



**evoqua**  
WATER TECHNOLOGIES



# **THE ORBAL<sup>®</sup> SYSTEM FOR BIOLOGICAL TREATMENT**

**SIMULTANEOUS NITRIFICATION-DENITRIFICATION**

**Envirex<sup>®</sup>**  
an evoqua brand



## THE ORBAL SYSTEM

The Orbal system was first introduced in 1968 and there are now over 800 installations. It is an important part of the Envirex® product line of Evoqua. The Orbal® system is a reliable solution for enhanced nutrient removal, Stormflow and energy management. It provides process flexibility to meet today's stringent effluent requirements.

# SERIES OPERATION ENABLES SIMULTANEOUS NITRIFICATION-DENITRIFICATION (SND)

The Orbal® system from Evoqua is an activated sludge process designed to address the nutrient and Stormflow issues of today. The Orbal system has been on the leading edge of implementing SND plant designs for over 50 years. With over 800 installations it has been proven to deliver results.

## NUTRIENT REMOVAL

The simultaneous nitrification-denitrification (SND) process is the backbone of the design. The Orbal system incorporates a unique concentric loop configuration that creates dedicated zones for specific treatment purposes. These treatment zones operate in series which is essential to the SND process. The volume split of the concentric loop configuration naturally applies the correct volume to oxygen input ratio required in the design of a SND plant.

The concentric loops also save on concrete and construction costs of the aerobic basin volume by using common wall construction. The SND design allows for the elimination of a dedicated anoxic zone, which saves further on construction costs.

## STORMFLOW

Operating tanks in series allows for diverting the Stormflow downstream of the first reactor, preventing clarifier washout of biomass and storing it in the first reactor of the system. This mode of operation has been proven effective in treating greater than seven times peak flow.

## SYSTEM DESIGN

The concentric loop configuration of a typical Orbal system operates in series. The unique design has channels varying in size with the outer channel having 50% of the volume. Influent and return activated sludge enter the outer channel which is operated under an oxygen deficit (anoxic) condition to promote simultaneous nitrification-denitrification.

By design, the aeration discs placed in the outer channel supply approximately 50% of the system's total oxygen requirement. The design ensures a constant oxygen deficit condition throughout this channel with the DO set-point below zero. The oxygen deficit environment of the outer channel delivers an overall denitrification performance rate of 80% without internal recycle. The majority of the system's nitrification takes place in the outer channel where the anoxic condition also drives denitrification.

The mixed liquor then flows hydraulically to the middle channel where DO conditions swing depending on daily load variation. Finally the mixed liquor flows to the inner channel where the DO is designed to operate at 2.0 mg/l. Final nitrification is completed in the inner channel (or oxygenation zone) in surplus oxygen conditions.

The center island of the Orbal system houses the effluent structure that maintains the water level throughout the channels of the basin. This structure can also serve the purpose of a clarifier splitter box.

## KEY BENEFITS OF ORBAL SYSTEMS

### Biological Treatment

SND in the same zone results in 80% denitrification without the need for an internal recycle pump.

### Eliminate Structures

Allows for elimination of a dedicated anoxic zone typically used in biological nutrient removal processes. This design saves the associated treatment footprint, concrete cost, mechanical mixers and operational energy cost for the mechanical mixer in the anoxic zone.

### Energy Efficient

Operating a majority of the system volume at a strong oxygen deficit allows for much higher oxygen transfer efficiency in comparison with operating a system with a 2mg/l DO or greater throughout the process.

### Process Adaptability/Flexibility

Adaptable to achieve lower TN or TP as regulations change. Typically, only minor mechanical or setpoint changes are required.

### Stormflow Treatment Operation

In Stormflow treatment operation, solids are stored in the outer channels, reducing solids loading on clarifiers and preventing any loss of biological treatment during the storm event.

