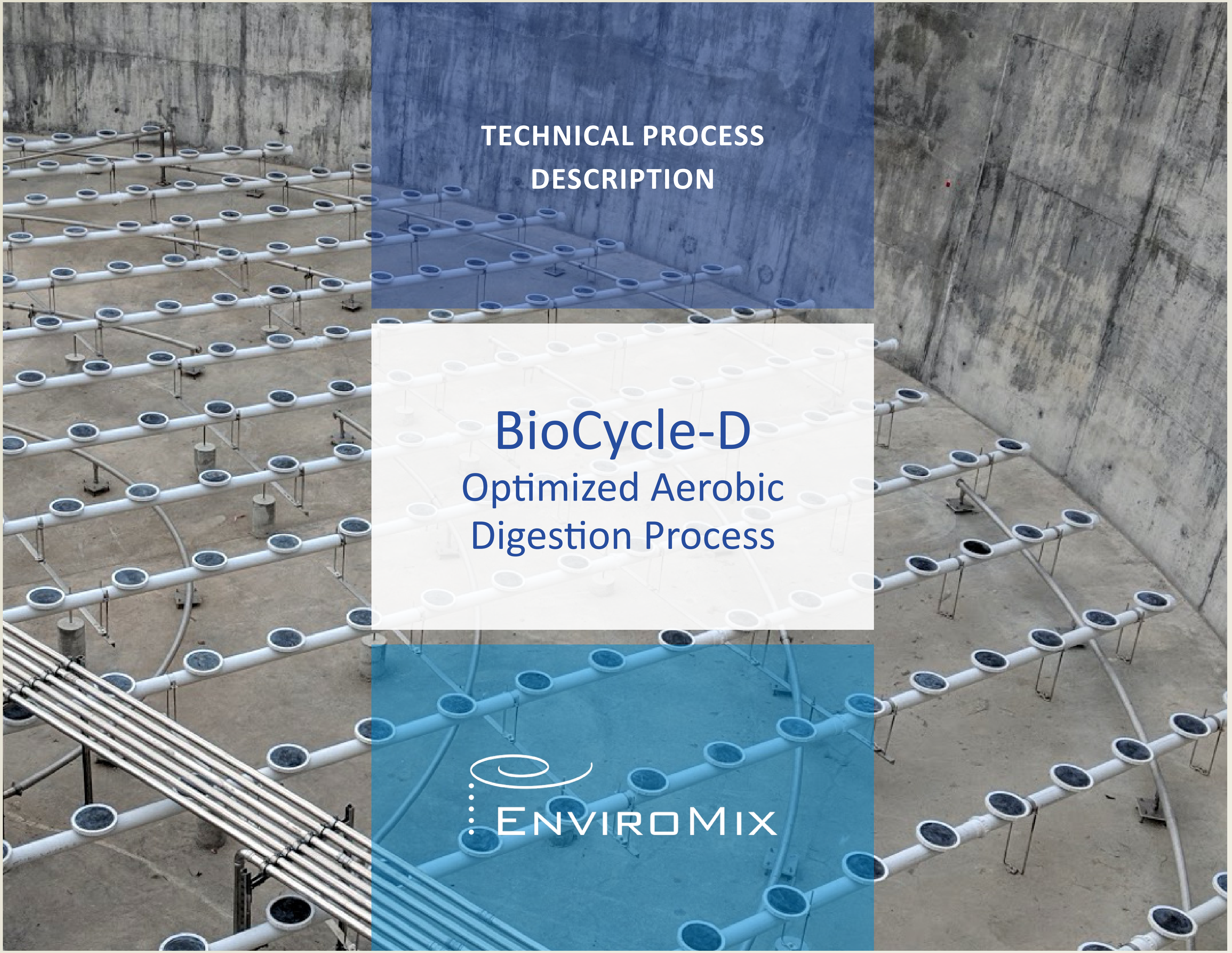


TECHNICAL PROCESS DESCRIPTION

BioCycle-D

Optimized Aerobic Digestion Process

EnviroMix

CONTENTS

Aerobic Digestion

Overview

Conventional Approach

Challenges

Solutions

BioCycle-D

Introduction

Overview

Process

Applications

Modes of Operation

AEROBIC DIGESTION

- Aerobic digestion is a common treatment technology used at small to medium sized plants for the treatment of waste activated sludge (WAS).
- **The objective of aerobic digestion is to treat the sludge for disposal**, and for those trying to meet Class B biosolids, further reduce volatile solids (VS) and pathogens to ensure the sludge is suitable for land application.
- In the aerobic digestion process, when no primary sludge is added, there is no "food" added to the sludge. Therefore, the process oxygen requirement is for the breakdown of the sludge only.

Endogenous Respiration

- **VS is destroyed through a process called endogenous respiration**, where some of the micro-organisms begin to decay and are consumed by other micro-organisms.
- The process of endogenous respiration produces carbon dioxide and ammonia, which then nitrifies. Nitrification consumes alkalinity and more oxygen as as ammonia is converted into nitrate.
- Uncontrolled nitrification will eventually lead to a drop in pH.
- Endogenous respiration reactions:

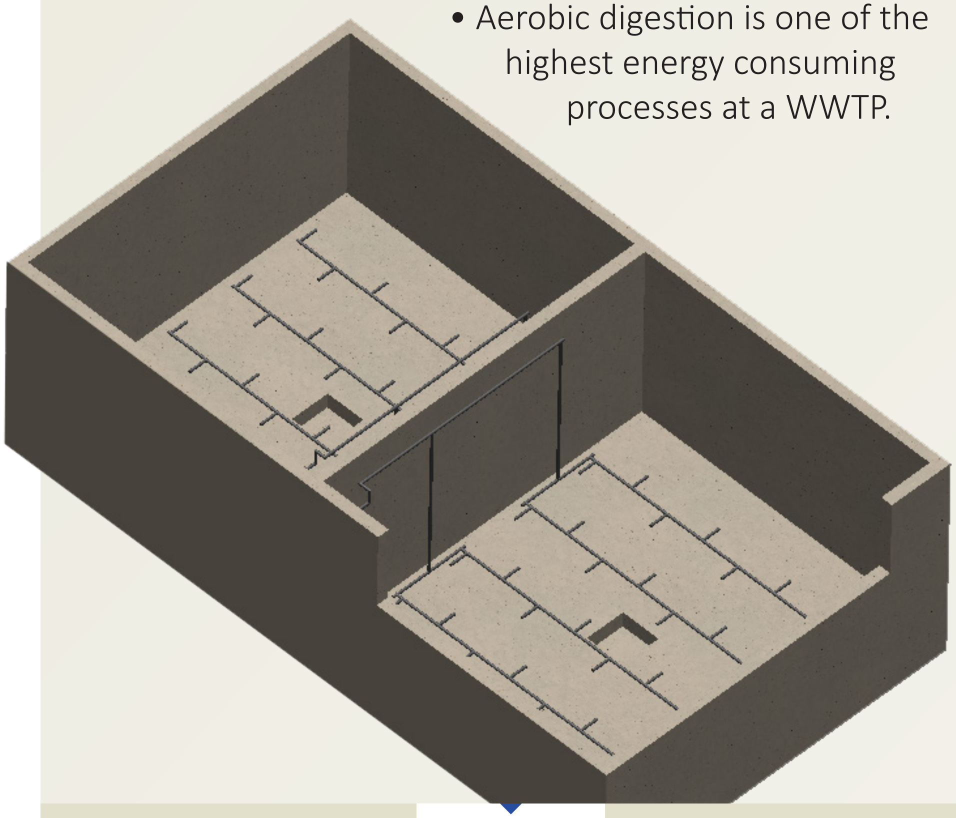
$$BOD_{Bugs} + O_2 \rightarrow Less\ BOD_{Bugs} + CO_2 + H_2O + NH_3$$

