TECHNICAL PROCESS DESCRIPTION

BioMix-DC

Enhanced Anaerobic Mixing System

EnviroMix

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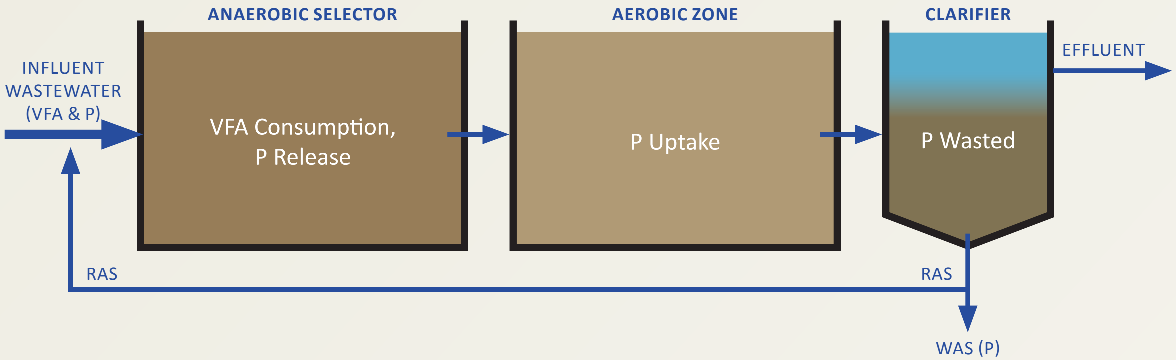
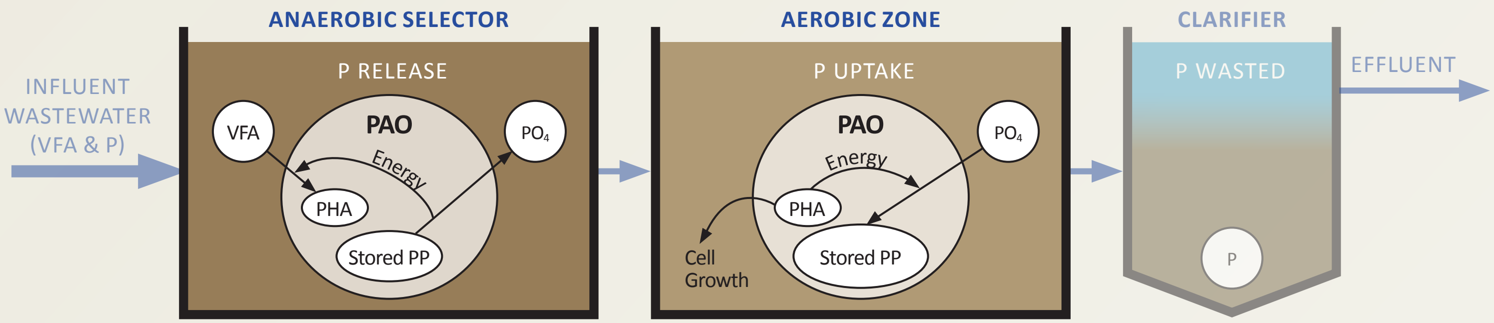
ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL

Many wastewater treatment plants (WWTPs) are required to reduce phosphorus discharges to address nutrient impairment of waterways. To reach permit limits, designers have a range of available processes to utilize, including chemical and biological phosphorus removal. Chemical removal can be costly and generates additional sludge, while **enhanced biological phosphorus removal (EBPR)** is a more sustainable and cost effective alternative.

- EBPR relies on the selection and proliferation of a specialized microbial population capable of taking up phosphorus in greater amounts than their normal metabolic growth requirements.
- EBPR uses sequential anaerobic and aerobic environments to provide conditions that encourage the growth of these specialized **phosphorus accumulating organisms (PAOs)**.
- PAOs must first be conditioned by exposure to **volatile fatty acids (VFA)** under anaerobic conditions, then phosphorus uptake occurs under aerobic conditions.
- PAOs store excess phosphorus in their cell mass, and phosphorus is removed with the waste sludge.



ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL



Reactions in the Anaerobic Selector

- In the anaerobic selector, the PAOs take up and store VFA as carbon compounds such as polyhydroxyalkanoates (PHAs).
- The energy required for PHA accumulation is provided by the separation of stored polyphosphate (PP).
- The splitting of energy-rich PP bonds results in the release of phosphorus into the mixed liquor.

Reactions in the Aerobic Zone

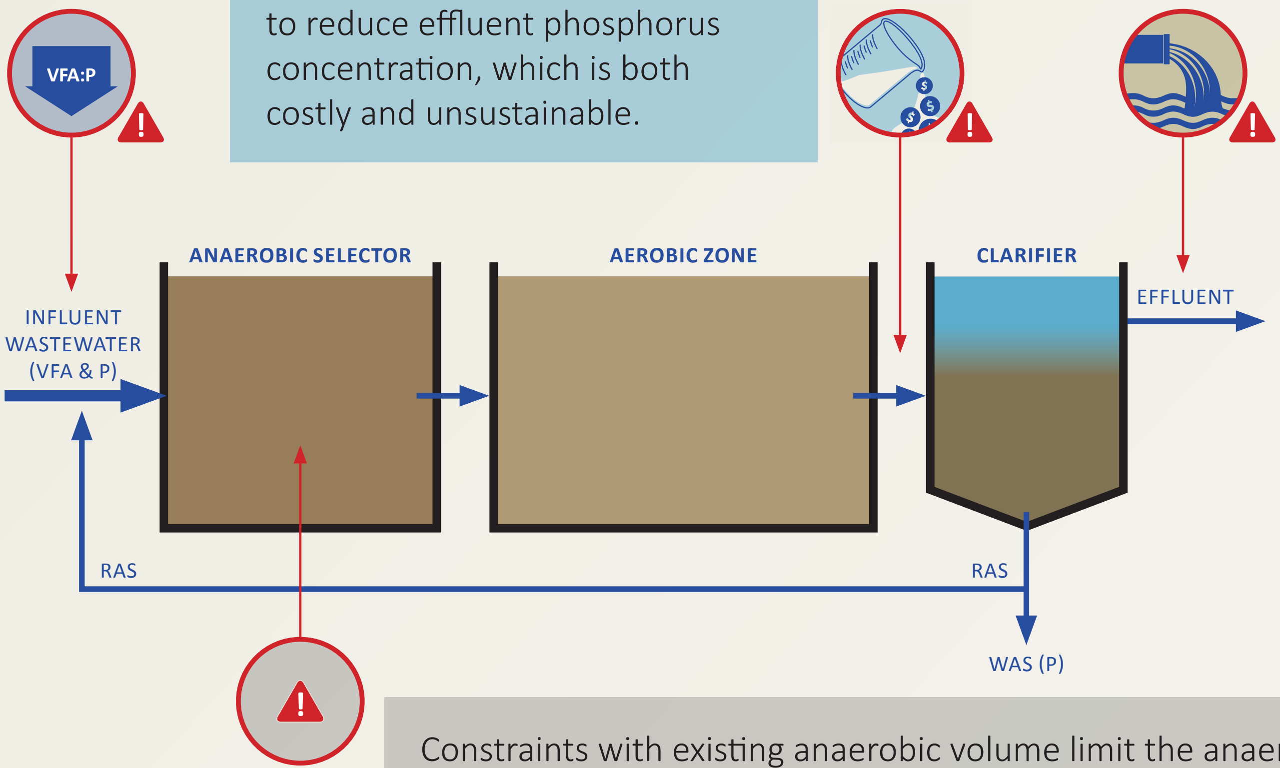
- Under aerobic conditions, PAOs use PHAs as a source of carbon and energy for metabolism and cell growth.
- PAOs restore their supplies of glycogen and PP in the aerobic zone.
- To replenish their stored PP, PAOs take up excess phosphate from the mixed liquor.
- Uptake of phosphorus in the aerobic zone is dictated by the amount of VFA stored by PAOs and the energy/ phosphorus released in the anaerobic selector.