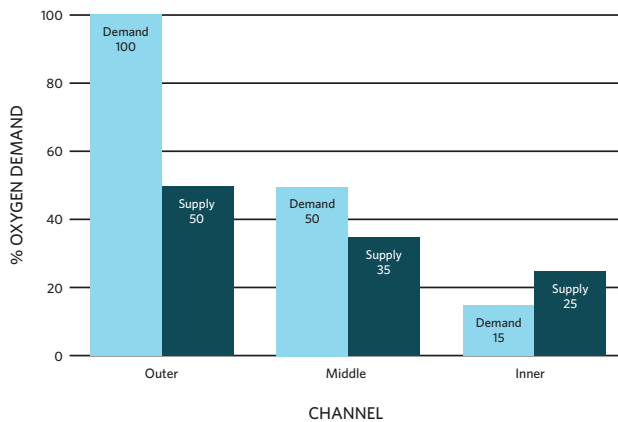
### Process Knowledge

Evoqua process engineers have been designing SND biological treatment systems for more than 50 years meeting the most stringent effluent quality requirements.

## ORBAL® SYSTEM REQUIRES LESS OXYGEN

Oxygen is introduced at multiple points in each channel resulting in low intensity oxygen delivery and higher oxygen transfer efficiency. An important part of the process is operating the outer channel at an oxygen deficit. This deficit creates an environment where specific nitrifying bacteria thrive. The chart below shows how the oxygen supply does not match the demand in the first two channels which corresponds to a low DO. In the inner channel the supply is greater than the demand and results in a positive DO.

### SND OXYGEN DEMAND VS. SUPPLY



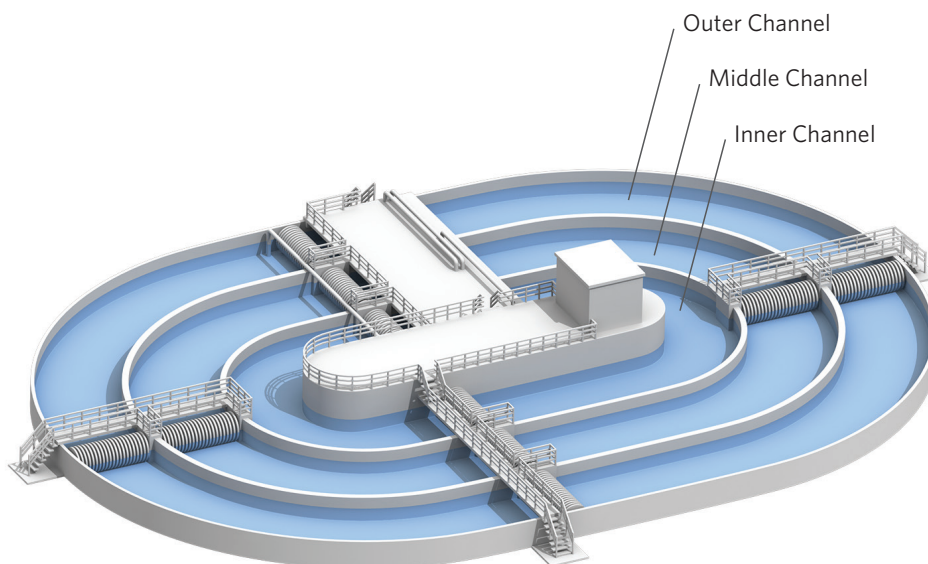
## PROCESS FLEXIBILITY

The Orbal system can be easily modified to meet a large variation of effluent limits. The chart below explains the typical configurations of the Orbal system. Typically only a simple process setpoint or mechanical change is needed to meet more stringent nitrogen or phosphorus effluent limits.

## EFFLUENT QUALITY

Typical effluent of an Orbal system provides BOD < 10 mg/l and NH<sub>3</sub>-N < 1 mg/l. Effluent quality can be further improved with the configuration of the Orbal system outlined below.

CONFIGURATION	EFFLUENT (MG/L)
2-channel Orbal	60% TN removal TN<15
3-channel Orbal	80% TN removal TN<10
3-channel Orbal w/ internal recycle	90% TN removal TN<5 TP<1
3-channel Orbal w/ internal recycle & Anaerobic zone	90% TN removal TN<5 TP<1
3-channel Orbal w/ internal recycle, Anaerobic zone & Post Anoxic zone	90% TN removal TN<5 TP<0.5



Orbal system including its unique Concentric Loop design

### WHAT DOES THE SND SYSTEM PROVIDE?

SND provides a highly efficient aeration process. It is efficient in several parameters.

