Sidestream Biological Phosphorus Removal: The New Frontier

Lucas Botero, James L. Barnard, Ed Kobylinski, and Kenny Blanton

Enhanced biological phosphorus removal (EBPR), also known as biological phosphorus removal or simply bio-P, has been practiced for decades in water resource recovery facilities (WRRFs). The underlying principles for EBPR are the introduction of an area devoid of nitrates and oxygen (anaerobic zone) where phosphate accumulating organisms (PAOs) are conditioned by taking up volatile fatty acids (VFAs) in lower forms (acetic and propionic acids; Fuhs and Chen, 1975) and releasing phosphate as an energy source for uptake, then allowing luxury phosphate uptake in the subsequent oxic areas of the reactor.

This original configuration was a result of Barnard's observations of a pilot plant at the Daspoort WRRF in Pretoria, South Africa, where he tested different configurations by varying the reactor volumes, as well as changing the recycle locations. One of the configurations tested was a four-stage anoxic/aerobic/anoxic/aerobic, but in order to make a smaller reaction volume work within the existing tankage used for the pilot, he introduced a baffle adjacent to the second anoxic zone, where two small holes were left to allow hydrostatic pressure equalization because the baffle was a nonwater-bearing wall (Figure 1).

As a result, a high amount of phosphate removal was detected in the second anoxic zone, which resulted in full phosphorus uptake in the second oxic zone (ortho-P in the effluent <0.2 mg/L). Experiments were carried out in the laboratory to simulate the original Daspoort pilot plant configuration, but the dead zone dynamics could not be reproduced at the laboratory scale. Barnard then postulated that when activated sludge passed through anaerobic conditions, it would stimulate PAOs to release phosphorus and take up all released phosphates and all phosphates in the influent upon aeration, which was the basis for the development of the EBPR processes now in use. He suggested using the primary effluent to create those anaerobic conditions.

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Rethinking Original Postulations

The earlier experiments at the Daspoort pilot plant led to the original Phoredox configuration (later termed A/O in the United States), which includes an anaerobic zone as part of the mainstream flow for conditioning PAOs. While this concept became the standard EBPR configuration and has been partially successful, recently researchers and practitioners in several parts of the world started experimenting with different EBPR configurations, and, more specifically, placed a lot of attention on fermentation processes that could supplement mainstream EBPR when the characteristics of the wastewater entering EBPR reactors were not optimal, i.e., low VFAs or readily biodegradable chemical oxygen demand (rbCOD), improper biochemical oxygen demand (BOD_5) to total phosphorus (TP) ratio, etc.

In 2011, the Cedar Creek WRRF in Olathe, Kan., was expanded using a five-stage Bardenpho configuration, with the addition of a mixed liquor suspended solids (MLSS) fermentation process due to the low rbCOD at the facility's influent.

The fermenter supernatant (with rbCOD and some VFA) was designed to be discharged at the head end of the anaerobic zone to achieve better EBPR. Soon after the facility was commissioned and proper biological nutrient removal (BNR) performance was established with the fermenter feeding the anaerobic zone, a severe plant upset occurred and the plant lost nitrification. After troubleshooting the BNR process and not finding any possible culprits within the plant, attention was then focused on a toxic upset from the collection system, based on the fact that the plant exhibited a different odor during the upset.

A few weeks after the first episode, a second toxic release was detected, but this time the city quickly diverted influent to the influent equalization basin to prevent a BNR upset. Most of the toxic material was caught, but the plant still had nitrification interference. A few days afterward, a third toxic release occurred and the city was able to track down the source to the industrial discharger.

The WRRF has an annual average limit of 8 mg/L total nitrogen (TN) and 1.5 mg/L TP; however, after all the toxic upsets, the annual average for that year was 7.95 mg/L and plant staff was quite worried about possible future upsets and permit compliance. In order to make up for it, the fermentate was diverted from the anaerobic cell to the anoxic cell to drive more denitrification, while feeding ferric chloride to the BNR train to address phosphorus removal.

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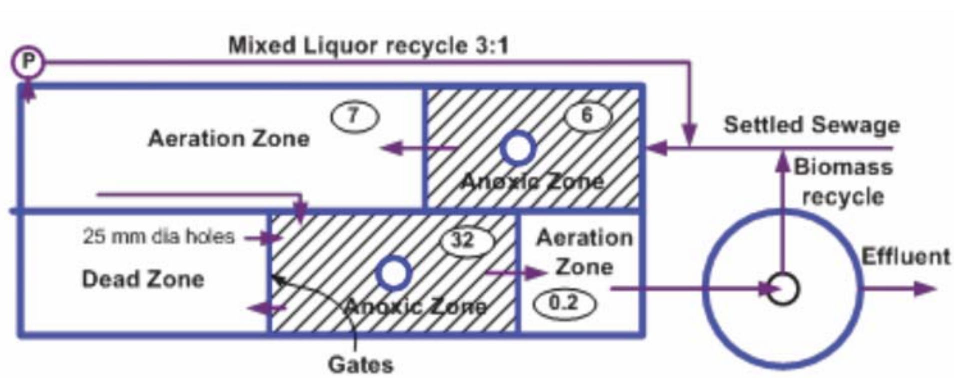
Figure 1. Pilot Plant at Daspoort Pretoria Wastewater Treatment Plant