CHALLENGES

WWTPs aiming to improve EBPR may face the following challenges.

Unfavorable ratio of influent VFA to phosphorus results in poor biological phosphorus removal.

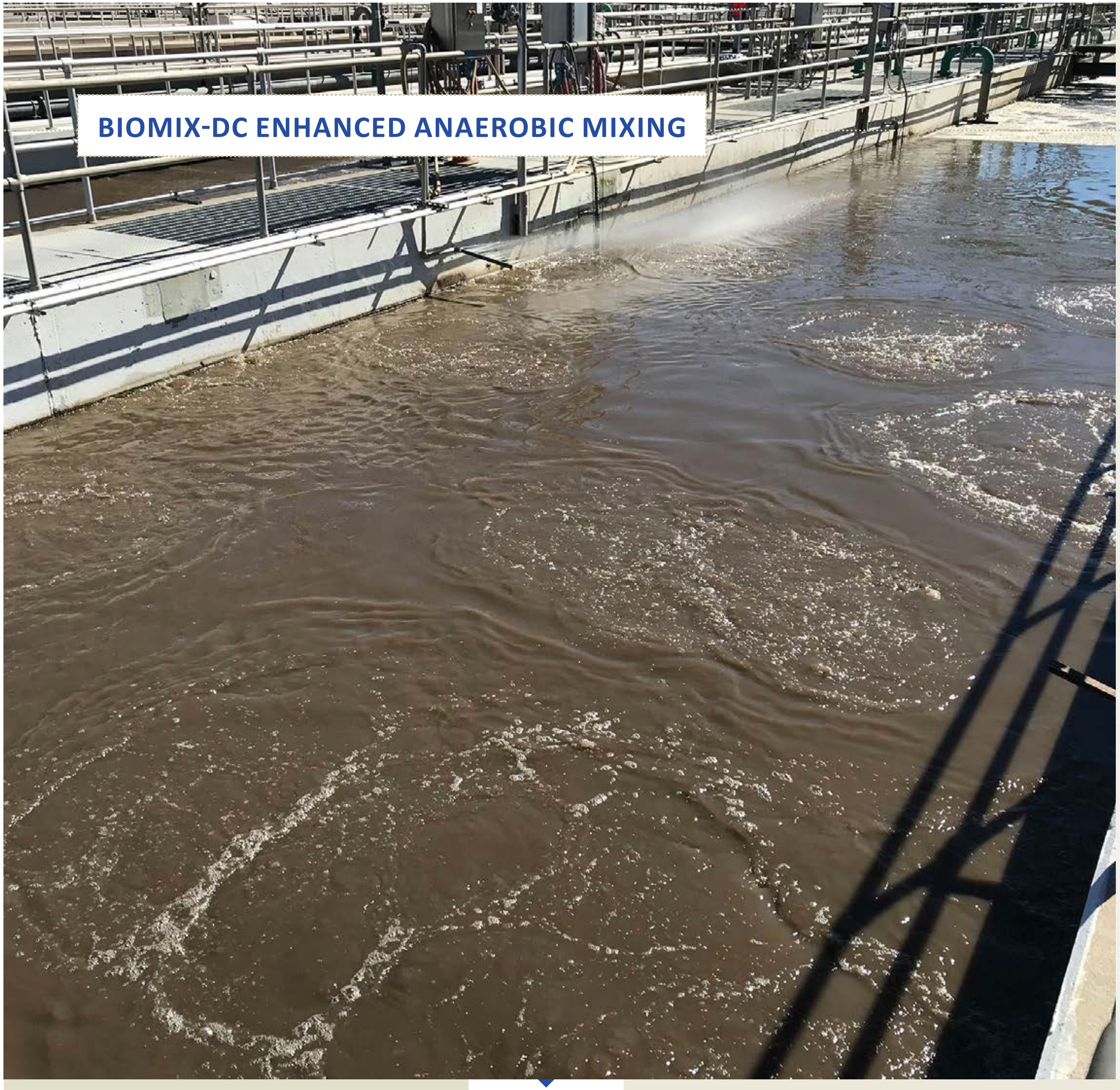
Influent carbon limitations lead to plants adding chemical coagulants to reduce effluent phosphorus concentration, which is both costly and unsustainable.



Inconsistent effluent phosphorus levels can lead to regulatory violations and harm the environment.

Constraints with existing anaerobic volume limit the anaerobic solids retention time (SRT) and fermentation potential, hindering phosphorus removal.

BIOMIX-DC ENHANCED ANAEROBIC MIXING



- Maximizes **VFA formation** and utilization
- Enhances biological phosphorus removal for **consistently low effluent phosphorus**
- Provides **energy savings of 90%** or greater
- **Minimizes chemical addition** and sludge production

ANAEROBIC FERMENTATION

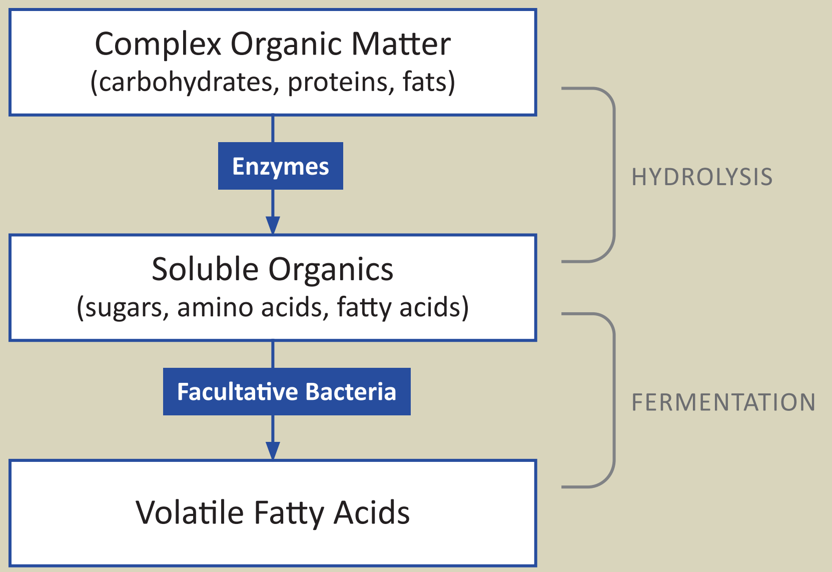
Why is fermentation important?