- **Total tank volume.** The Orbal system counts the oxygen deficient zone as part of the total aerobic SRT. Conventional systems with a separate anoxic zone will not account for the anoxic zone as aerobic SRT and require additional tank volume. The Orbal system accounts for this volume because it is truly being aerated. Approximately 80% of the air is applied in such conditions.
- **Energy.** The SND in the Orbal system typically results in a 35% reduction in power over a conventional system due to oxygen recovery from the inherent denitrification process.
- **Alkalinity.** Approximately 50% of alkalinity consumed by the nitrification process is recovered. This helps control the pH level in the system and eliminates the need to add alkalinity for typical municipal wastewater plants.

### DESIGNS FOR TN LIMIT

Orbal® plants designed for TN removal will usually split the oxygen delivery equally across all three channels. Adding an internal recycle will increase denitrification from 80% to above 90%. Additional considerations and design features are offered to plants where carbon to nitrogen ratios is reduced due to primary clarification or industrial waste factors. For enhanced TN removal, an internal recycle pump is introduced to achieve effluent total nitrogen levels less than 5.0mg/l.

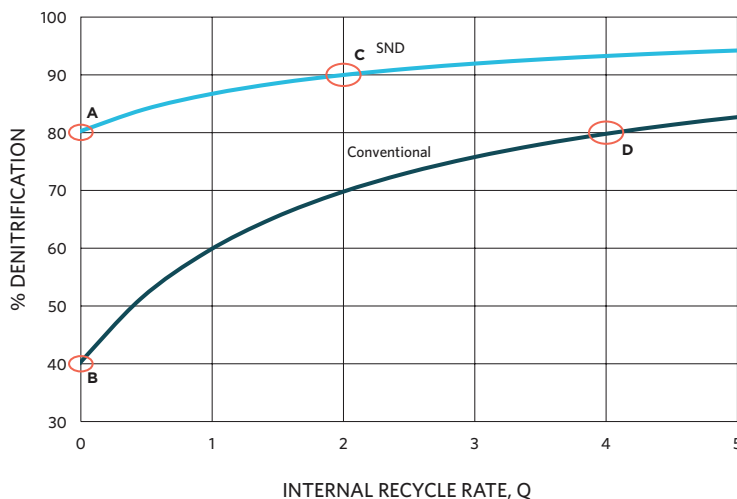
### DESIGNS FOR TP LIMIT

Orbal plants designed for biological phosphorus removal are set for a low oxygen delivery in the outer channel. Typically, 20% is applied to the outer channel with the remaining oxygen demand being satisfied in remaining channels. Envirex® Disc Aerators provide sufficient mixing and oxygen delivery in the outer channel without need for supplemental mixing.

### ORBAL SYSTEM INTERNAL RECYCLE PUMP DESIGN

Conventional plant designs rely entirely on an internal recycle pump for denitrification. The recycle pump for the Orbal system is a polishing step as SND takes place in the basin.

### RECYCLE PUMP ADVANTAGE



The Orbal system process achieves 80% denitrification without internal recycle (*circle A*) where a conventional plant will have 40-50% (*circle B*). The internal recycle pump is a polishing step for lower nitrogen limits. Adding a 2Q internal recycle will increase the denitrification to 90% (*circle C*) in the Orbal system, where as a 4Q recycle is typically used to achieve 80% denitrification (*circle D*) in a conventional plant.

The SND biological treatment system eliminates the need for a nitrate recycle pump compared to a conventional activated sludge process saving capital and energy costs.

## STORMFLOW TREATMENT OPERATING MODE

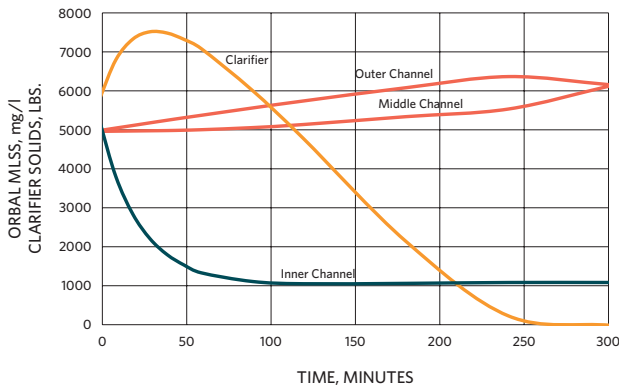
When the Orbal® system operates in Stormflow treatment mode, the influent flow is directed from the outer channel to the inner channels for treatment. The return activated sludge from the clarifier continues to be pumped to the outer channel.