$$NH_3 + O_2 + Alkalinity \rightarrow NO_2\text{-}$$

$$NO_2\text{-} + H_2O + Alkalinity \rightarrow NO_3\text{-}$$

CONVENTIONAL APPROACH TO AEROBIC DIGESTION

- In a typical aerobic digestion process, **aeration is used to both provide the oxygen needed for endogenous respiration and to completely mix the tank**.
- A typical retention time is 10-60 days.
- There is little to no automated process control or instrumentation feedback, and operators manually run the process.
- Aerobic digestion is one of the highest energy consuming processes at a WWTP.



Land Application and Surface Disposal of Biosolids

- The federal regulation for land application in the U.S. is 40CFR503, and aerobic digestion can be used to meet Class B biosolids.
- The treatment objectives for Class B are to destroy pathogens and to reduce vector attraction.
- The Class B requirement for pathogen destruction is based on retention time at specific temperatures or a specific reduction in pathogen density.
- The requirement for vector attraction reduction is based on VS destruction, at least 38%, or specific oxygen uptake rate (SOUR).

CHALLENGES WITH THE CONVENTIONAL APPROACH

When the energy or air demand required for the biology is LESS than that required for mixing, the process is considered mixing limited.

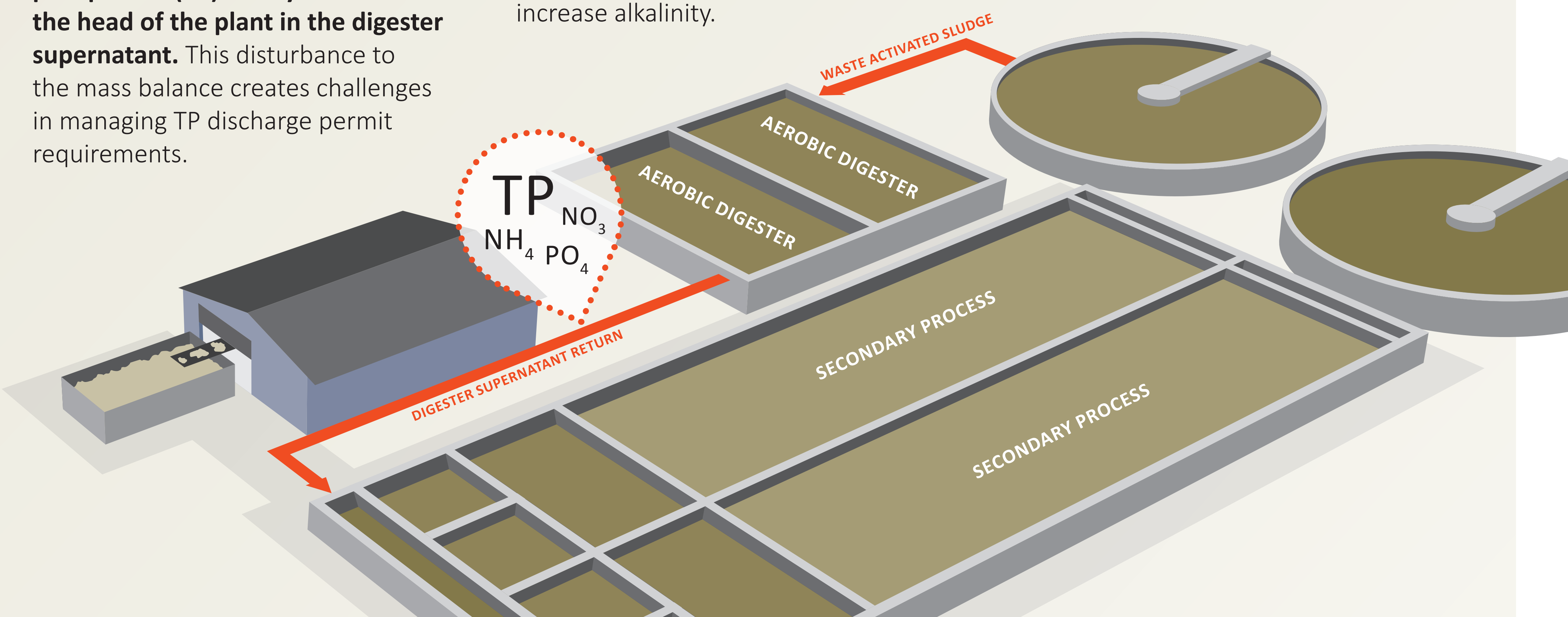
Most aerobic digesters are mixing limited, leading to:

- **Excess aeration** – resulting in high energy consumption.
- **Lack of process control** – resulting in uncontrolled nitrification, pH drop, and chemical addition to control alkalinity.
- **Lack of visibility into the process** – resulting in uncontrolled DO, over- or under-aeration, digester process upsets, and foaming.
- **Excess nutrients returned to the head of the plant** – resulting in secondary treatment process upsets and increased chemical dosing for phosphorus removal.

For a typical aerobic digester, the system is mixing limited.

EFFECTS ON BIOLOGICAL NUTRIENT REMOVAL

- Just as ammonia is released during endogenous respiration, biological phosphorus is also released from cells as they are lysed.
- **Many treatment plants have reported that a large load of total phosphorus (TP) is recycled back to the head of the plant in the digester supernatant.** This disturbance to the mass balance creates challenges in managing TP discharge permit requirements.
- Phosphorus concentration has also been shown to increase in aerobic digesters when the pH drops. Because alkalinity is consumed during excessive nitrification, low pH is a common issue many treatment plants face, often leading them to use caustic to increase alkalinity.
- Phosphorus can be kept in the sludge by processing solids at the right time, cutting over-aeration and creating conditions for luxury biological phosphorus uptake in the sludge.



SOLVING THE CHALLENGES

1. **Independent oxygen delivery and complete mixing** provide optimal process control and significant energy savings.

2. **Instrumentation feedback** allows for real-time control to address changing process conditions.