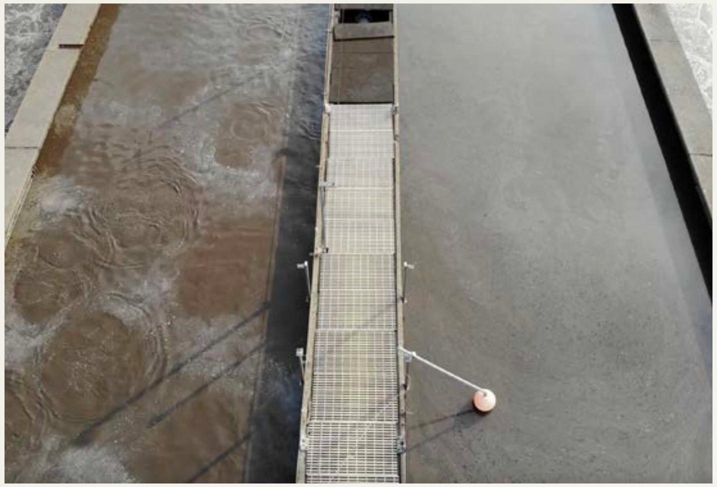
- EPBR success is primarily determined by influent wastewater characteristics and the amount of VFA present in proportion to the amount of phosphorus to be removed.
- VFA formation is maximized through hydrolysis and fermentation:
  - Complex organic matter such as carbohydrates, proteins, and fats are broken down by enzymes to create soluble organics such as sugars and acids.
  - Facultative bacteria then convert soluble organics to VFA.

Ways to encourage fermentation

To encourage fermentation in the anaerobic selector, it is important to maintain optimal anaerobic conditions by:

- Ensuring negative oxidation reduction potential (ORP)
- Allowing mixed liquor suspended solids (MLSS) to settle and accumulate
- Increasing anaerobic SRT



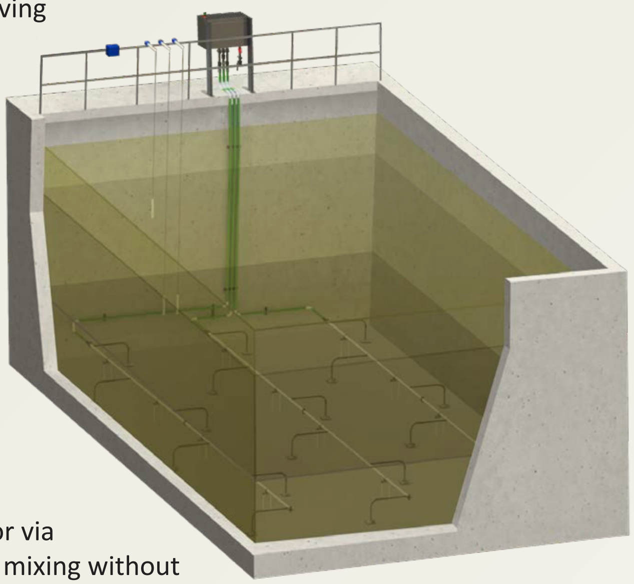


HOW IT WORKS

BioMix-DC Enhanced Anaerobic Mixing System optimizes the anaerobic fermentation process by selecting the right frequency and duration of the mixing cycle.

DEEP CYCLE

Long periods without mixing allow solids to accumulate, increasing anaerobic SRT and driving down ORP.

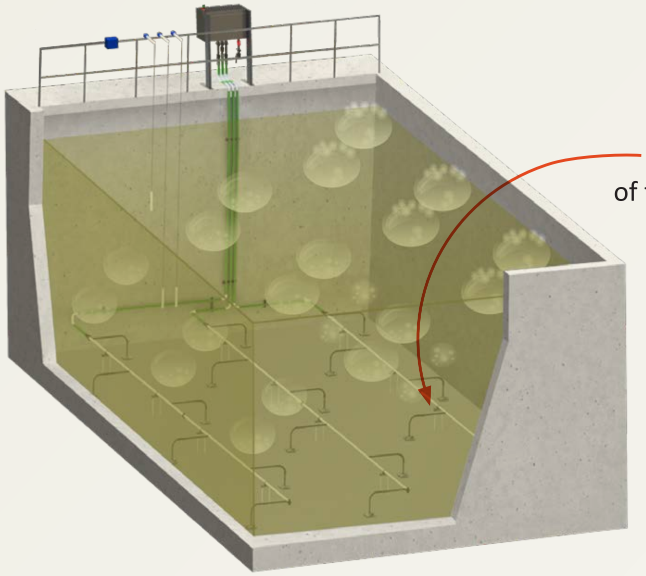


A longer anaerobic SRT combined with a lower ORP environment increases VFA production, enhancing biological phosphorus removal.

VFA are transported throughout the reactor via intermittent pulses of mixing without disrupting the fermentation blanket.

MIXING CYCLE

Mixing destratifies the selector and quickly resuspends solids.

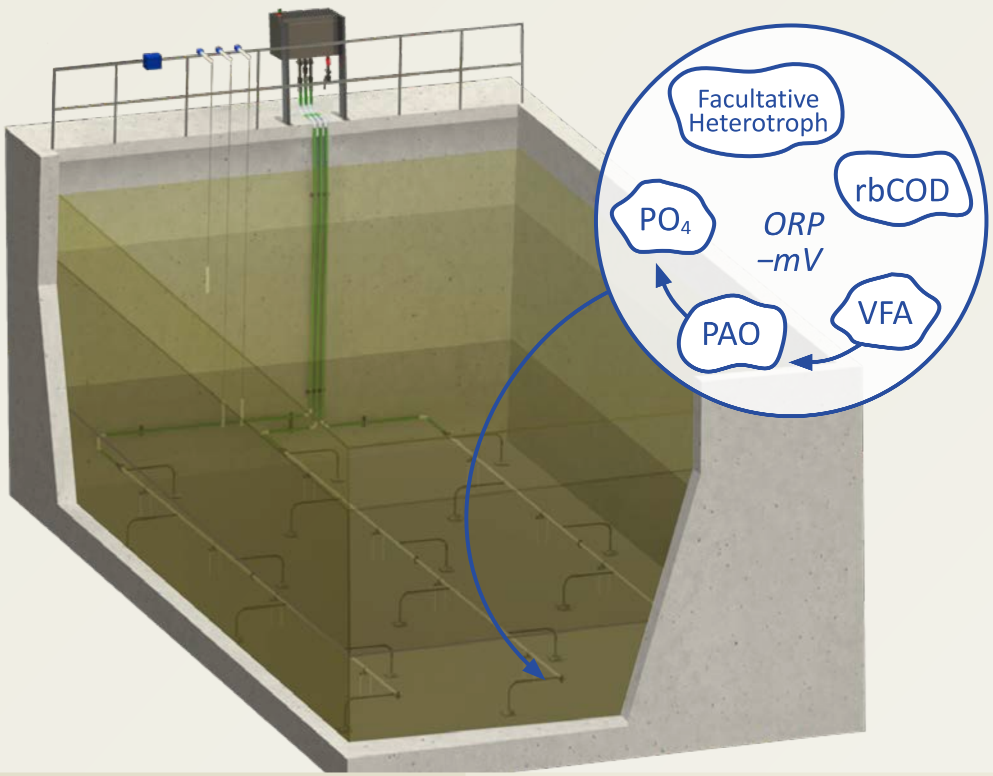


Nozzles near the floor of the tank release short bursts of compressed air, providing effective mixing.