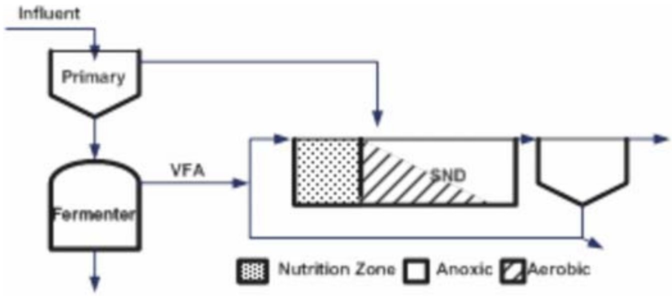


Figure 2. Orange Water and Sewer Authority Flow Sheet

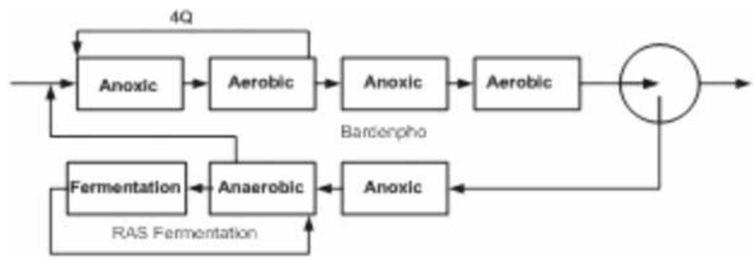


Figure 3. Biological Nutrient Removal Plant Designed for South Cary, N.C.

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After these modifications were made, the plant improved TN removal significantly and had effluent concentrations averaging less than 5 mg/L TN, while the TP effluent concentration remained less than 1 mg/L TP.

A week or so after the new revised plant operation was implemented, plant staff made a very interesting discovery. The ferric chloride line feeding the BNR basins was broken at a plant manhole, and no ferric chloride was reaching the BNR basin, so no chemical phosphorus removal was occurring. Without phosphorus release being detected in the anaerobic zone of the plant (not enough influent rbCOD/VFA to drive EBPR), the facility still consistently achieved EBPR. The question then was: What is happening in this facility?

Afterward, the designers of the facility started linking the Daspoort pilot plant observations with the Cedar Creek WRRF, and realized that they had one thing in common: the absence of phosphorus release in the anaerobic zone before an anoxic zone and the existence of a sidestream fermenter discharging to it. This led to the development of the theory that somehow the fermenter was not only serving as the source for VFA generation, but the PAOs were also being grown and conditioned in this reactor in such a way that EBPR could occur. This configuration was termed sidestream EBPR (SEBPR).

A literature review and data analysis in other plants with similar configurations was conducted to start validating the SEBPR theory. At the Orange Water and Sewage Authority (OWASA) in Carrboro, N.C., Kalb and Roeder (1992) converted a trickling filter/activated sludge plant to EBPR by using one of two primary tanks as a fermenter, and then fed the fermenter's supernatant to a "nutrition" (fermentation) zone, where it came into contact with the return activated sludge (RAS), as shown in Figure 2. Turbine aerators were used in the main aeration basin, which allowed the control of air supply independent from mixing. Unaerated sections were formed, which resulted in simultaneous nitrification and denitrification. Eventually, the trickling filters were eliminated and phosphorus was reduced to less than 1 mg/L.

In subsequent research, a SEBPR process was developed, consisting of fermentation of a portion of the RAS (Lamb 1994), which was pumped to a sidestream fermentation zone. Effluent from the sidestream fermentation zone is sent back to the anaerobic zone, as the VFA source, while all primary effluent goes to the anoxic zone. Lamb's process differed from the fermentation of the RAS in the Phostrip process in that the fermented RAS was sent to a sidestream anaerobic zone, rather than to the aeration basin, and there was no lime treatment to remove surplus phosphorus. The RAS fermentation process, developed by Lamb, Stroud & Martin (2001), upgraded the South Cary, N.C., BNR plant after it experimented with, and finally adopted, the flow sheet shown in Figure 3, which consisted of a conventional four-stage Bardenpho process where all the primary effluent went to the first anoxic zone, while some of the RAS was fermented. They succeeded in reducing the average TN to below 3 mg/L and the effluent TP to less than 1 mg/L.

At the 100-mil-gal-per-day (mgd) Robert W. Hite Treatment Facility (north plant) in Denver, Colo., an existing plug-flow RAS reaeration tank was retrofitted with a series of eight slow-speed vertical entry mixers (Cavanaugh et al., 2012; Carson 2012). The mixing energy was 2 W/m^3 (0.08hp/kcf), which caused little movement of the contents near the surface, but prevented severe stratification while approaching ideal plug-flow conditions. A third of the RAS flow and supernatant from adjacent gravity thickeners was discharged to this fermenter.

The layout of the plant is shown in Figure 4. The effluent orthophosphates dropped from approximately 2 mg/L to less than 0.2 mg/L within two weeks.