3. Systemwide **process controls** provide visibility to adapt digester operation to meet treatment needs.

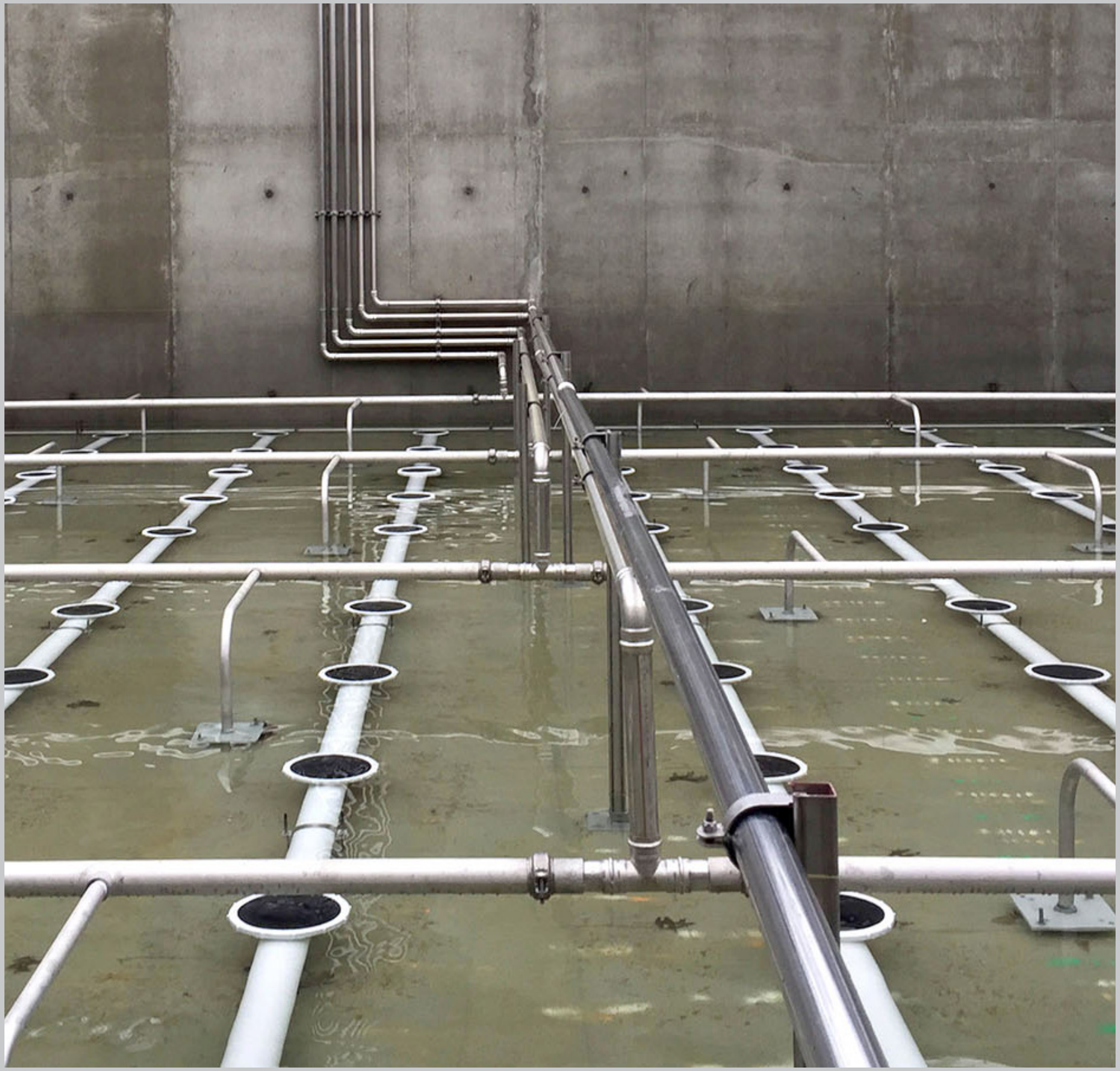
4. **Aerobic/anoxic cycling** stresses the cells causing them to rupture and expel contents which improves dewaterability.

5. **Anoxic cycling promotes denitrification to recover alkalinity** consumed during nitrification and prevents recycling of nitrogen in the supernatant to the secondary treatment process.

6. **Anoxic cycles stabilize the pH**, eliminating the need for caustic chemical addition.

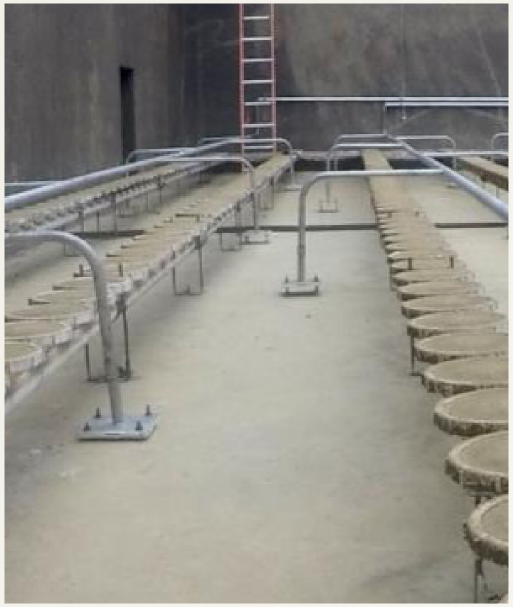
7. **Sequestration of phosphorus in the sludge** prevents recycling in the supernatant to the secondary treatment process, improving the efficiency of bio-P removal.

8. **Maximized VS destruction** reduces sludge volume, thereby reducing sludge disposal costs.