Periods of mixing are important to homogenize the substrate and microorganisms.

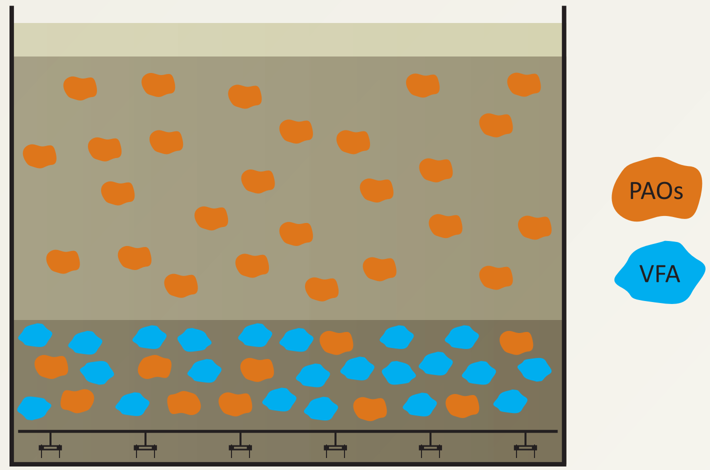
DEEP CYCLE

- **Long periods without complete mixing cause the anaerobic selector to stratify and accumulate fermentable substrate.**
- Accumulating solids create a higher concentration sludge fermentation blanket.
- **The fermentation blanket drives down ORP and increases VFA production.** It also increases anaerobic SRT, generates surplus VFA, and enhances biological phosphorus removal.



During the non-mixed, deep cycle:

- The fermentation blanket forms and VFA production resumes.
- PAOs in the blanket begin releasing phosphorus in exchange for VFA consumption.
- When the PAOs have released all their stored phosphorus, VFA concentrations begin to increase in the blanket.
- In this environment, the PAOs within the blanket are full, and the PAOs outside the blanket need access to the VFA.



DEEP CYCLE: VFA GENERATION

Total suspended solids (TSS) data show stratified layers of solids, confirming the establishment of a fermentation blanket. In BioMix-DC installations, the bottom layers have average concentrations that are roughly 10 times the surface concentrations.

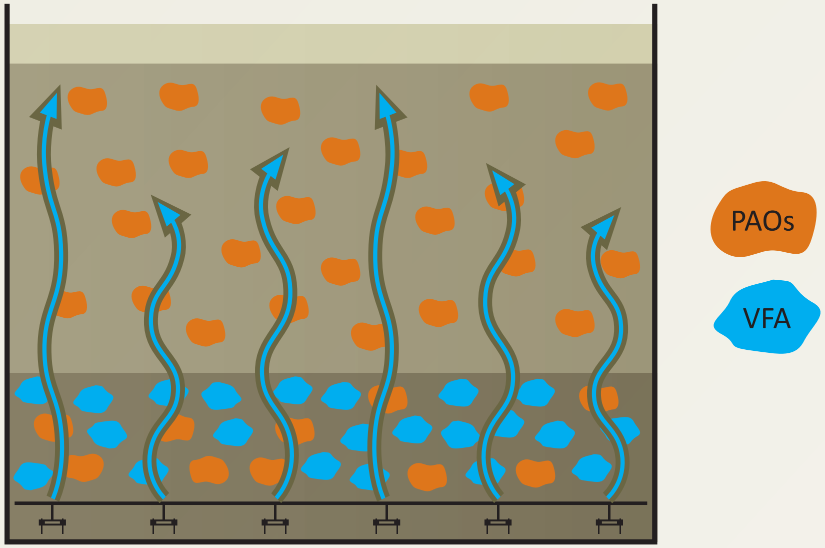
VFA — or soluble chemical oxygen demand (COD) — measurements show that BioMix-DC generates ten times the concentration of VFA in the fermentation blanket as in the bulk liquid. This surplus indicates that BioMix-DC delivers VFA generation beyond what the PAOs can consume.

When PAOs consume VFA, they release phosphorus. **Concentrations of orthophosphate** in the fermentation blanket have been found to be 10 to 100 times higher than concentrations in the influent or the bulk liquid. Subsequent phosphorus uptake in the aerobic zones completes the bio-P process.

	TSS Levels	Soluble COD	P Release
Surface Layer	500-2,000 mg/L	NA	NA
Bullk Liquid	3,000-5,000 mg/L	50 mg/L	1-5 mg/L
Fermentation Blanket	>10,000 mg/L	500-1,000 mg/L	20-150 mg/L

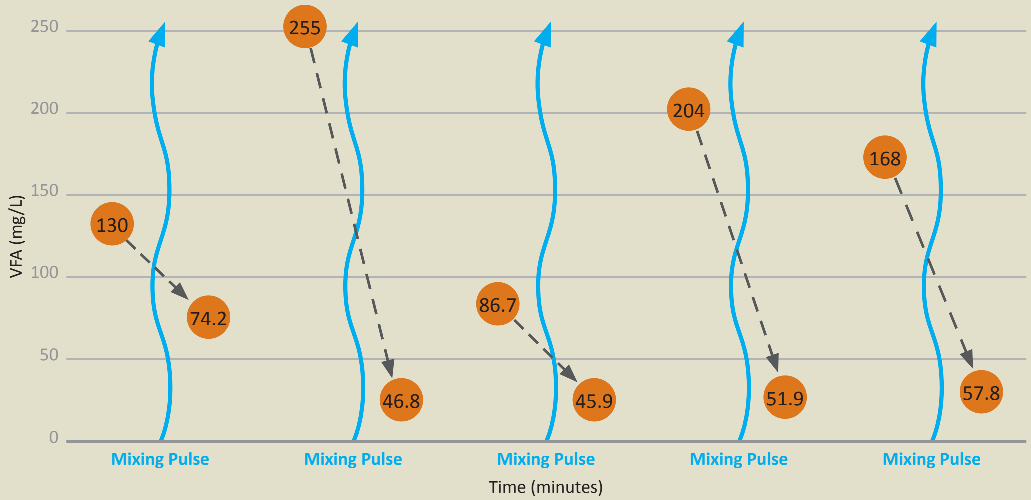
DEEP CYCLE: VFA TRANSPORT

- Surplus VFA **enhance bio-P** and create a stable process.
- **VFA must be accessible to the PAOs** throughout the anerobic selector, not only in the fermentation blanket.
- BioMix-DC provides **low-intensity intermittent pulses** of mixing to transport the VFA to the PAOs in the bulk liquid without disrupting the fermentation blanket.
- This proprietary approach results in better bio-P and lower effluent soluble phosphorus.



