WRF 4973 Fact Sheet: ID 1820

Strategy: Chemical Savings

Chemical Testing and Selection

Chemical Dosing Station.
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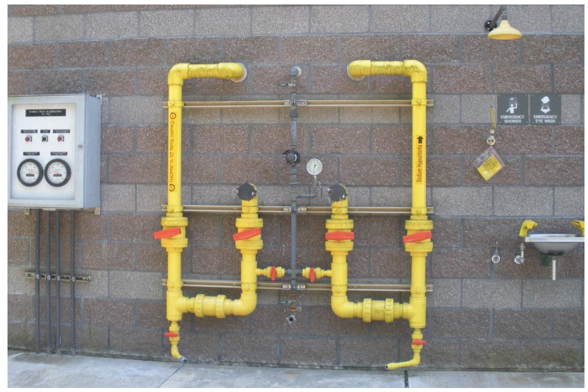

Chemical Receiving Station.
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Chemical selection is a daunting task. The primary selection criteria for a chemical application are usually (1) the ability of the chemical to help meet discharge permit requirements reliably and (2) cost for chemical dosing. There are, however, multiple other factors to consider such as safety, staffing needs, dose control, ease of application, training requirements, delivery, storage, supply-chain reliability, secondary impacts, and many others. A complete evaluation of chemical alternatives in a water resource recovery facility (WRRF) process will go beyond the scope of a typical life-cycle analysis (LCA) and account for all these non-cost factors that apply to the WRRF.

This fact sheet presents information about evaluating the effectiveness and cost of chemicals to be added. Chemicals are added for both nitrogen (N) and phosphorus (P) removal, alkalinity addition and pH adjustment, the minimization of unwanted precipitation, and to improve solids separation processes. For each of these objectives, several technical-grade chemicals and proprietary chemical blends or mixtures are commercially available. In addition, some industrial waste products can be used for treatment process optimization. Commercial chemicals are provided with material safety data sheets (MSDSs) that state the composition of the chemical; potential hazards (health, fire, reactivity, and environmental); and physical, chemical, and other properties of the product.

Selecting chemicals that are intended to improve the biological process (for example, increase denitrification or enhanced biological phosphorus removal [EBPR]) may require lab-, pilot-, or full-scale testing. Chemical reactions for chemical P removal are rapid and can be achieved in lab-scale jar tests. In these evaluations, the investigator starts with a theoretical assessment to establish the dose range that should be evaluated. The performance of this range of doses is then evaluated through jar tests to identify the optimal dosage within that range.

See the discussion in the Additional Information section for details and references on these tests.

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
		I&C strategies
		Sidestream mgmt.
		Energy savings
	R	Chemical savings
	R	Operational savings
		Other means of NutRem
Nutrient	R	Ammonia
	R	NOx
	R	TN
	R	Ortho-P
	R	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
	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	Chemical testing and selection
Description	Many technical-grade and commercial chemical formulations are available for carbon addition, alkalinity supplements, and P removal. This fact sheet outlines and points to procedures to analyze and compare different chemical options for a variety of uses.
Application	Optimize chemical use to reduce cost for chemicals and residual management. This evaluation includes: • Compare metal salts or proprietary formulations for P precipitation • Compare carbon sources to enhance denitrification and total nitrogen (TN) removal • Evaluate industrial chemical sources as a replacement or supplements to technical-grade chemicals
Constituents removed	Oxidized nitrogen (nitrate + nitrite) (NO_x), TN, orthophosphate (PO_4-P), total phosphorus (TP)
Development status*	LIFT TDL 5
O&M considerations	Evaluating alternative chemicals should also include secondary impacts. These include changes in operations and maintenance (O&M) effort, safety, storage, delivery, and other factors.
Benefits	Evaluating chemical alternatives provides an opportunity not only for reducing chemical costs, but also for selecting more operator-friendly chemicals. Some alternative chemicals may also have other application benefits; for example, some proprietary aluminum formulations do not consume alkalinity when added to water.
Limitations	Availability of chemicals and pricing is volatile at times. Chemical deliveries may not be neighbor-friendly.
Design considerations	The chemical storage and dose equipment and materials of construction must be compatible with the chemical. Corrosion, hazard, and other properties of the selected chemicals should be considered. The dose application rates may require different chemical feed pumps for range and material compatibility.
Potential fatal flaws	Chemical storage and dose equipment currently in use at a WRRF may not be compatible with the optimal chemical for the task.
Footprint requirements	None, unless chemical storage and dose equipment are not compatible with the newly selected chemical
Residuals	Residual quantities could change by a modest amount, depending on the selected chemical
Cost considerations	Any investment toward selecting an optimal chemical should be offset by the provided operational cost savings that result from usage of that chemical within a reasonable return-on-investment period
Past experience	Coeur d'Alene, Idaho: Switch to a polyaluminum chloride (PACl) proprietary chemical to eliminate alkalinity demand from alum. City of Las Vegas, Nevada: Replace alum with ferric for chemical P removal at primary clarifier with trickling filter plant. Ferric provided added benefit for odor control.
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. 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., K. Bilyk, T. Bruton, P. Pitt, and R. Latimer. 2009. "Evaluation of Alternative Supplemental Carbon Sources at Four BNR Facilities." WEF's 82nd Annual Technical Exhibition and Conference. Orlando, Florida: WEFTEC 2009.
Related fact sheets	1301: Overview of Chemical Addition 1310: External Carbon Sources 1320: Chemical Phosphorus Removal 1401: Optimize Carbon Use for Nutrient Removal 1801: Overview of Chemical Saving Strategies 1850: Reuse Chemical Sludge
Date updated	9/10/2022
Contributors	Mario Benisch, Eric Evans, Justin Macmanus, JB Neethling, Anand Patel