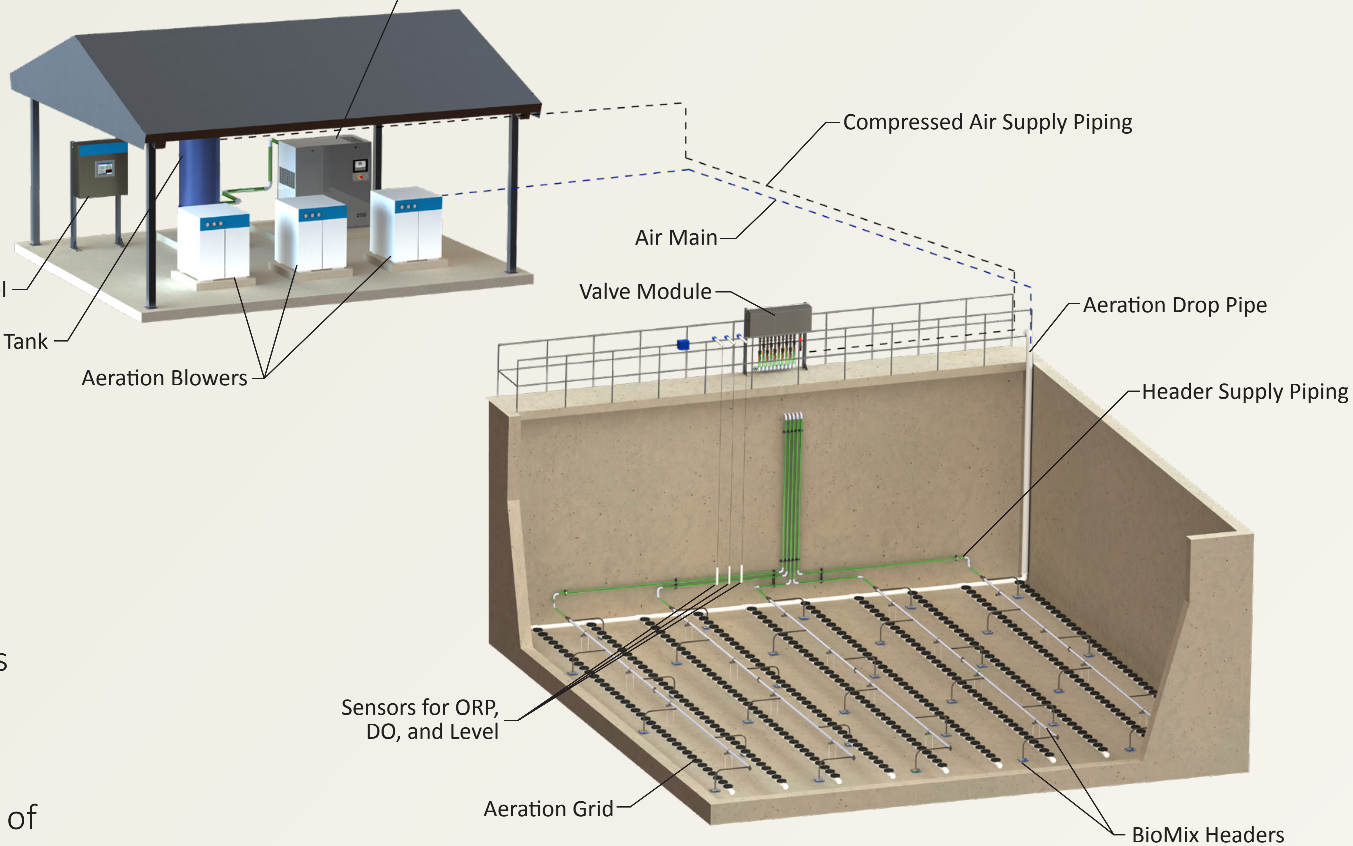
BIOCYCLE-D

Introducing BioCycle-D Optimized Aerobic Digestion Process, your reimagined sludge treatment solution.



EQUIPMENT OVERVIEW

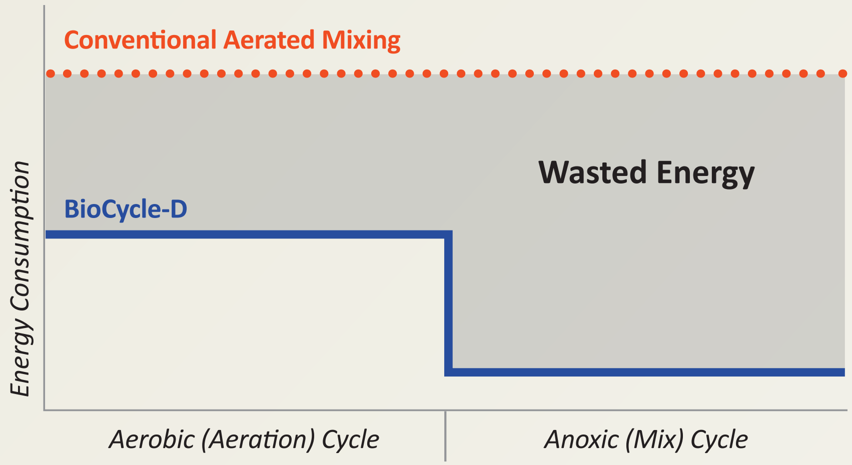
- Dedicated blower per digester prevents maldistribution of air between digesters under variable level operation.
- Common air compressor can provide mixing air for multiple digesters simultaneously.
- DO, ORP, and level sensors in each digester provide real-time instrumentation feedback and control under changing process conditions.
- Fine bubble diffused aeration system is "right sized" to satisfy process oxygen demands.
- Valve module controls the distribution of compressed air to the nozzles to uniformly mix the digester.

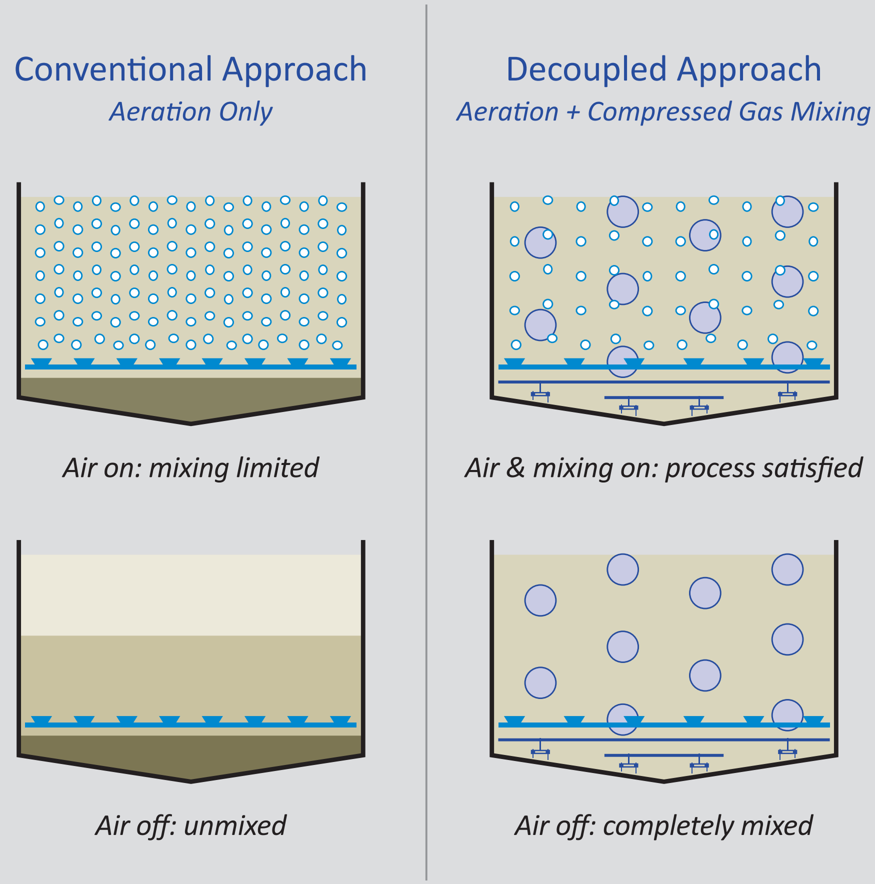


DECOUPLED APPROACH RESULTS IN ENERGY SAVINGS

- Decoupling aeration from mixing facilitates independent control over oxygen delivery and mixing, preventing over-aeration and wasted energy
- BioMix Compressed Gas Mixing uniformly mixes the tank contents at 85% less energy than diffused air mixing.
- **Decoupling aeration from mixing provides over 50% energy savings at design loading and even more at less than design loading.**