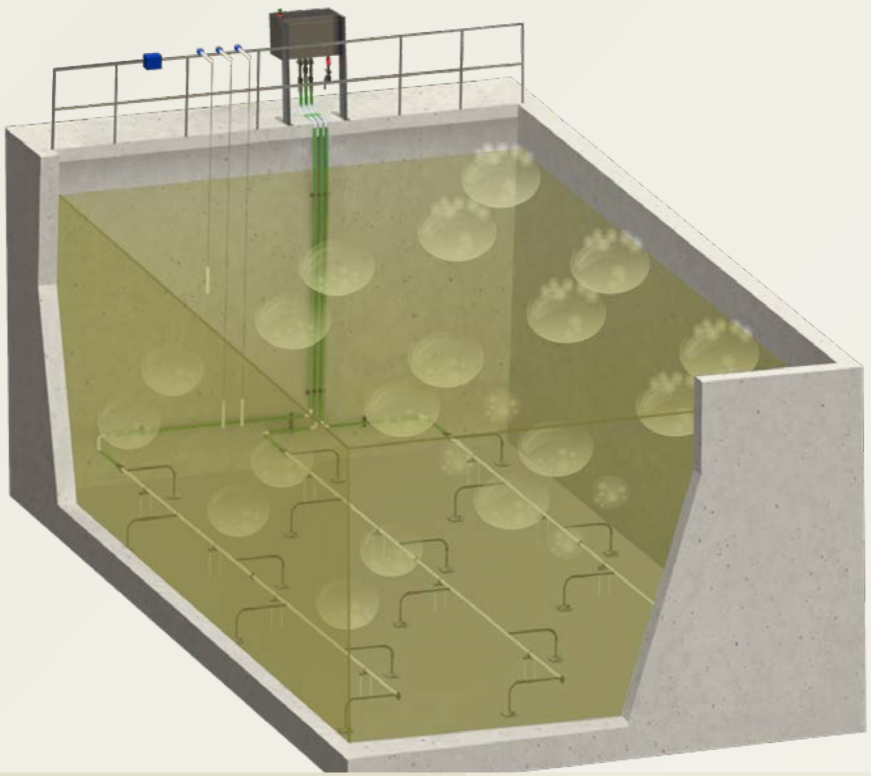
VFA in the Fermentation Layer Before and After Mixing Pulse

- It is non-optimal if the accumulated VFA cannot be adequately transported to the PAOs for utilization.
- This chart shows VFA measurements in the fermentation blanket immediately prior to the intermittent pulses of mixing and again immediately after. The resulting drop in VFA concentration indicates VFA transport from the fermentation blanket to the bulk liquid.

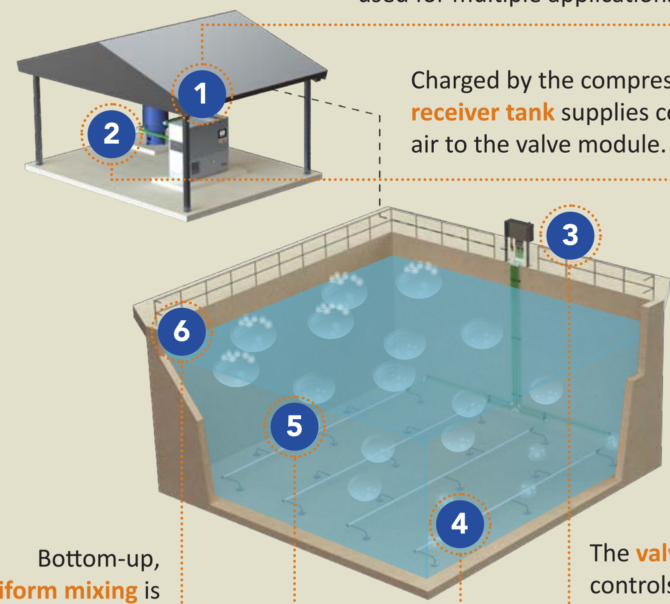


MIXING CYCLE

- Resuspending solids is important to **homogenize the substrate** and microorganisms to refuel the fermentation process.
- Rapid resuspension **de-stratifies the selector** within minutes.
- **BioMix Compressed Gas Mixing** generates large compressed gas volumes that **expand upward and outward**.
- Expanding bubbles provide **controlled turbulence**, fluid displacement, and circulatory currents.