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

Jar Testing for Chemical Phosphorus Removal

Jar tests are commonly used to evaluate and compare chemicals through a dose-response analysis to achieve a specific objective. The objectives can be:

- Reduce the soluble reactive phosphorus (SRP), which represents mostly PO_4-P, to a target concentration
- Add coagulants to improve filter particle removal
- Evaluate chemicals and chemical combinations for chemically enhanced primary treatment (CEPT)
- Reduce struvite formation potential (by tying up SRP)

The general procedure is as follows:

1. Establish the objective.
2. Place an aliquot in a jar. Usually, six or eight jars are tested simultaneously.
3. Add chemical to achieve the target dose concentration while mixing rapidly. Vary the dose if multiple jars are tested.
4. Continue slowly mixing the solution for a set time.
5. Allow the mixture to settle (and potentially filter) the supernatant.
6. Measure the outcome/objective (e.g., SRP).
7. Analyze the data to determine the lowest dose that will meet the objective.

The results from a jar test are impacted by the physical test conditions. These conditions include the initial mixing intensity and duration, mixing intensity and duration of the flocculating period, temperature, etc. Several industry standards are available with prescriptions for the test to conduct a comparative evaluation (see ASTM 2019; AWWA 2014).

It is recommended that the jar test conditions be adjusted to simulate the local conditions when testing chemicals for nutrient removal optimization. The mixing intensity or flocculation time during the test may be adjusted to better simulate the conditions in the full-scale process.

Cautionary note: If chemically precipitated PO_4-P particles are present in the sample, this chemically bound phosphate (PO_4) will measure as reactive phosphorus during the standard measurement procedures. The sample must therefore be filtered to remove the chemically bound PO_4 from the liquid before measuring the SRP (to reflect PO_4 in solution).

Chemical Testing for Denitrification

Comparing chemical efficiency as a carbon supplement requires a biological test. Biological tests require a robust denitrifier population to be present during the test. If biomass is available at the WRRF, then that could be used to conduct denitrification kinetic studies. The kinetic study will involve tracking the denitrification rate (measuring residual nitrate over time) and adjusting the results for the biomass present in the full-scale process.

In general, comparative testing in the laboratory is complicated because the test conditions need to be reflective of the application conditions. This requires that the biopopulation be “adjusted” for the specific carbon feed, because different denitrifying communities can only use certain carbon sources. Reasonable comparisons are possible for carbon sources that are chemically similar (e.g., acetate-based proprietary compounds). In general, it is advisable to grow biomass using a carbon substrate to establish a robust denitrifier population for a particular carbon source over several weeks before conducting tests on unfamiliar carbon sources.

Procedures for evaluating carbon sources were developed by Gu and Onnis-Hayden (2010) under the Water Environment Research Foundation (WERF) Nutrient Removal Challenge. Detailed information on these procedures can be found in their report referenced below.

References

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.

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.

Abbreviations

BOD	Biochemical oxygen demand
CAS	Conventional activated sludge: BOD removal only
CEPT	Chemically enhanced primary treatment
CNR	Conventional nutrient removal
I&C	Instrumentation and controls
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
mgd	Million gallons per day
MSDS	Material safety data sheet
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	Phosphate
PO_4-P	Ortho-phosphorus as P
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
SRP	Soluble reactive phosphorus
TDL	Technology Development Level
TN	Total nitrogen
TNR	Tertiary nutrient removal
TP	Total phosphorus
UV	Ultraviolet
WERF	Water Environment Research Foundation
WRF	The Water Research Foundation
WRRF	Water resource recovery facility