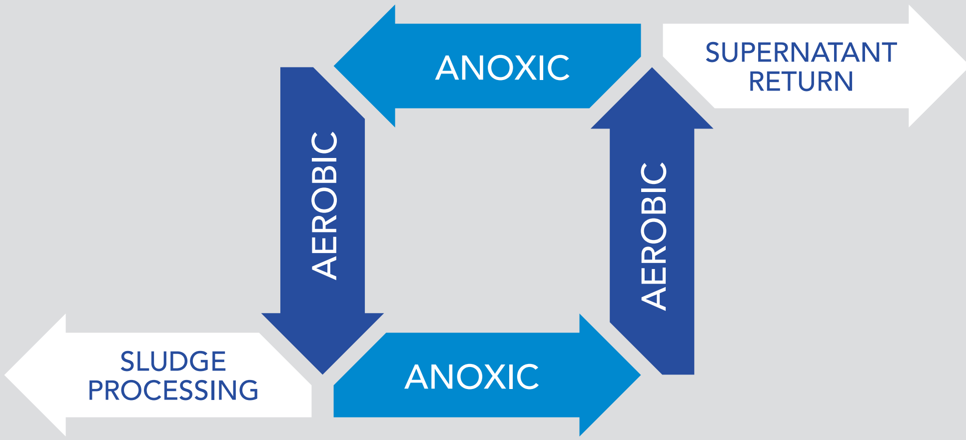
Energy Usage



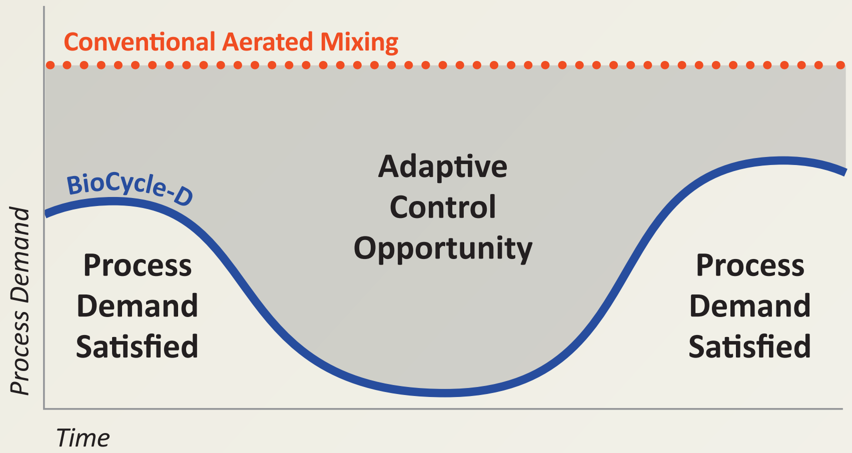


OPERATIONAL CYCLES MEET CHANGING PROCESS DEMANDS

There's no such thing as "steady state" in wastewater treatment, so a plant deserves a control system that adapts with them. As sludge volumes increase or decrease due to wasting cycles or seasonality, it is important for the aerobic digester operation to adjust to the dynamic conditions. BioCycle-D modifies the lengths of the aerobic and anoxic cycles based on process demands in the tank.



Process Flexibility



- **Aerobic cycle** satisfies process oxygen demand.
- **Anoxic cycle** provides denitrification and saves energy.
- **Sludge processing mode** maintains homogeneous sludge concentration.
- Operator controlled **supernatant return mode** provides sludge thickening and minimizes nutrient return to the secondary treatment process.

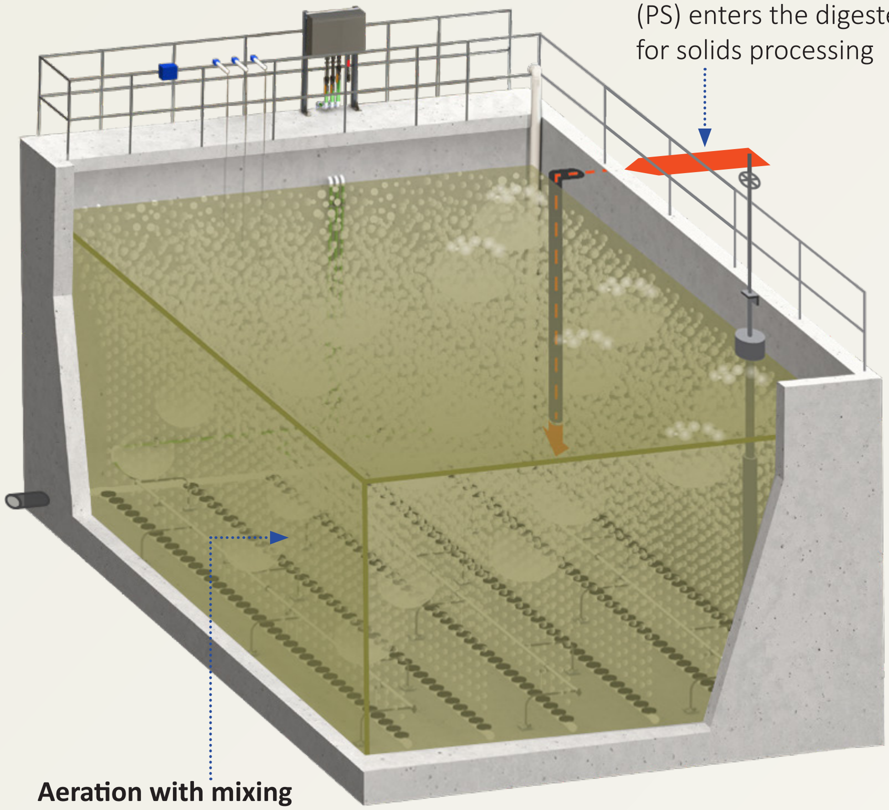
AEROBIC CYCLE

Features

- DO regulation: Adjusts blower speed to deliver the right amount of oxygen needed for the process, without excess aeration.
- Syncro Mix: Automatically identifies when BioMix system is needed to support aeration — i.e. when airflow rate falls below that required for mixing.
- No dead zones: BioMix nozzles are mounted along the slope of the floor or cone, so the complete area underneath the aeration grid is mixed.