BioMix Compressed Gas Mixing



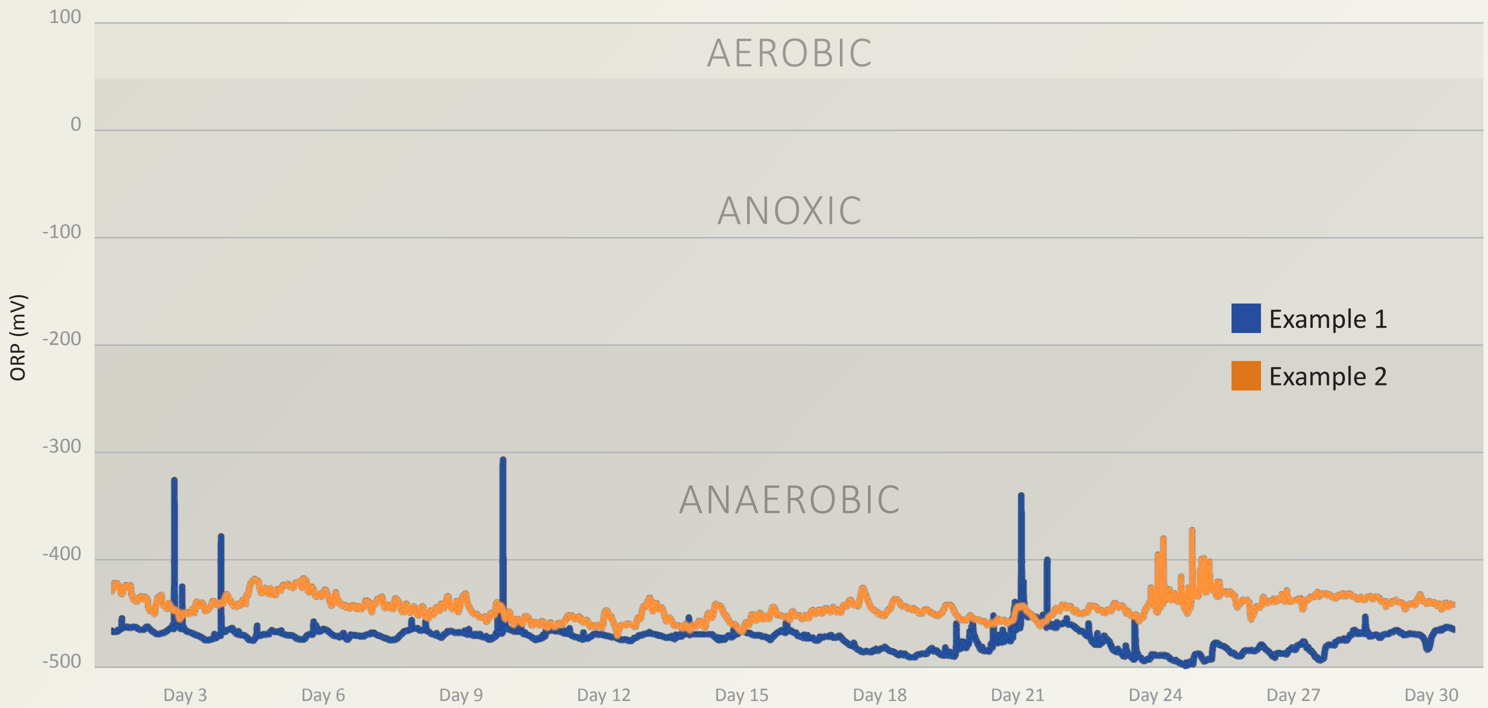
1. A **centralized compressor** can be used for multiple applications.
2. Charged by the compressor, the **receiver tank** supplies compressed air to the valve module.
3. The **valve module** controls firing parameters of pressure, frequency, duration, and sequence.
4. **Engineered nozzles** near the floor of the tank distribute short bursts of compressed air.
5. **Large air volumes** expand upward and outward without introducing measurable oxygen.
6. Bottom-up, **uniform mixing** is provided in basins of any geometry or floor slope.

MIXING CYCLE

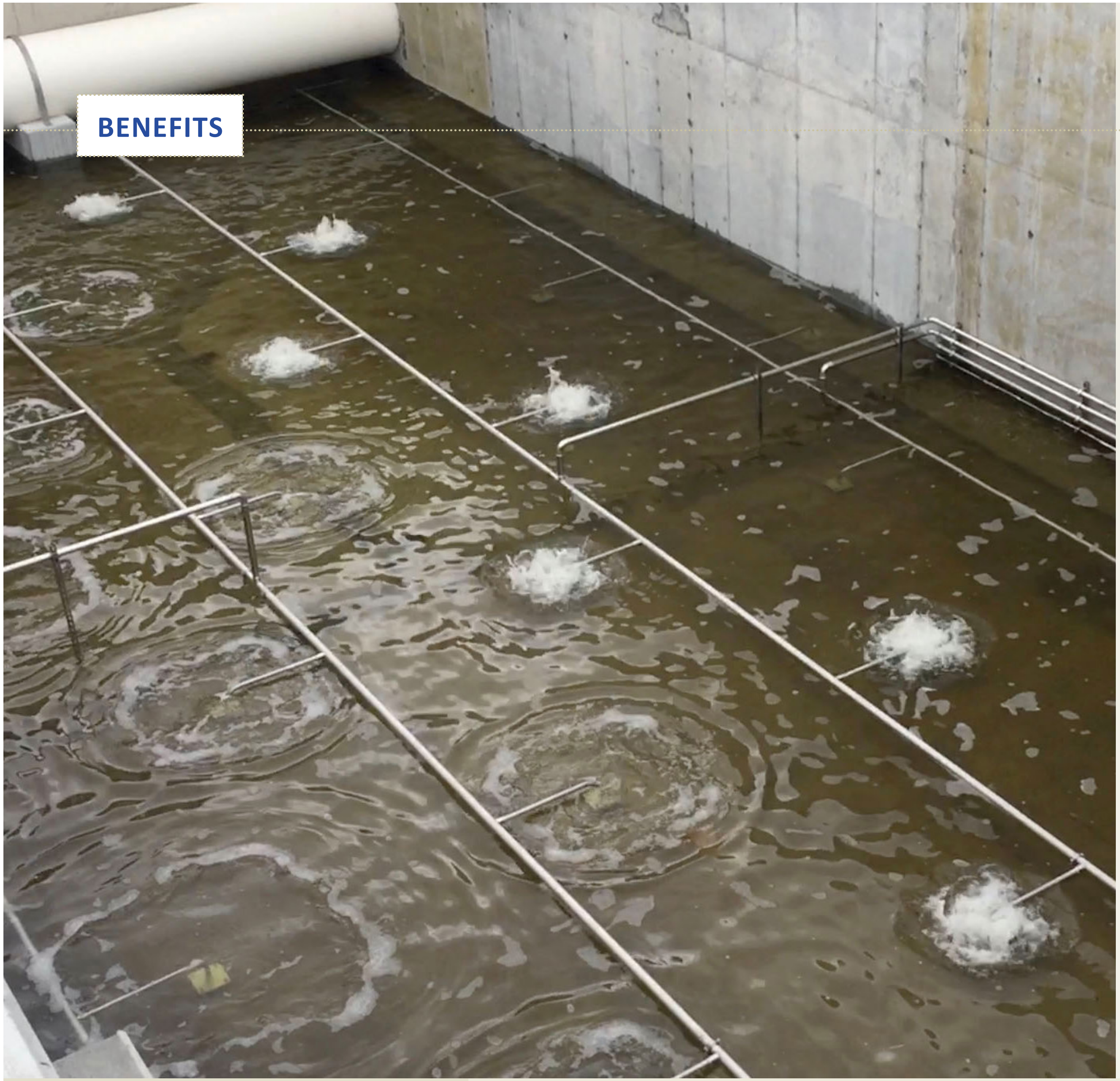
- To achieve low effluent soluble orthophosphate, **an anaerobic selector with a strict anaerobic environment is important**.
- A strict anaerobic environment means that there is no free oxygen nor any chemically bound oxygen like nitrate.
- BioMix-DC is able to produce a strict anaerobic environment with an average ORP of less than industry recommended-200 mV.