The Stormflow treatment mode represents an adjustment in solids inventory to the outer channel of the Orbal system to prevent solids washout during peak hydraulic events.

When flows return to normal, the influent flow is simply returned to the outer channel and treatment proceeds routinely.

This operating mode eliminates the need for an equalization basin. The conversion of normal to Stormflow mode can be manually controlled or automatic through the SmartBNR™ control system.

## STORMFLOW TREATMENT MODE ADVANTAGE



The chart above shows the activities of the Orbal system and clarifier biological solids during a Stormflow event. Influent is diverted to the inner channel. The MLSS for the inner channel drops as the dilute influent displaces a portion of the solids to the clarifier (blue line). The clarifier solids will initially increase, but decrease (yellow line) as the RAS pumps transfer the solids to the outer channel. This action will increase the MLSS in the outer and middle channel thus storing solids (red lines).

Activated sludge treatment will take place in the inner channel as there are biological solids and oxygen in contact with the influent. The RAS contacts the influent through the displacement of liquid in the outer and middle channel and flowing into the inner channel.

This operating mode eliminates the need for an equalization basin. In many applications the use of this mode can also reduce the size and/or number of clarifiers.

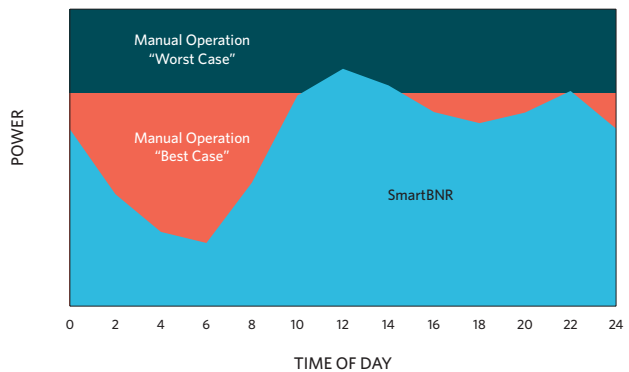
## SMARTBNR CONTROLS

The biological aeration system typically consumes the most power in a wastewater treatment plant. Evoqua process engineers work closely with electrical engineers to optimize power consumption and process effluent quality for the Orbal system. The SmartBNR controls utilize a touch screen operator interface with ORP and DO analyzers to continuously monitor and adjust the aerator speed based upon the actual wastewater conditions and characteristics of the disc. The controls also adjust for long-term variations or sudden surges in demand by turning on/off individual assemblies.

To meet strict ENR limits, the SmartBNR control system optimizes TN and TP levels through ammonia probes and phosphate analyzers. The control system has standard control options for Stormflow treatment mode of operation, nitrate recycle pumps, RAS pumps, SRT control, and chemical feed.

The SmartBNR control system from Evoqua provides remote access to the system control screens for process analysis and adjustments.

## AERATION POWER WITH TYPICAL DIURNAL FLOW PATTERN



SmartBNR control systems save operating costs by only providing the aeration power required to match the diurnal load throughout the day.

## THE OX™ DISC AERATOR ENABLES SND

The mechanical backbone of the Orbal® system is the unique and \*patented aeration disc. It delivers a high oxygen transfer rate and unmatched mixing efficiency.



The non-metallic OX™ Disc Aerator provides a longer, more cost-effective life when compared to galvanized or painted carbon steel brush rotor designs.

Aeration and mixing are provided by nodules on the face of the disc, with oxygen delivery and energy consumption varying with changes in speed and immersion depth.

The disc is split into two half sections and can be directly attached to the aerator shaft at any location. The number of discs allotted for each channel is a function of the oxygen delivery requirements. In a typical 3-channel Orbal system, the outer disc aerator assembly spans the outer channel. The inner aerator assembly spans the inner and middle channel.

## REDUCED SPEED IMPROVES MIXING EFFICIENCY

Mixing efficiency, defined as the number of gallons mixed per 1 hp to maintain a 1 fps channel velocity, is an extremely important feature of the Orbal system. The disc is designed so that mixing efficiency improves as speed is reduced. This characteristic is beneficial to the Orbal basin as it allows the process to keep a DO deficit in the outer channel during underloaded conditions, while still keeping a velocity sufficient to keep solids in suspension. Independent mixing devices are not needed to maintain anoxic conditions in the outer channel.

