals Used
Alkalinity addition	Raise pH typically to maintain stable nitrification pH adjustment after addition of metal salts pH adjustment for chemical efficiency or disinfection	Lime Caustic Magnesium hydroxide Quicklime
Chemical phosphorus removal	Tertiary P removal to improve effluent quality Tie up phosphate to avoid nuisance precipitants such as struvite Polishing effluent (P removal)	Lime Caustic Ferrous chloride Cerium chloride PAX PACl
Enhanced biological phosphorus removal (EBPR)	Supply readily degradable organics (readily biodegradable chemical oxygen demand [rbCOD]) to grow polyphosphate-accumulating organisms (PAOs) Supplement rbCOD to maintain a favorable feed composition when influent composition changes	VFAs Acetic acid Sodium acetate Glycerol Commercial product (e.g., MicroC) Industrial source (e.g., sugar or beer waste)
Nitrogen removal	Increase readily degradable organics (rbCOD) to improve denitrification and reduce effluent N Supplement organics because of influent variability	Methanol Ethanol VFAs Acetic acid Sodium acetate Glycerol Commercial product (e.g., MicroC) Industrial waste source (ex. sugar or beer waste)
Chemically enhanced primary treatment (CEPT)	Improve BOD removal in primary to divert organics away from secondary biological process to increase capacity Reduce P through metal salt addition	Alum Ferric chloride Polymer
Struvite control/P recovery		Alum Ferric chloride Ferrous chloride Cerium chloride Magnesium hydroxide Magnesium chloride
Foam/filament		Chlorine PAX

Source: Adapted with permission from HDR Engineering, Inc.

Abbreviations

BNR	Biological nutrient removal
BOD	Biochemical oxygen demand
CEPT	Chemically enhanced primary treatment
CAS	Conventional activated sludge: BOD removal only
CNR	Conventional nutrient removal
EBPR	Enhanced biological phosphorus removal
I&C	Instrumentation and controls
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
PACl	polyaluminum chloride
PAO	Polyphosphate-accumulating organism
PAX	A proprietary of the PACl family
P	Phosphorus
rbCOD	Readily biodegradable chemical oxygen demand
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
TDL	Technology Development Level
TDS	Total dissolved solids
TN	Total nitrogen
TNR	Tertiary nutrient removal
TP	Total phosphorus
UV	Ultraviolet
VFA	Volatile fatty acid
WAS	Waste activated sludge
WRF	The Water Research Foundation
WRRF	Water resource recovery facility