ORP Measurements

- True anaerobic conditions are critical to promote the growth of PAOs.
- ORP measurements in anaerobic selectors mixed with BioMix Compressed Gas Mixing demonstrate **consistently low ORP levels below -300 mV.**



BENEFITS

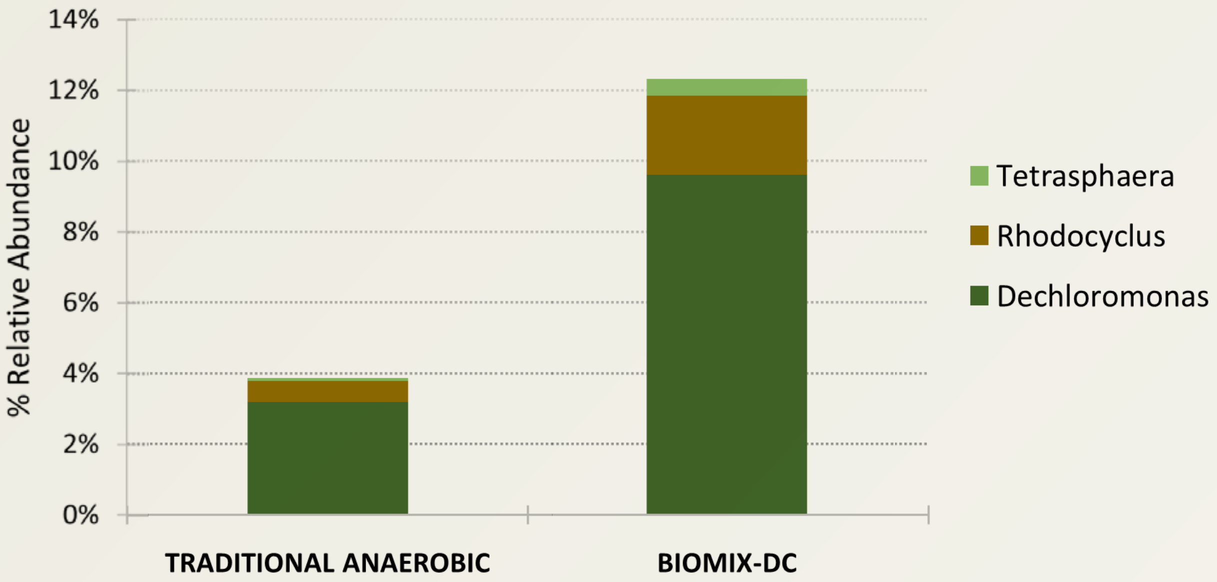


- Ensures **PAOs are never VFA limited**
- **Delivers consistently low effluent** soluble orthophosphate
- Creates energy **savings of 90%** or greater compared to continuous mechanical mixing in anaerobic selectors
- Significantly **reduces chemical addition**

PROLIFERATION OF PAOs

- One key to EBPR is the production of surplus VFA, which leads to the proliferation of PAOs, whereby PAOs are never VFA limited.
- DNA analysis can be used to determine relative population abundance of PAOs.
- The WWTP represented in the chart below has two parallel separated A/O activated sludge processes, one operating with a conventionally mixed anaerobic selector and the other with BioMix-DC.

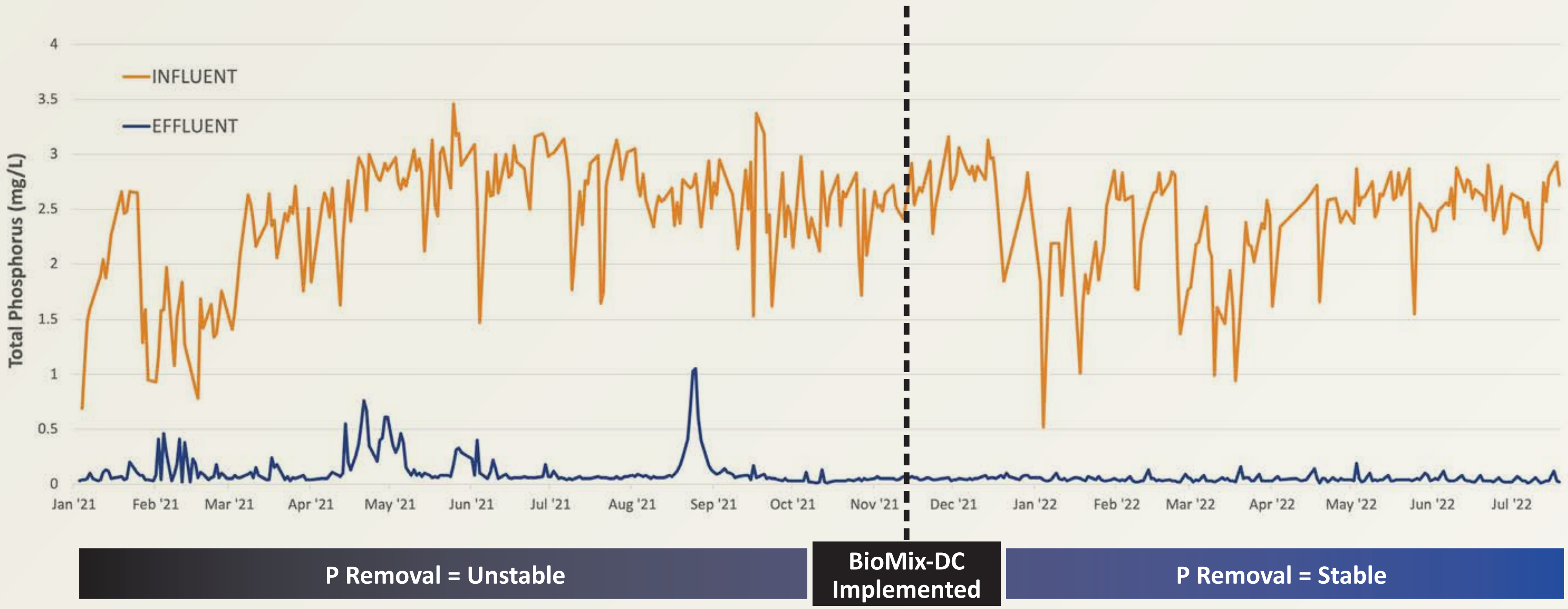
DNA Analysis: PAOs Relative Abundance



- Samples were taken from both sludge systems.
- The A/O process with traditional anaerobic selector mixing showed only about 4% PAO relative abundance, whereas the system with BioMix-DC showed more than 12% .
- Dechloromonas are often abundant in EBPR plants and may also be important for nitrogen removal, specifically denitrification.

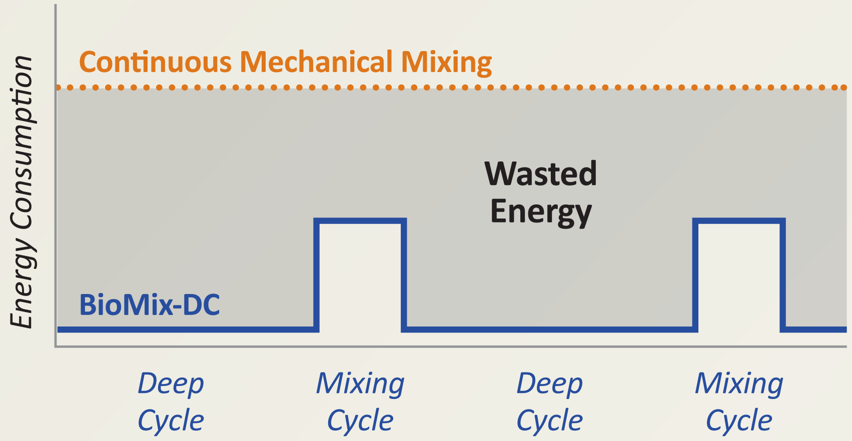
LOWER EFFLUENT P

- The end-goal of EBPR is to produce low levels of effluent soluble orthophosphate.
- The graph shows the influent total phosphorus represented by the orange line and the effluent orthophosphate represented by the dark blue line.
- The vertical dashed line represents when the conventional A/O process was converted to BioMix-DC operation.
- The removal efficiency improved to over 95% orthophosphate removal and the consistency of removal improved greatly.