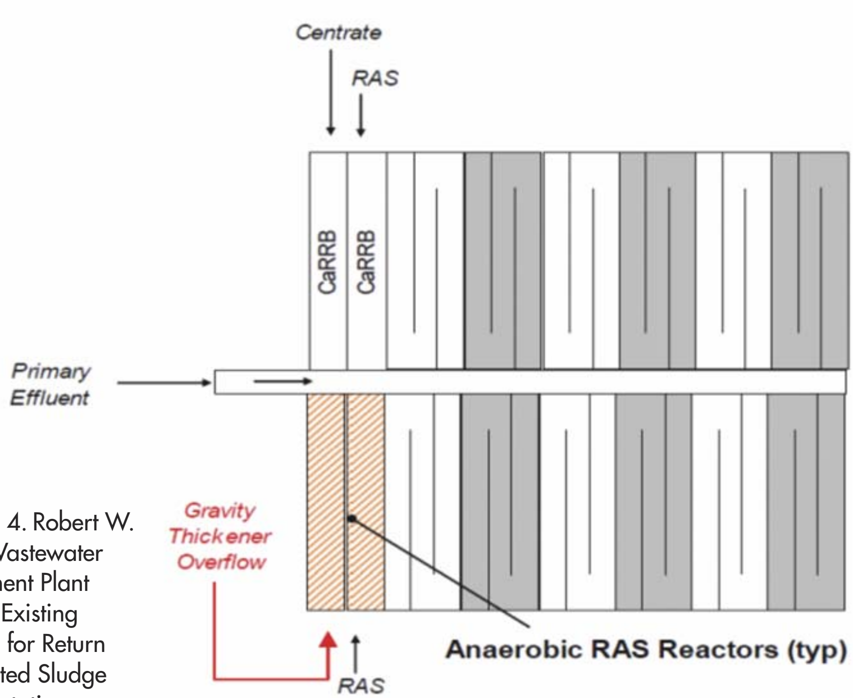

Figure 4. Robert W. Hite Wastewater Treatment Plant Using Existing Basins for Return Activated Sludge Fermentation

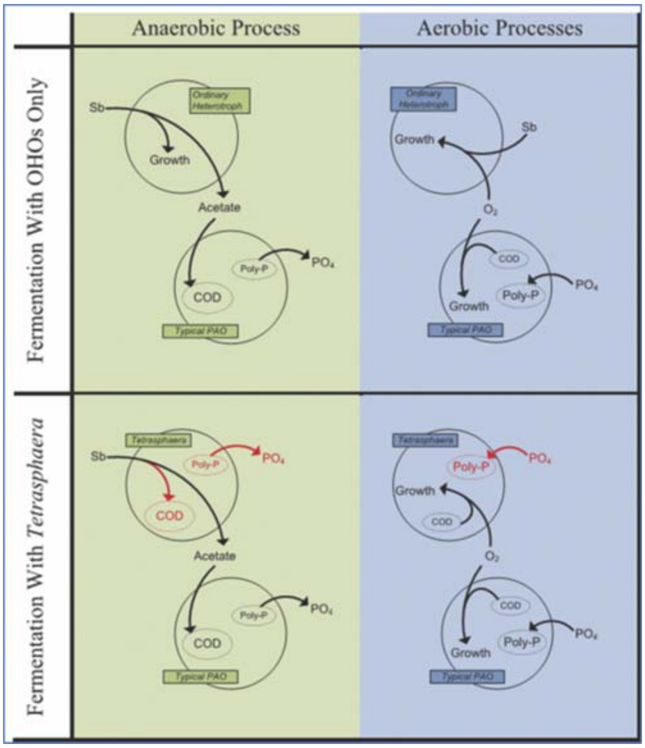

Figure 5. Two-Phosphate Accumulating Organisms Model

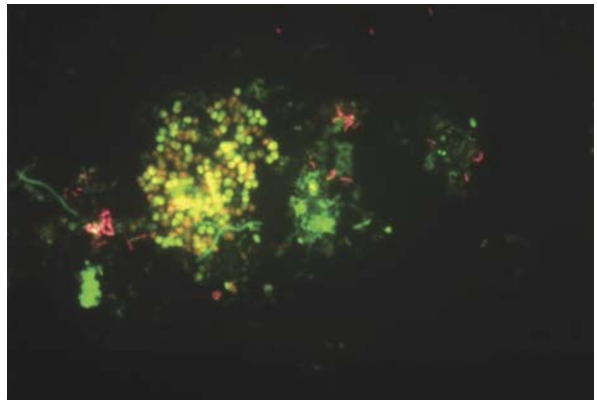

Figure 6. FISH Image From Westside Regional Wastewater Treatment Plant Sludge With Electric Upright Bass Mix (all bacteria) Shown in Green, Tet2-174 (Tetrasphaera clade 2B) in Orange, and Tet3-654 (Tooker)

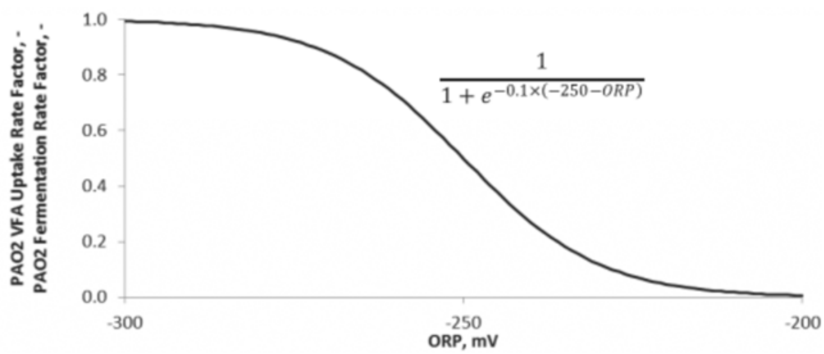

Figure 7. Two-Phosphate Accumulating Organisms Anaerobic Activity Switch Function

All of these examples showed that the SEBPR theory was feasible, but more detailed research was needed to confirm these findings.

