WRF 4973 Fact Sheet: ID 1630

Strategy: Reject Water Management

Sidestream Phosphorus Treatment, Control, and Recovery

AirPrex Installation, Saltzgitter, Germany.
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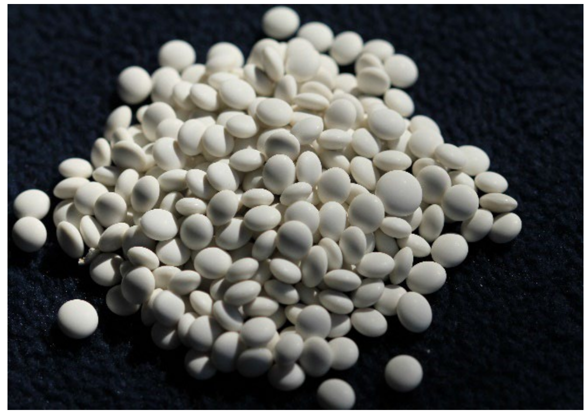

P-Recovery Product.
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The soluble reactive phosphorus (SRP, typically orthophosphate [PO_4-P]) concentration in anaerobic digesters can be high. Water resource recovery facilities (WRRFs) that use enhanced biological phosphorus removal (EBPR) have very high SRP concentrations in anaerobic digesters (200–800 milligrams per liter [mg/L]). This high phosphorus (P) concentration is the result of SRP release from EBPR in addition to P from destruction of volatile solids in the digester. When this high SRP concentration is returned to the WRRF influent, the influent SRP concentration can increase 30%–90% above the influent.

Traditional strategies to control or remove SRP from the reject water are with chemical addition. Metal salts such as ferric or alum can be added to generate a chemical sludge that can be captured in the dewatering process and sent to disposal. In recent years, intentional struvite precipitation with magnesium addition has evolved as an attractive strategy for some WRRFs to manage and reduce the P recycle. If the phosphate-metal precipitant is returned to the WRRF, it will be captured in primary treatment or with the waste activated sludge (WAS) and eventually also enter the digester and be disposed with the solids stream.

The P recycle can also be interrupted by reclaiming the P as a struvite or brushite precipitant that can be used as a beneficial product. These strategies have added potential benefits in terms of improved dewaterability. This strategy for P recovery also requires EBPR to extract P from the wastewater and release SRP under anaerobic conditions, specifically anaerobic digestion.

If the WAS from an EBPR process is managed and dewatered separately (e.g., composting), it avoids P release during solids processing and can significantly reduce the P recycle. In this strategy, the EPBR phosphorus is disposed with the dewatered cake. This cake can be used in compost production and retain the P fertilizer value of the cake.

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
	R	Sidestream mgmt.
		Energy savings
		Chemical savings
	R	Operational savings
	R	Other means of NutRem
Nutrient		Ammonia
		NOx
		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
	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*	4–5	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	Sidestream treatment for phosphorus
Description	Sequestration of soluble orthophosphate in the sidestream through chemical addition or P recovery
Application	EBPR WRRFs' phosphate-rich recycle streams from anaerobic or aerobic digesters, sludge storage lagoons, or digester decant Sequestration of dewatering reject water's phosphorus may occur upstream and or downstream of dewatering
Constituents removed	PO_4-P, total phosphorus (TP)
Development status*	LIFT TDLs: 4–5 P sequestration through chemical addition using alum or ferric is well established. Technologies such as sludge conditioning upstream of digestion through magnesium addition and struvite formation during anaerobic digestion are still only in the pioneering stage. P recovery from dewatering centrate downstream of digestion as struvite is well established with multiple technical solutions on the market. P recovery from dewatering centrate following stored P release is an emerging technology.
O&M considerations	Operations and maintenance (O&M) requirements are similar to conventional chemical feed systems, including chemical management and dose control. Struvite-based sludge conditioning systems such as MagPrex and Nuresys add more complex process controls to manage the struvite precipitant. Foam control is required for some installations. P recovery systems that harvest crystals for commercial application require operation control to maintain struvite particles suitable in size, texture, and consistency to be useful as a fertilizer. P sequestration upstream of dewatering may require selection of a different dewatering polymer and/or a dose adjustment. In most cases the P sequestration improves dewaterability.
Benefits	Greatly reduce reject water P recycle to WRRF and reduce biological nutrient removal (BNR) influent PO_4-P. This improves process reliability and reduces effluent P. Effective struvite control for dewatering, dewatering recycle equalization, and conveyance. Revenue source from recovered product. Improved dewaterability (dryer cake, lower polymer dose).
Limitations	Chemical addition for P removal will reduce the ability for beneficial P recovery. Specialized equipment is costly and may require capital project.
Design considerations	For chemical P sequestration: • Design chemical feed facilities with the ability to switch to alternative chemical or chemical formulations • Consider multiple dose points for chemical feed systems to provide operational flexibility • Ensure good initial mixing • Select pipe and accessories material to avoid struvite precipitation For P recovery (EBPR typically required): • Protect tanks and conveyance from nuisance struvite formation on equipment • Locate recovery system in close proximity to dewatering
Potential fatal flaws	The presence of hydrous metal oxide sludge from metal salt addition at the WRRF or entering into the WRRF from the collection will capture P and reduce the recoverable P.