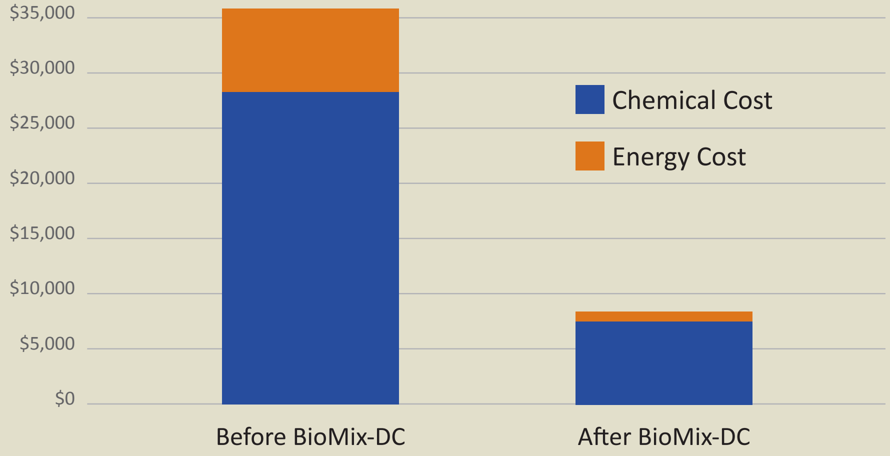


OPERATIONAL SAVINGS

- BioMix-DC creates net energy savings of 90% or greater compared to continuous mechanical mixing in anaerobic selectors.
- Core BioMix technology uses 40-60% less energy than conventional mixers.
- Energy consumption is nearly eliminated during the deep cycle.



Energy & Chemical Cost Savings



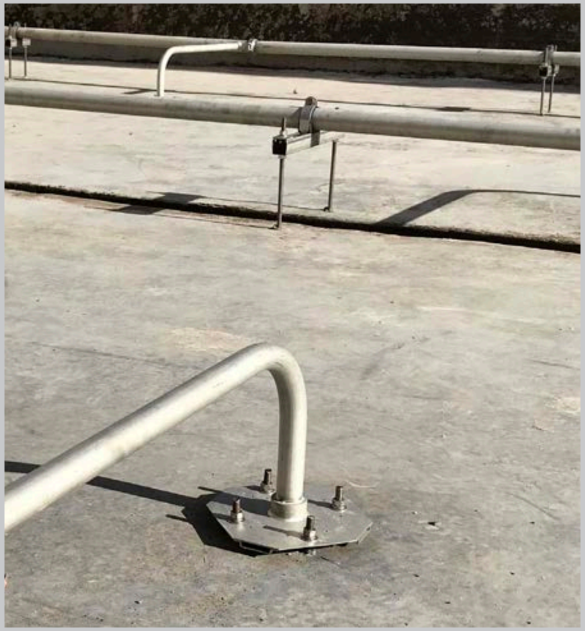
At one midwest treatment plant, BioMix-DC delivers:

- 89% reduction in power consumption.
- 73% reduction in ferric consumption.

CRITICAL FACTORS

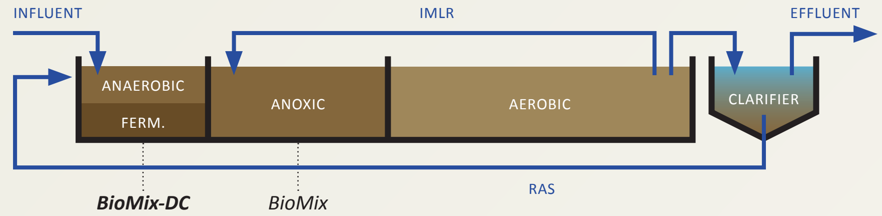
Research at numerous WWTPs confirms that BioMix-DC successfully enables these critical factors for strengthening EBPR:

- Anaerobic selector with low ORP
- Fermentation blanket
- VFA generation
- VFA transport
- Phosphorus release
- Surplus VFA leading to proliferation of PAOs
- Lower effluent P
- Lower chemical usage

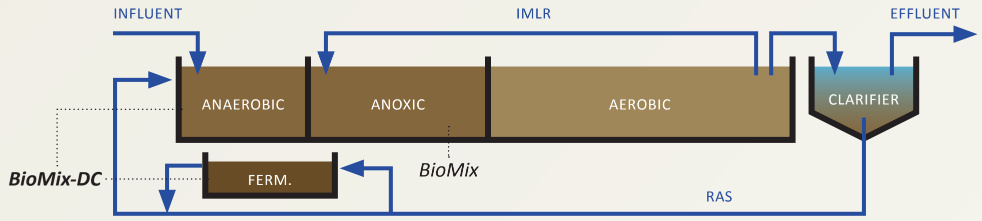


CONFIGURATION OPTIONS

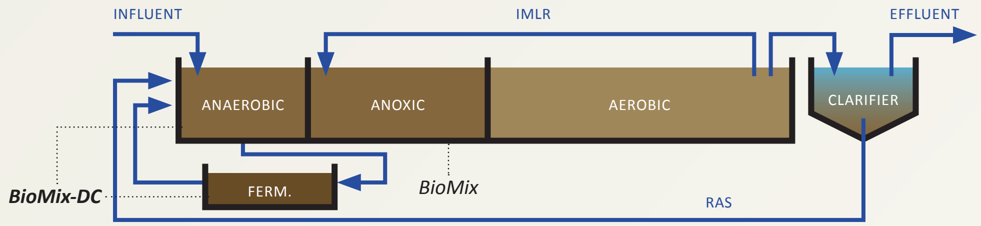
In-Line Mixed Liquor Fermentation is ideal for retrofitting existing anaerobic selectors or repurposing excess aerobic volume with 1-2 hours of hydraulic retention time (HRT) to generate more VFA and improve the EBPR process.



Side Stream RAS Fermentation utilizes a side stream reactor where 10-15% of return activated sludge (RAS) is used as the substrate for hydrolysis and fermentation to produce VFA, which are then fed to the mainstream anaerobic selector. The HRT in a side stream RAS fermentation tank may be between 30-48 hours.



Side Stream Mixed Liquor Fermentation uses a side stream reactor as well, where mixed liquor from the anaerobic selector is sent to the MLSS fermenter with an SRT of 2 days and HRT of 30 minutes. This is often used when the existing anaerobic selectors need more volume to generate VFA.



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