Sidestream Enhanced Biological Phosphorus Removal Fundamentals

Nguyen et al., (2011) pointed to the possibility that other PAOs may get involved and their behavior may differ from that of the much-researched *Accumulibacter* species found primarily in conventional BNR plants. Nguyen's findings pointed to the existence of *Tetrasphaera* bacteria in elevated levels compared with the more standard PAO *Candidatus Accumulibacter*, which could contribute to phosphorus release and stability in the EBPR process. Stokholm-Bjerregaard et al., (2015) in a poster presentation showed that, in 24 plants that were studied in Denmark, the relative abundance of *Tetrasphaera*, PAO (*Accumulibacter*), and GAO, or glycogen accumulating organisms (*Competibacter+Defluviicoccus*) was 8.85 percent, 0.57 percent, and 0.53 percent, respectively, further corroborating the importance of *Tetrasphaera* in SEBPR.

The most important factor determining the abundance of *Tetrasphaera* could be the availability of glucose and amino acids and the anaerobic residence time in the reactor, where the longer residence time will benefit fermentation. This would imply that residence under deeper anaerobic conditions, and not when the oxidation-reduction potential (ORP) is higher than about 250 millivolts (mV), is critical for proper EBPR.

Existing EBPR process models do not accurately reflect the P-removal seen in SEBPR systems (Dunlap et al., 2014). Several different ways to address these shortcomings have been proposed, including multiple metabolic-based PAOs modules, additional mechanisms to PAOs models, or multiple culture PAOs group model.

Black & Veatch has been using the third approach for SEBPR modeling by creating a two-PAOs model in the SUMO™ commercial simulator, shown in Figure 5, with an ORP-based inhibition for the second PAOs VFA uptake and fermentation rate equations per the function shown in Figure 7.

Table 1 shows the results obtained in the calibration of the two-PAO model for the Westside Regional WRRF using the two-PAO approach work described.

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Table 1. Phosphate Accumulating Organisms Calibration Results

	Anaerobic ORP (mV)	PAO1 Concentration (mgCOD/L)	PAO2 Concentration (mgCOD/L)	Eff NOx-N (mg/L)	Eff PO4-P (mg/L)
Conventional EBPR Simulations					
Mainstream Anaerobic Zone 1 PAO Model (SUMO1 Default)	-256	251	NA	27.4	0.14
Mainstream Anaerobic Zone 2 PAO Model	-256	250	2	27.4	0.14
S2EBPR Simulations					
Sidestream Anaerobic Zone 1 PAO Model (SUMO1 Default)	-298	193	NA	13.9	0.78
Sidestream Anaerobic Zone 2 PAO Model	-298	6	205	13.4	0.06

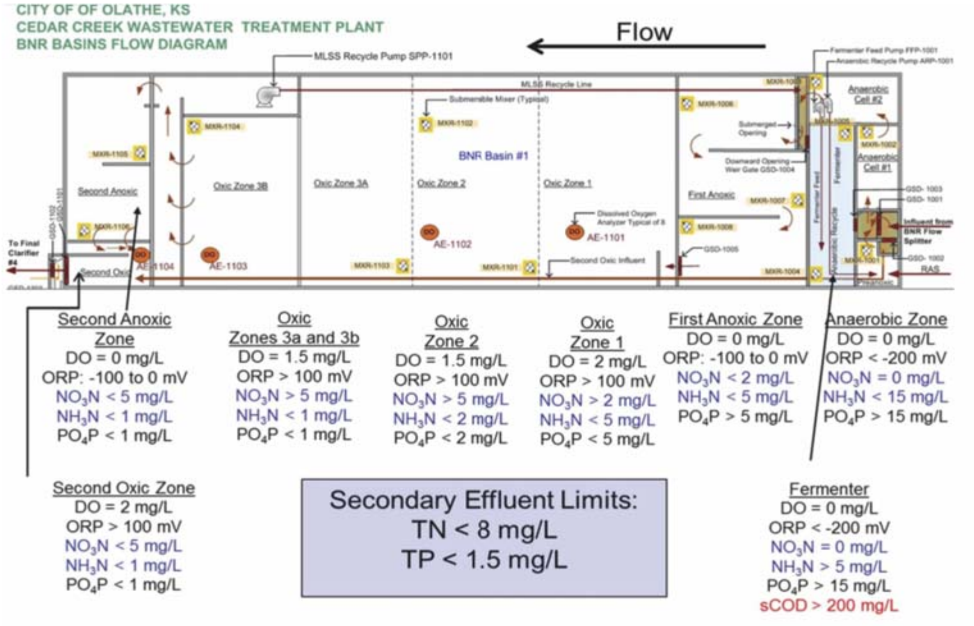

Figure 8. Cedar Creek Biological Nutrient Removal Basin Configuration With Mixed Liquor Suspended Solids Fermenter