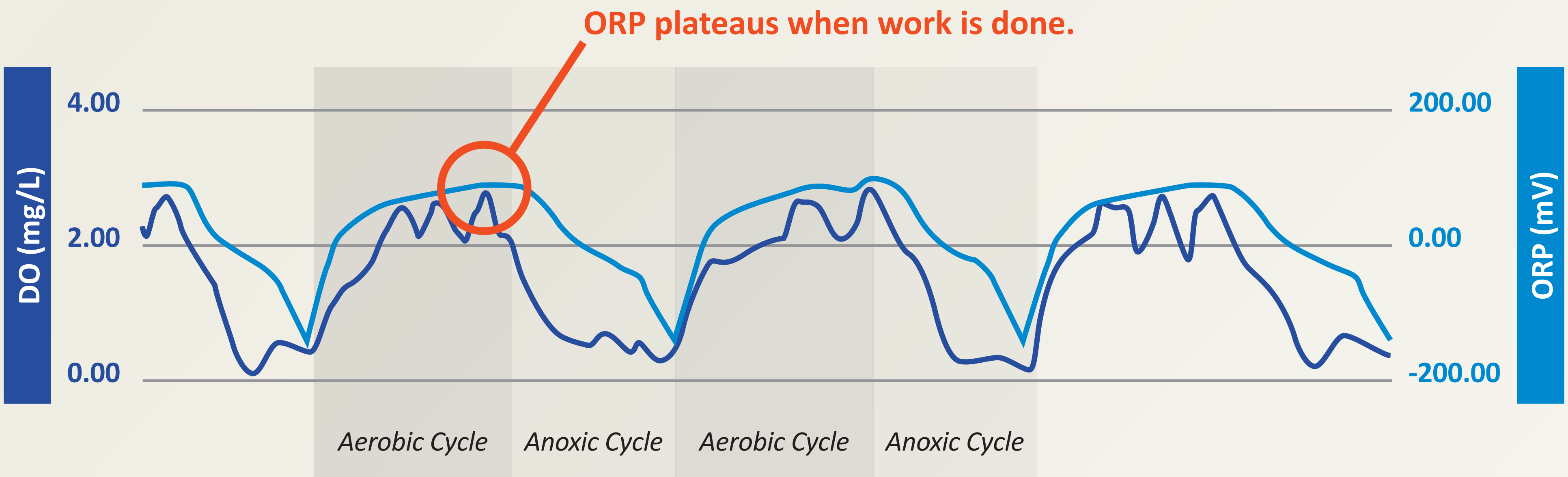
Advantages

- Simultaneous optimal air delivery and mixing **reduces energy consumption**.
- Endogenous decay of the sludge **facilitates VS destruction and reduces sludge volume**.
- Nitrification occurs, converting ammonia to nitrate.



TRANSITION BETWEEN AEROBIC AND ANOXIC CYCLES

- To aid in further VS destruction, **the system switches from the aerobic cycle to the anoxic cycle once the ORP value plateaus** to the high ORP setpoint.
- If the high ORP setpoint is not reached, the cycle time controller will initiate the transition.
- Since ORP plateaus will be plant dependent, our process experts work with each individual plant to determine recommended setpoints during process training.
- The cycling between aerobic and anoxic periods encourages cell lysing.



ANOXIC CYCLE

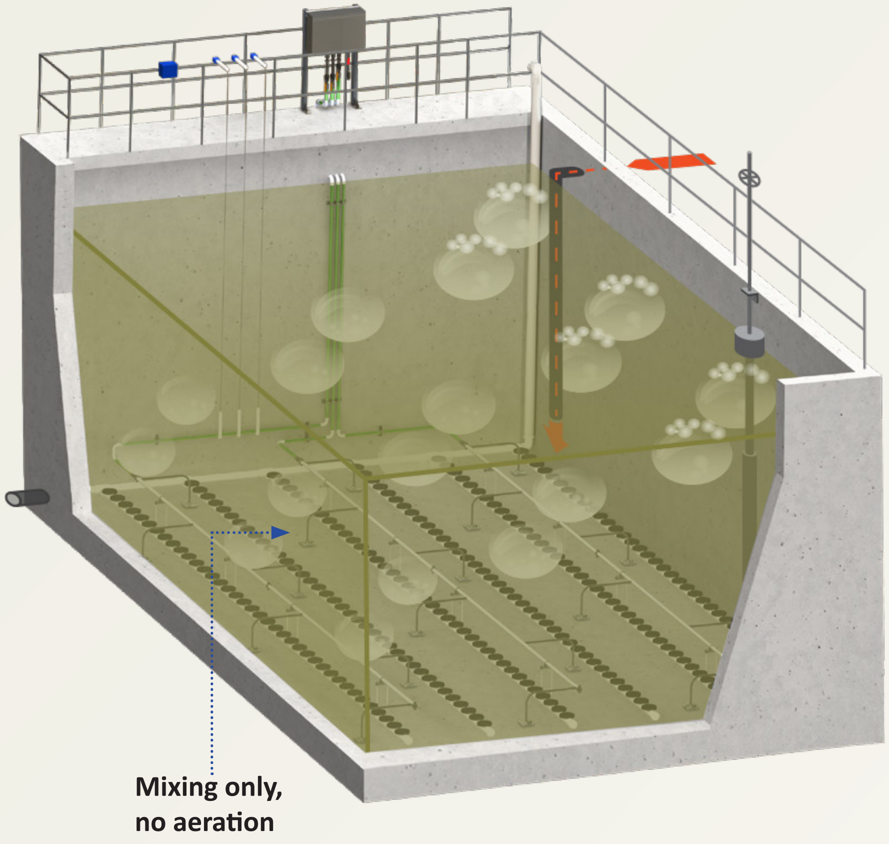
Features

- Adjustable mixing intensity allows for a completely mixed tank at a fraction of the operating cost incurred by using diffused aeration to mix.
- Long air off-cycle results in 0 mg/L DO concentrations and low ORP values, putting the system in an anoxic and, at times, subsequent anaerobic state.