	Chemical P removal at the WRRF (e.g., for tertiary treatment, hydrogen sulfide [H_2S], or struvite control) will reduce P recovery product yield.
Footprint requirements	Conventional chemical P removal: • Minimal: storage tanks and containment area P recovery: • Facilities for storage, managing struvite residuals • 10%–20% of digester footprint including product storage
Residuals	Chemical sludge is typically disposed with dewatered sludge. P recovery product for beneficial use.
Cost considerations	Chemical purchase costs for conventional chemical P removal. Capital costs to implement a commercially available P recovery process. The cost for capital investment and chemical addition to form struvite can be offset with the marketable product. P recovery to create a commercial product requires specialized equipment, increased operator supervision, and quality control. A life-cycle cost evaluation is recommended.
Past experience	Howard County, Maryland, Little Patuxent Water Reclamation Plant: P sequestration upstream of dewatering (MagPrex) Pima County, Arizona, Tres Rios Water Reclamation Facility: P sequestration upstream of dewatering (Nuresys) Durham Advanced Wastewater Treatment Plant (WWTP) (Oregon): P recovery from dewatering centrate (Ostara) Hampton Roads Sanitation District (HRSD) Nansemond WWTP (Virginia): P recovery from solids processing (Ostara PEARL process) West Boise Water Reclamation Facility (Idaho): P recovery from dewatering centrate (Multiform Harvest)
Publications	Barnard, J., H. Phillips, and M. Steichen. 2012. “State-of-the-art recovery of phosphorus from wastewater.” WEF’s 85th Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC. Baur, R. 2011. “Results of the First Full Year of Operation of North America’s First Full Scale Nutrient Removal Facility.” Nutrient Recovery and Management Conference. Miami, Florida: WEF/IWA. Bennett, J., M. Roser, C. Woods, and J. Sober. 2015. “Optimizing Operations to Reduce Sidestream Recycle of Phosphorus: Recycling of Phosphorus at the Trinity River Authority of Texas Denton Creek Regional Wastewater System Plant.” Nutrient Symposium. San Jose, California: WEF. Fang, Y., C. Wilson, and D. Katehis. 2013. “Side Stream Phosphorus Removal/Recovery-Breaking Loop of Phosphorus in EBPR Plants.” Proceedings of the Water Environment Federation, 2013(12), 4195–4202. Kabouris, J.C., M. Engelmann, J. Dulaney, B. Narayanan, R.A. Gillette, and A.C. Todd. 2009. “EBPR With Struvite Recovery to Reduce Chemical Consumption and Increase Nutrient Removal Reliability.” WEF’s 82nd Annual Technical Exhibition and Conference. Orlando, Florida: WEFTEC. Mohan, G.R., J.C. Lan, R. Latimer, M. Lynch, and P. Pitt. 2018. “Nutrient Recovery Performance and Optimization of Biological Phosphorus Removal at the F. Wayne Hill Water Resources Center.” Nutrient Removal and Recovery Conference. Raleigh, North Carolina: WEF. Petzet, S. and P. Cornel. 2011. “Prevention of Struvite Scaling in Digesters combined with Phosphorus Removal and Recovery - The FIX-Phos Process.” Nutrient Recovery and Management Conference. Miami, Florida: WEF/IWA.
Related fact sheets	1301: Use of Chemicals to Improve Nutrient Removal 1320: Chemical Phosphorus Removal

	1601: Reject Water (Sidestream) Management Overview 1610: Sidestream Return Flow Management 1820: Chemical Testing and Selection 1901: Optimize Operation and Maintenance
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Note

* Technology ranking based on LIFT 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 (https://www.waterrf.org/sites/default/files/file/2019-07/LIFT%20Scan%20Application-LIFT%20Link%2BHub_0.pdf : accessed September 2020)

Additional Information

Table 1 contains a list of the common chemicals used for P sequestration.

Table 1. Chemicals Used for Phosphorus Precipitation.

P Removal Strategy	Chemical Commonly Used	Comments
Coagulant addition	Ferric chloride Aluminum sulfate	Sequestered P remains in cake Coagulant addition generates chemical sludge and consumes alkalinity
Struvite-based sequestration	Magnesium chloride	Sequestered P remains in cake
P recovery	Magnesium chloride Magnesium hydroxide Calcium	Sequestered P is recovered Consider doing a business case evaluation Anaerobic digestion required for struvite-based recovery Chemical sludge (metal salt) will limit P recovery

A schematic overview of commercially available P recovery or sequestration technologies (as of 2021) is provided in Figure 1. The impact of different P recovery approaches on the WRRF phosphorus mass balance is illustrated in Figure 2 and different P recovery technologies are compared in Figure 3.