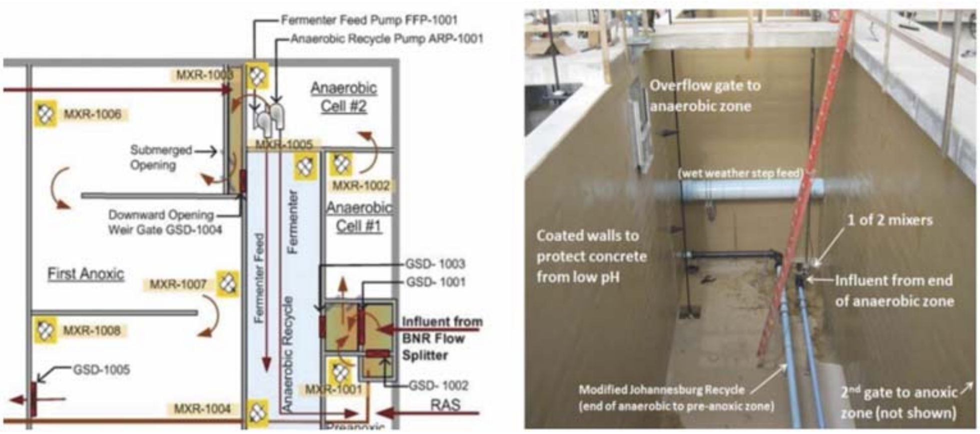

Figure 9. Olathe Water Resource Recovery Facility Biological Nutrient Removal Basin Plan and Fermenter

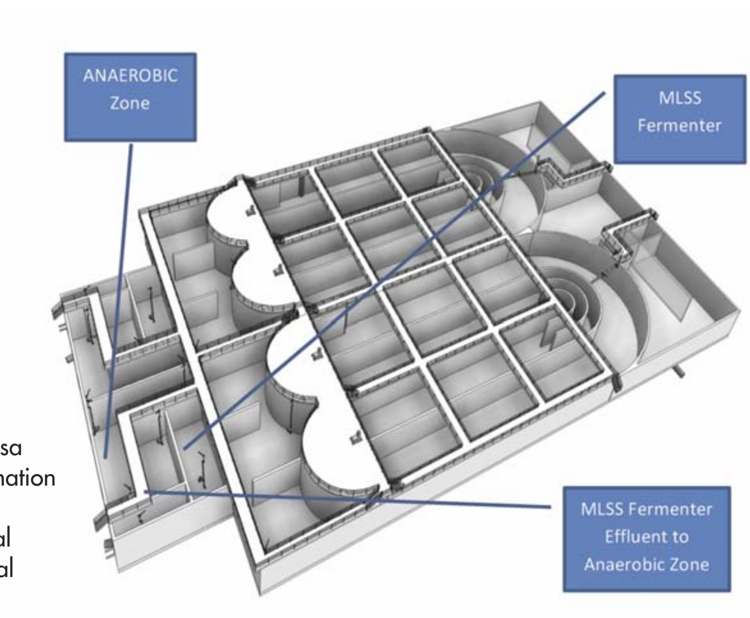

Figure 10. Wakarusa Wastewater Reclamation Facility Sidestream Enhanced Biological Phosphorus Removal

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Practical Examples of Sidestream Enhanced Biological Phosphorus Removal Configurations

Cedar Creek Water Resource Recovery Facility

The Cedar Creek WRRF is a 5.25-mgd annual average daily flow (AADF)-permitted facility with a five-stage BNR process configuration.

Due to the low rbCOD of the influent, an MLSS fermenter was initially projected to supplement VFA, but it is also used to condition PAOs in a SEBPR configuration as previously described. The fermenter is operated to maintain a set solids retention time (SRT) through the management of submersible mixers. The ORP is monitored for proper SEBPR performance.

Figures 8 shows the MLSS fermenter layout used at this WWRF.

Wakarusa Wastewater Reclamation Facility

The Wakarusa WRRF, located in Lawrence, Kan., will be rated for 2.5 mgd average annual (AA) capacity, and will be commissioned in 2018. The BNR reactor configuration is very similar to the Olathe layout (Figure 9), with an MLSS fermenter with multiple discharge locations. Given the great results in Olathe, the plant will be operated in an SEBPR mode. Figure 10 is a 3-D rendering of the BNR basin.

Sacramento Regional and Liverpool Wastewater Reclamation Facilities

The Sacramento (Calif.) Regional WRRF (Regional San) treats around 140 mgd of mostly domestic wastewater and discharges to the Sacramento River, which flows south to the San Francisco Bay (Barnard et al., 2014). At present, the Regional San treats the wastewater through a high-purity oxygen (HPO) plant with final clarifiers. The future plans include constructing a BNR plant between the existing primary sedimentation tanks and final clarifiers, while keeping the HPO plant operational until the BNR plant is constructed and commissioned. The design flow for 2050 was estimated at 180 mgd. The technology selection committee developed a process concept, which was based on a four-stage nitrification/denitrification plant to allow control of the effluent nitrates by acetate addition to the second anoxic zone when necessary to meet the monthly nitrate requirement.

A pilot plant was operated at an average dry weather flow of around 10 liters per second (L/s), but with diurnal flow variations, that mirrored the flow pattern of the main plant. Initial pilot studies showed that substantial chemical addition, in the form of acetate, would be re-

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quired to comply with an effluent nitrate concentration of less than 10 mg/L, and additional alkalinity was required to prevent the pH from dropping lower than 6.5 units. Second anoxic zones were designed as swing zones so that they could be aerated when they were not needed to reduce nitrates.

Most of the influent rbCOD is currently destroyed by chlorine, which is applied for odor control. In the future, the chlorine will be replaced by nitrates through nitrification of return stream ammonia, which will still have the effect of destroying influent rbCOD and will result in existing and future unfavorable COD/Total Kjeldahl Nitrogen (TKN) ratios for nitrogen and phosphorus removal. During the period of operation with SEBPR shown in Figure 6, the ORP was measured in the mixed liquor fermenter (MLF); most of the time, the ORP was around -400 mV.