The mixing efficiency of the aeration discs in an Orbal system basin is unmatched by any other aerator device. As an example, an outer channel with 1 million gallons of volume requires only 10 hp of disc aerators to maintain a 1 fps channel velocity. The high mixing efficiency of Envirex aeration discs ensures unparalleled biological process performance under all load conditions.



Evoqua's OX™ Disc Aerators provide superior aeration and mixing without creating unwanted aerosols and sprays.

## FLWSHEET SOLUTIONS: TECHNOLOGY COMBINATIONS CREATE GREATER VALUE

Evoqua draws on its leading biological wastewater portfolio and applications experts to support projects where multiple technologies can be combined into a high performing cost effective solution. The Orbal® system, for example, can be combined with:

- Tow-Bro® high performance clarifiers to achieve stringent nutrient levels and handle peak flow rates
- A Forty-X™ Disc Filter for low TP applications
- The innovative CoMag® Magnetite Ballasted Treatment System to produce near MBR quality effluent in a small footprint
- TIW® Control System Solutions that deliver seamless controls across technologies without costly redundancy

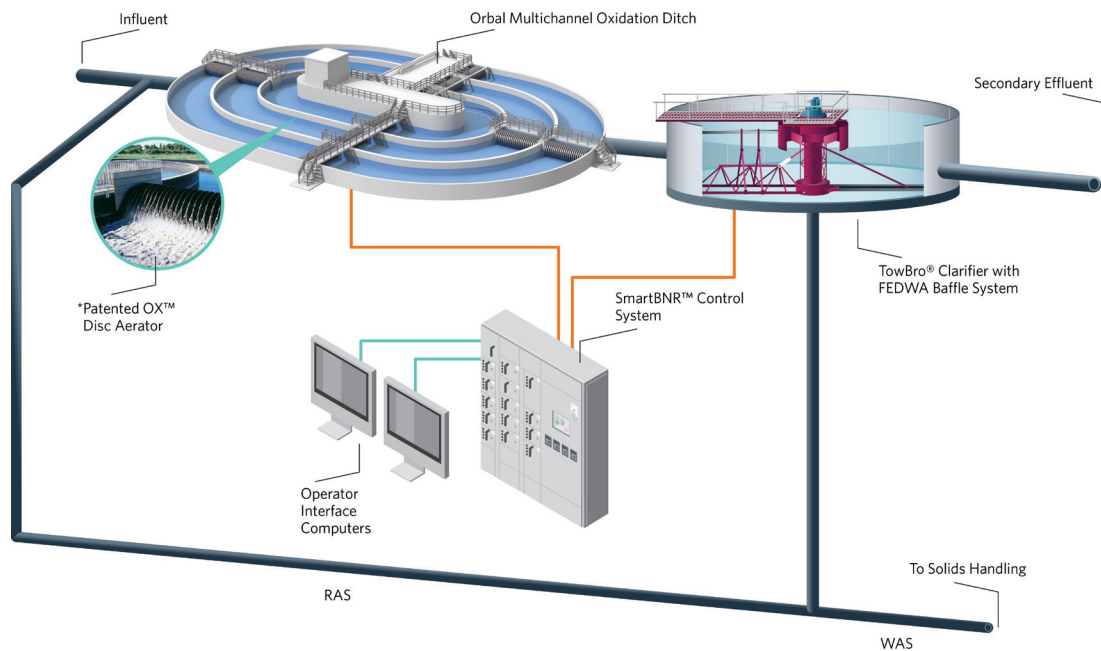
Evoqua Flowsheet Solutions are supported with a dedicated single technical point of contact who assures coordinated, timely, and accurate project execution, along with a comprehensive upfront evaluation of alternatives.

### Ready to put the technology, experience, and expertise of Evoqua to work?

Learn more how the Orbal system creates a simultaneous nitrification - denitrification environment and addresses nutrient and Stormflow issues.

Connect with an expert at [www.evoqua.com/orbal](http://www.evoqua.com/orbal).

Flowsheet Solutions from Evoqua provide expertise and project support across technologies.



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