Advantages

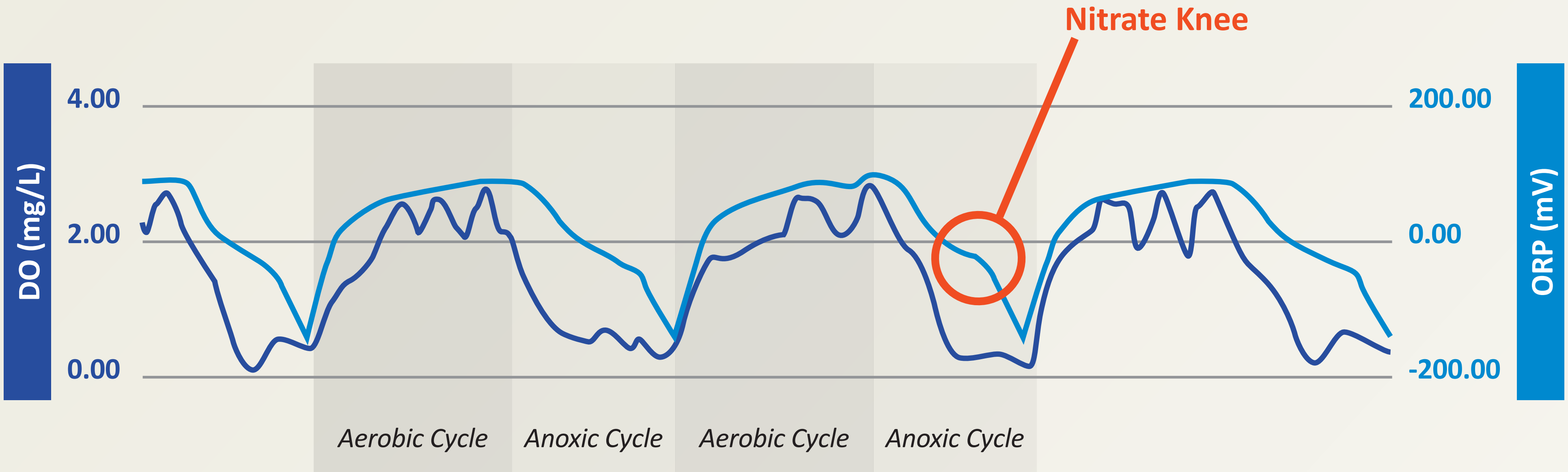
- Sludge remains completely mixed, allowing for continued treatment at **minimal energy consumption**.
- Nitrate is converted to N_2 gas through denitrification, which can return half of the alkalinity, **eliminating the need for chemical addition** to regulate pH.
- Once the nitrate is removed, PAOs release P that they will subsequently uptake with additional available P when aerobic conditions are restored.
- Cycling the aerobic biomass into anoxic states stresses the cell wall causing lysing, which results in **further VS destruction** and release of stored water inside the cell.

Anoxic cycle provides complete mixing to facilitate denitrification, alkalinity recovery, and energy savings



TRANSITION BETWEEN ANOXIC AND AEROBIC CYCLES

- Alternating between anoxic and aerobic cycles allows for destruction of soluble extracellular polymeric substances (EPS), reducing the bound water in the sludge and, therefore, improving sludge dewaterability.
- **Observing the nitrate knee provides indication of the end of denitrification and start of anaerobic conditions and phosphorus release.**
- Since the observance of the nitrate knee will be plant dependent, our process experts work with each individual plant to determine recommended setpoints during process training.
- Once P release occurs during anaerobic conditions, subsequent luxury uptake will occur when aerobic conditions resume.



SLUDGE PROCESSING MODE

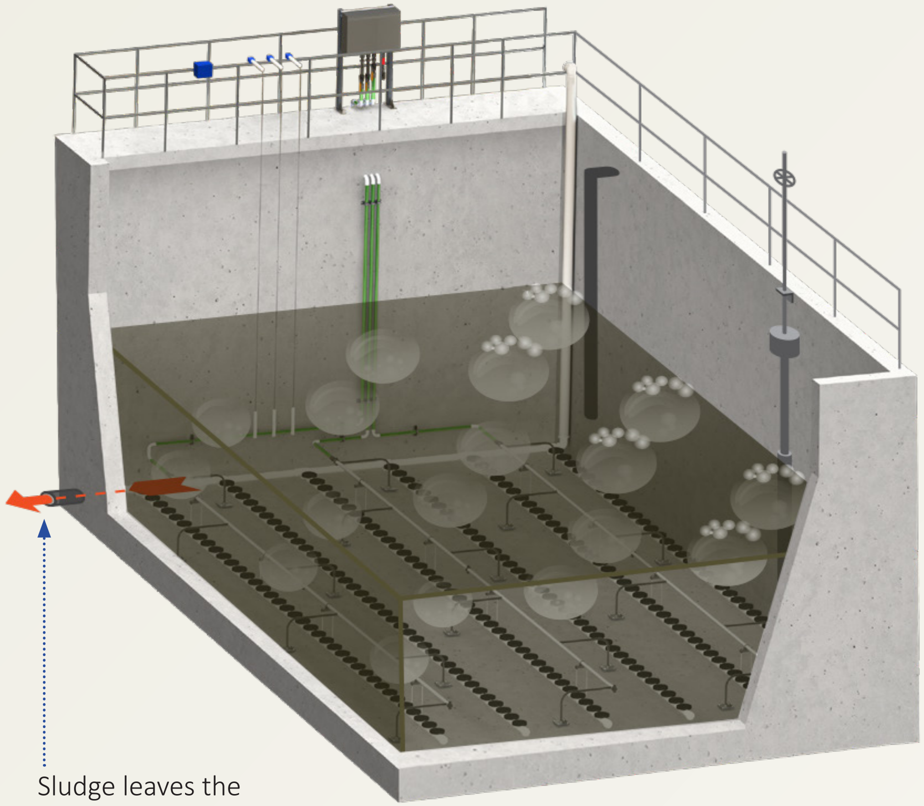
Features

- Complete mixing during sludge removal ensures sludge is **homogeneous for downstream processing**.

Advantages

- Aerobic/anoxic cycling destroys cell walls, causing cell lysing and resulting in **better dewaterability of the sludge**.
- Low oxic state ensures P remains in the sludge while **optimizing energy savings**.

Optional **sludge processing mode** ensures sludge is homogenous for downstream processing and maintains phosphorus in the sludge through low oxic states