When the pilot plant was operated using the four-stage Bardenpho process, the effluent TP averaged 3.2 mg/L, which was higher than the 2.2 mg/L in the effluent of the main plant using the HPO process. The design team selected a five-stage Bardenpho process, which included an anaerobic zone to act both as a selector for improved sludge settling and to comply with the requirement to not increase the effluent phosphorus content when switching from the HPO to the nitrogen removal. With insufficient carbon for both denitrification and phosphorus removal, fermentation of a portion of the mixed liquor solids to augment the VFA was recommended for reducing nutrients to the required levels. In the MLF, a portion of the remaining rbCOD, volatile solids, heterotrophic biomass, and colloidal material was fermented to produce additional VFA that was used to enhance biological phosphorus removal and achieve the required level of denitrification. Barnard et al. (2011), describes the use of the MLF.

The pilot plant was adapted to incorporate an anaerobic zone and a sidestream fermenter. During startup of this phase, the effluent nitrate concentration was around 12 mg/L and the effluent phosphorus concentration exceeded 3 mg/L, as indicated in the graph in Figure 11. Acetate was added to control the effluent nitrates and phosphates, while alkalinity was added to maintain the pH. The acetate feed was stopped and 50 percent of the primary effluent passed to the anoxic zone. As can be seen in Figure 11, the effluent orthophosphorus increased to around 3 mg/L. Mixed liquor was then pumped from the anaerobic zone to the sidestream fermenter and allowed to flow back; the sludge retention time in the fermenter was around two days. The orthophosphates were gradually reduced to less than 0.3 mg/L, while the nitrate concentration was also reduced to less than 7 mg/L.

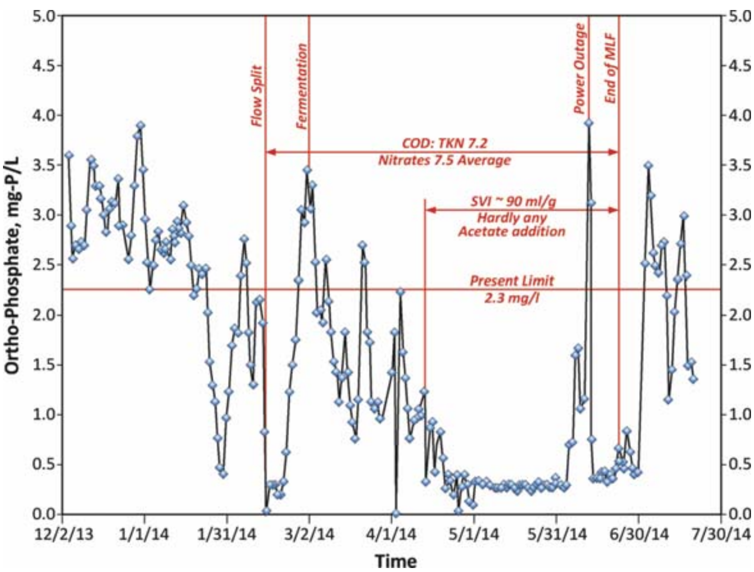
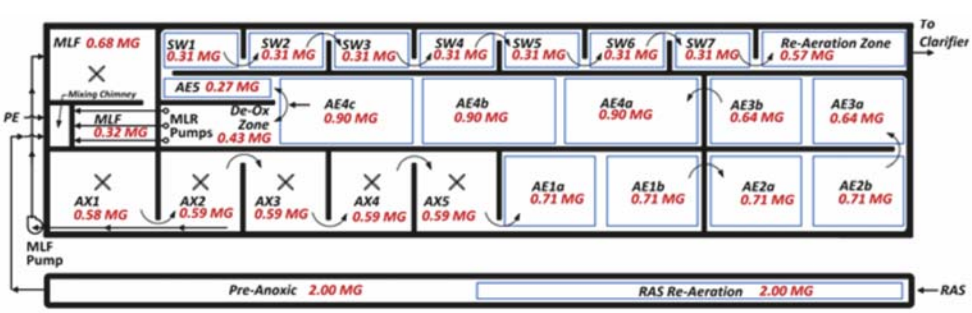


Figure 11. Results From Using Mixed Liquor Fermenter in Sacramento Pilot Plant (Barnard et al., 2015)

Figure 12. Sacramento Regional Single Biological Nutrient Removal Reactor Sidestream Enhanced Biological Phosphorus Removal Layout



There was little need to add acetate or alkalinity during the period when the operation was being directed. The sludge volume index (SVI) was also reduced to less than 90 mL/g during this period; previously high SVIs might have resulted from some acetate leaking through to the reaeration zone where it would encourage the growth of filamentous organisms (Jenkins et al., 1984). The MLF and primary effluent diversion were included in the design of the main plant, which could potentially save millions of dollars in chemicals per year. At the end of this experimental period there was a power outage, which increased the effluent orthophosphates (after which it recovered), but the average orthophosphates concentration was still well below the required goal of 2.4 mg/L. Then, the pilot plant operation was handed back to the previous operators.

The selected reactor configuration with SEBPR is shown in Figure 12.

Liverpool Wastewater Reclamation Facility

The Liverpool WRRF is in Medina County, Ohio, and has a rated plant capacity of 15 mgd. The facility currently has an A/O configuration with a Zimpro process for processing solids at the plant. Given the high energy requirements of this process, the county decided to upgrade the WRRF through a performance contract, with the goal of improving the liquid stream process and replacing the Zimpro system with a thermal hydrolysis system, followed by mesophilic digestion. Funding for the process improvements will come from the savings generated with the new process, which will be guaranteed by the energy performance service contractor.