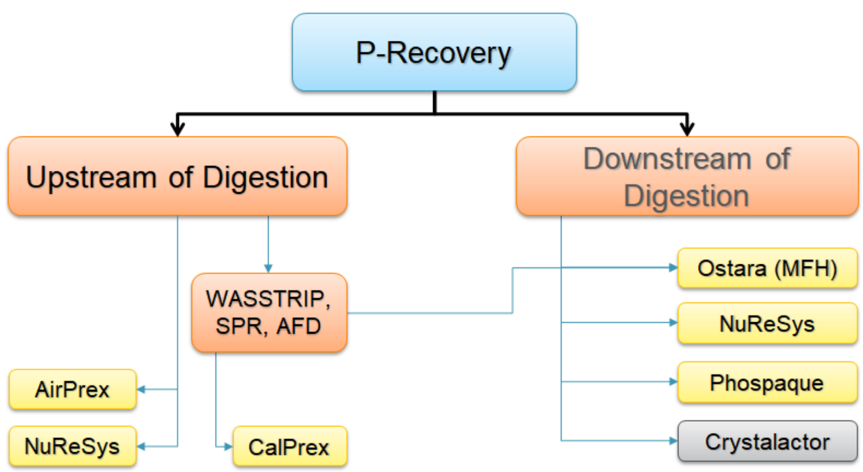

Figure 1. P Recovery and Sequestration Technology Options.
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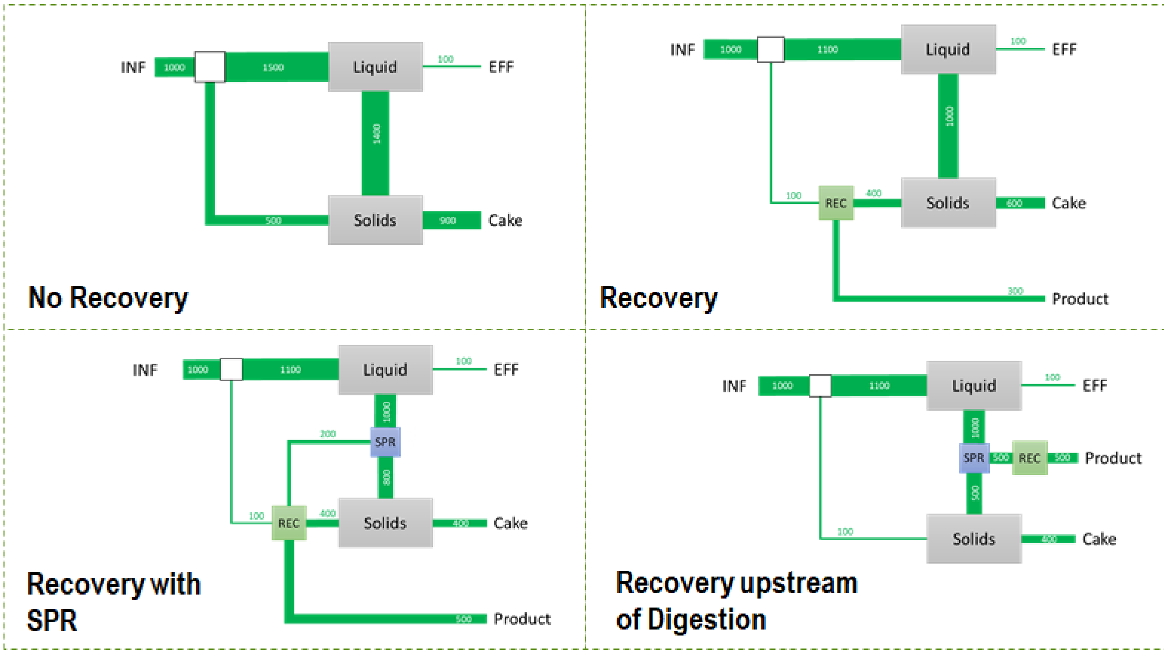

Figure 2. Impact of Recovery on P Mass Balance.
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Note: SPR = stored phosphorus release, REC = recovery

	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

Figure 3. P Recovery Technology Comparison.
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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
H_2S	Hydrogen sulfide
HRSD	Hampton Roads Sanitation District
I&C	Instrumentation and controls
L	Liter(s)
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
mg	Milligram(s)
mgd	Million gallons per day
NAS	Nitrifying activated sludge
NO_x	Oxidized nitrogen (nitrate + nitrite)
NutRem	Nutrient removal
O&M	Operations and maintenance
P	Phosphorus
PO_4-P	Orthophosphate
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
WAS	Waste activated sludge
WRF	The Water Research Foundation
WRRF	Water resource recovery facility
WWTP	Wastewater treatment plant