Sludge leaves the digester and goes to processing or disposal

SUPERNATANT RETURN MODE

Features

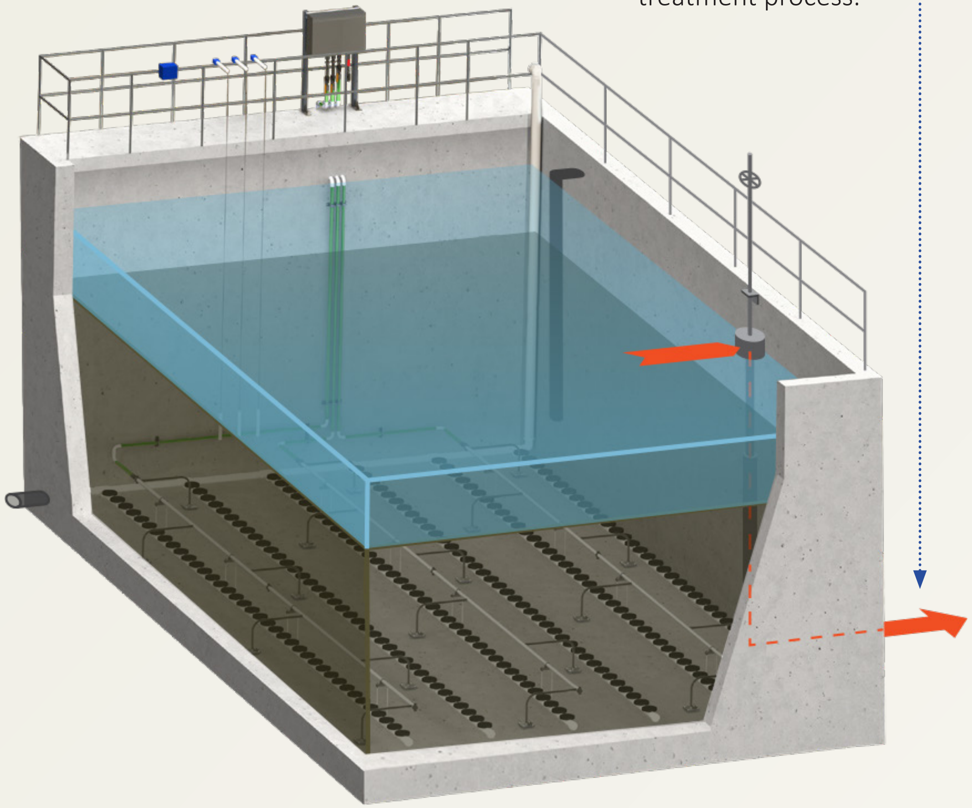
- Manual or automatic settle and decant mode is available.
- Setpoints to stop decanting may be based on time, level, TSS, or valve/weir position.

Advantages

- Solids carryover of older sludge is prevented, ensuring **no disruption of secondary treatment process**.
- N and P spikes to the main treatment plant are reduced or eliminated – **reducing the need for coagulants**.
- Tank volume is maximized by eliminating excess water produced during endogenous respiration and cell lysing (increasing solids concentration in the tank).

Optional **supernatant return mode** includes an automated settle and decant phase to thicken sludge.

Supernatant leaves the digester and returns to the head of the secondary treatment process.



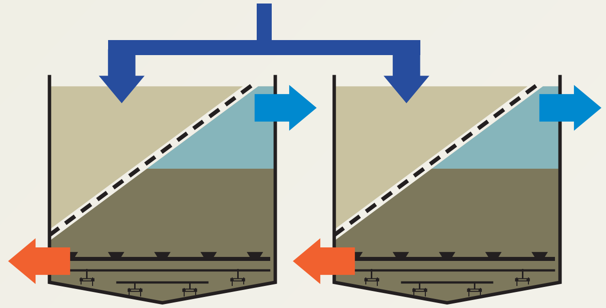
AEROBIC DIGESTION APPLICATION COMPARISON

Process	Condition	Operation	BioCycle-D Benefits
Sludge Holding Tank 3-day HRT	• Many applications are mixing limited, despite short HRT • VS destruction oxygen demand must be satisfied to prevent septicity • Denitrification to control pH • Process instrumentation feedback to provide precise process control	• Modest VS destruction by aerobic/anoxic cycling • Denitrification to control pH	• Precise control of VS destruction • Energy savings through anoxic cycling
Aerobic Digester 30-day HRT	• Application is mixing limited • VS destruction demand must be satisfied to meet SOUR • Denitrification to control pH • Phosphorus sequestration in sludge to prevent recycling to the secondary treatment process • Process instrumentation feedback to provide precise process control	• Increased VS destruction by aerobic/anoxic cycling • Denitrification to control pH	• pH control to prevent foaming, eliminate need for caustic • Provide VS destruction for stabilization and reduce disposal costs • Energy savings through anoxic cycling
Class B Aerobic Digester 60-day HRT	• Meet 40CFR503 Class B • 60-day HRT at 10°C to meet required pathogen reduction • 38% VS destruction or SOUR for vector attraction reduction • Application is extremely mixing limited • Process instrumentation feedback to provide precise process control	• Increased VS destruction by aerobic/anoxic cycling • Denitrification to control pH • Phosphorus release due to cell lysing with subsequent uptake to sequester phosphorus and prevent recycling to the secondary treatment process	• pH control to prevent foaming, eliminate need for caustic • Improved sludge dewaterability and reduced polymer cost • Maximize VS destruction for stabilization and reduce disposal costs • Substantial energy savings through anoxic cycling • Increased bio-P efficiency of the secondary treatment process

MULTIPLE MODES OF OPERATION

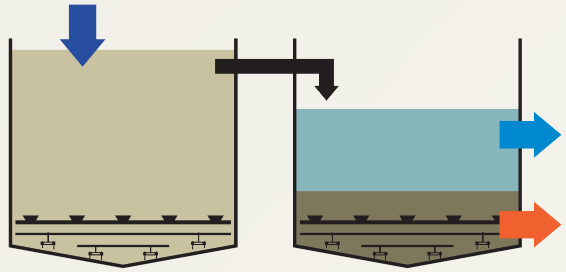
Parallel Operation

- **BATCH FEEDING** of sludge to either digester
- Settling and **DECANTING** in both digesters
- **SLUDGE PROCESSING** from both digesters
- Flexibility if one digester is out of service



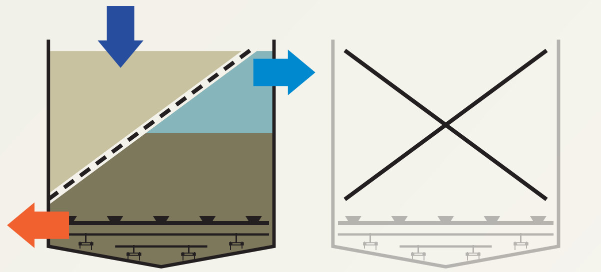
Series Operation

- **BATCH FEEDING** of sludge to primary digester
- Settling and **DECANTING** in secondary digester
- **SLUDGE PROCESSING** from secondary digester
- Increase VS destruction through series operation
- Reduced oxygen demand on secondary digester
- Alternative operating mode if overloaded



Single Tank Operation

- **BATCH FEEDING** of sludge to digester
- Settling and **DECANTING** in digester
- **SLUDGE PROCESSING** from digester
- Typically used if one digester is out of service or if the plant does not have redundancy.



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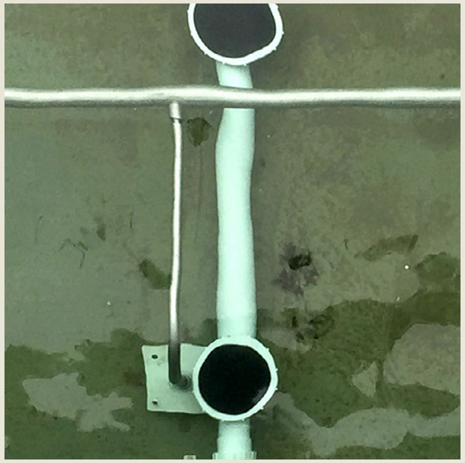

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