During the design of the project, it was determined that the plant did not have sufficient nitrification capacity for the future conditions; however, through the implementation of SEBPR, the plant was able to repurpose tankage currently used as anaerobic fermentation zones to nitrification/denitrification (swing zones) and increase the plant capacity. The SEBPR will be achieved by repurposing the existing sidestream tank into a RAS fermenter that will be operated to control the SRT. Phosphorus recovery through the use of an Airprex system will also help the removal of phosphorus at the plant.

Figure 13 shows the SEBRP modifications at the Liverpool WRRF.

Conclusions

The SEBPR has emerged as a viable and reliable process sheet to achieve EBPR. It involves conditioning the PAOs in a sidestream reactor separated from the mainstream flow, which has deeper anaerobic conditions than traditional anaerobic zones in mainstream BNR processes. This set of conditions allows the development of a wider variety of PAOs, including *Tetrasphaera*, which does not need a supply of VFA and also has the ability to denitrify and grow under deeper and longer anaerobic conditions. These longer anaerobic conditions also seem to curb the growth of GAOs, producing a microbial population that is more robust for phosphorus removal.

The SEBPR has several advantages, including conditioning of the PAOs in a separate reactor, which minimizes wet weather flow impacts for EBPR, minimizes the dependence of rbCOD in the plant's influent for successful EBPR, and enhances the denitrification potential of the plant. The process is simple and operator-friendly.

There are over 70 plants worldwide that practice SEBPR (either intentionally or unintentionally), which shows the robustness of the process.

While SEBPR has just recently emerged as a substitute to regular EBPR, it was through an SEBPR configuration that the original enhanced biological theory of anaerobic zones in the mainstream was developed. Only recently, however, were the original observations of the SEBPR finally understood, and its implementation should lead to more reliable EBPR at WRRFs.

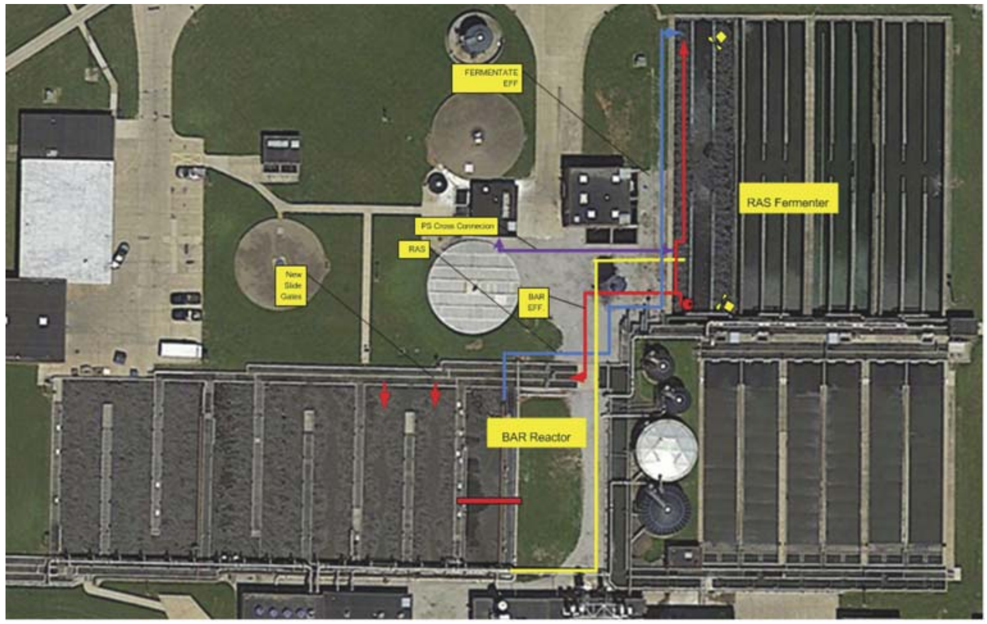


Figure 13. Liverpool Wastewater Reclamation Facility Sidestream Enhanced Biological Phosphorus Removal Layout

References

- Biowin Discussion: http://envirosim.com/files/downloads/WhatsNew40.pdf.
- Barnard, J.L. (1974). Cut P and N without chemicals. *Water & Wastes Engineering, Part 1*, (7), 33-36; Part 2, 11(8), 41-43.
- Barnard, J.L. (1976). A review of biological phosphorous removal in activated sludge process. *Water SA*, 2(3), pp. 136-144.
- Barnard, J.L. (1984). Activated primary tanks for phosphate removal. Water SA, 10(3), 121.
- Barnard, J.L. (1985). The Role of Full-Scale Research in Biological Phosphate Removal. *Proceedings of the University of British Columbia Conference on New Directions and Research in Waste Treatment and Residuals Management, Vancouver*, Canada, June 23-28.
- Barnard, J.L., M.T. Steichen, and D. Cambridge (2004). "Hydraulics in BNR Plants." *Proceedings of WEFTEC*, 2004.
- Barnard, J., Abraham, K. (2005). Key Features of Successful BNR Operation. IWA Specialized Conference, *Nutrient Management in Wastewater Treatment Processes and Recycle Streams*, Krakow, Poland 19-21 September, 2005.
- Barker, P. S. and Dold, P. L. 1997. General model for biological nutrient removal activated sludge system: model presentation. *Water Environment Research* 69(5):969–984.
- Barnard J., Houweling D., Analla H. and Steichen M. (2011). Fermentation of Mixed Liquor for Phosphorus Removal. *IWA Conference Nutrient Recovery and Management - Inside and Outside the Fence*, Miami, Fla., USA 2011.
- Barnard, J.L., W. Yu, M.T. Steichen and P. Dunlap (2015). Design of large BNR plant for state capital of California. *Proceedings of IWA Conference on Large Wastewater Treatment Plants*, Prague.
- Carson, K. (2012). Evaluation of Performance for a Novel Side Stream Enhanced Biological Phosphorus Removal Configuration at a Full-Scale Wastewater Treatment Plant. M.S. thesis, University of Colorado.
- Dunlap, P., Shaw, A., Barnard, J., Phillips, H., Wilson, D., and Abraham, K., (2014). Innovative Modelling in the Design of the Sacramento Regional Wastewater Treatment Plant for Biological Nutrient Removal. 4th IWA/WEF Wastewater Treatment Modeling Seminar, Spa, Belgium 2014, pp. 270-277.
- Dunlap, P., Martin, K., Stevens, G., Tooker, N., Barnard, J., Gu, A., Takacs, I., Shaw, A., Onnis-Hayden, A., Li, Y., (2016). Rethinking EBPR: What do you do when the model will not fit real-world evidence? 5th IWA/WEF Wastewater Treatment Modeling Seminar, Annecy, France 2016, pp. 39-62.
- Fuhs, G.W. and Chen, M. (1975), Microbiological basis of phosphate removal in the activated sludge process for the treatment of wastewater. *Microbiol. Ecol.*,2(2), 119-138.
- Gerber, A., Mostert, E.H., Winter, C.T. and de Villiers, R.H. (1986). The effect of acetate and other short-chain compounds on the kinetics of biological nutrient removal processes. *Water SA*, 12, 7-12.
- Kalb, K. and Roeder, M. (1992), Nutrified sludge in the OWASA system. Presented at Annual Conference of the North Carolina Water and Pollution Control Association, Charlotte, N.C.
- Kristiansen, R., Nguyen, H. T. T., Saunders, A. M., Nielsen, J. L., Wimmer, R., Le, V. Q., Nielsen, P. H. (2013). A metabolic model for members of the genus *Tetrasphaera* involved in enhanced biological phosphorus removal. The *ISME Journal*, 7(3), pp. 543–554.
- Lamb, J., (1994). Wastewater treatment with enhanced biological phosphorus removal and related purification processes. *U.S. Patent US 5288405A*. Feb. 22, 1994.
- Levin, G.V., Topal, G.J. and Ternay, A.G. (1975). Operation of full-scale biological phosphorus removal plant. *Journal WPCF*, 47, 577.
- Nguyen, H. T. T., Le, V. Q., Hansen, A. A., Nielsen, J. L., and Nielsen, P. H. (2011). High diversity and abundance of putative polyphosphate-accumulating Tetrasphaera-related bacteria in activated sludge systems. *FEMS Microbiology Ecology*, 76(2), pp. 256–267.

Shanin Speas-Frost

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Work title and years of service.

I have been the drinking water state revolving fund (DWSRF) program administrator and division of water restoration assistance outreach supervisor for three years. I've been with the Florida Department of Environmental Protection (FDEP) for over 19 years, previously working as the water reuse coordinator and the wastewater treatment wetlands coordinator in the domestic wastewater program.

What does your job entail?

The DWSRF program provides financial savings for projects that benefit protection of public health and disadvantaged communities with their drinking water needs. The DWSRF program is by far FDEP's largest funding program, making \$100-200 million available, primarily to local governments and small communities, for drinking water projects each year.

What education and training have you had?

I have a bachelor's degree in environmental engineering from the University of Florida (Go Gators!) and a master's in business administration from Florida State University. I'm also a professional engineer in Florida.

What do you like best about your job?

The people I work with is my favorite thing about my job. I like being a supervisor as I am a people person. I also like being in the water industry and helping provide communities with the funding to do important water infrastructure projects. Additionally, being in charge of outreach for my division, I enjoy variety in what I do. No two days are the same; one day I am researching design-build procurement laws, and the next I am hiking through the woods with my colleagues to photograph a newly acquired spring as part of a grant project.

What professional organizations do you belong to?

I belong to AWWA, FWEA, WateReuse Association, and the Water Research Foundation.

How have the organizations helped your career?

Networking and education. I love being plugged into a community, as well as my career. The more people I know in the business, the more engaged I have become. These professional organizations provide that platform for engagement.

What do you like best about the industry?

Everyone, everything needs water. It feels important; it *is* important. It's also full of challenges. I like the complexity of the issues and that there is no easy solution.

What do you do when you're not working?

I mostly shuttle my two children, ages 11 and 9, to their competitive soccer, dance, and swim events around town, as well as out of town. I love photography, being in nature, and hanging out with my friends.

I am also a runner and triathlete, having recently completed my first full Ironman in Chattanooga last September. That's a 2.4-mile down-river swim, a 116-mile bike ride over the hills of North Georgia and back, and a 26.2-mile double-loop run around the picturesque neighborhoods of Chattanooga; and by run, I mean a zombie-like shuffle into the wee hours of the night toward the finish line. Why, yes, I am crazy! It only took me 15 hours and 45 minutes to complete and I currently have no immediate plans for a repeat.

Shanin with (left to right) her children, Xander Frost and Lita Frost, and husband Andrew Frost.