BIOLOGICALLY ACTIVE FILTER TECHNOLOGY APPLICATIONS FOR WASTEWATER TREATMENT UPGRADE

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INTRODUCTION

Wastewater treatment facilities are subject to many different drivers for completing upgrades. Among the most prevalent drivers is a need to keep current with ever-changing, and increasingly stringent, environmental regulations. These regulations frequently require upgrading a primary treatment facility (i.e. only screening and primary clarification) or secondary treatment facility (biological treatment for removal of BOD and TSS) to tertiary treatment and the removal of BOD, TSS and Total Nitrogen (TN).

This paper discusses approaches to these typical plant upgrades via two different variants of Submerged Biologically Active Filter (BAF) technologies, both using the BIOSTYR® system by Veolia. The first describes an approach to secondary treatment facility upgrades in which two (2) stages of BAF technology are added to an existing activated sludge treatment system. This is a well-established approach with traditional BAF technology. The second describes an approach to upgrade primary treatment facilities via an innovative new advancement in BAF technology whereby Moving Bed Biofilm Reactor (MBBR) technology is integrated into the BIOSTYR® system.

Figure 1: Top view of BIOSTYR® cells at 84 MGD facility

BACKGROUND

Veolia's BIOSTYR® system is a very compact process combining fixed film biological treatment and filtration in a single unit operation with relatively high pollutant loads depending on the carbon and nitrogen requirements (Rocher et al. 2012). Newman et al. (2005) confirmed that BAF processes are very well suited when space is an important site constraint. During the last 25 years, more than 150 BIOSTYR® facilities have been built and operated to treat municipal wastewater around the world, thereby also demonstrating the wide-range of treatment applications in the marketplace. Figure 2 shows a schematic of a conventional BIOSTYR® cell.

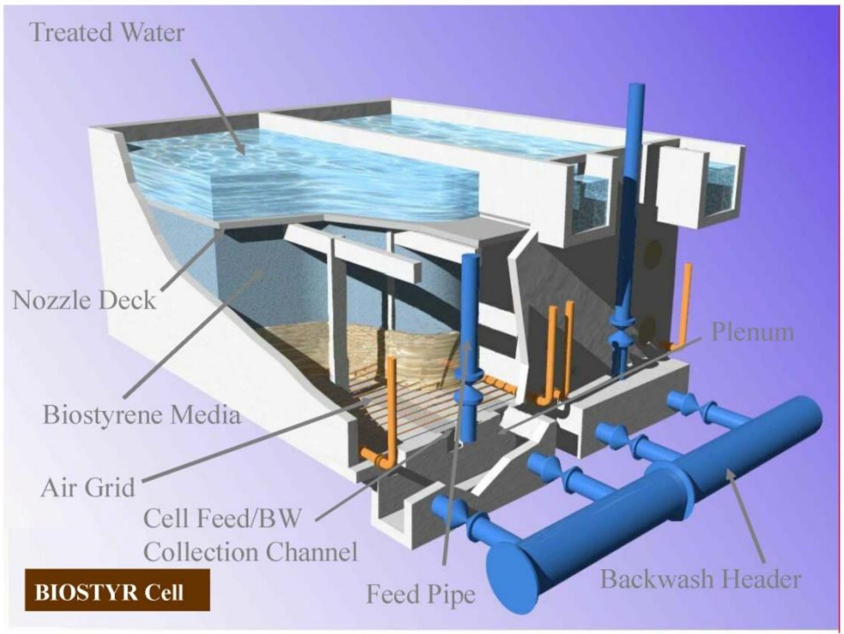

Figure 2: BIOSTYR® System Cell General Arrangement

BAFs utilize granular or spherical-shaped media to provide a large surface area-to-volume ratio for fixed-film microbial growth. The large surface area per unit volume results in BAFs having a small footprint compared to similar wastewater treatment processes (Stephenson et al., 1993).

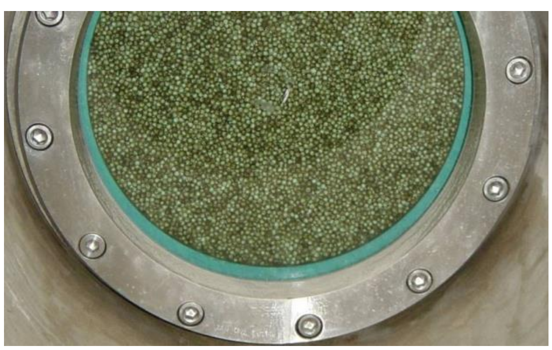

Figure 3: BIOSTYR® Media within System

Tertiary biological filters typically receive effluent from a secondary treatment process. In cases where an existing secondary process does not provide reliable nitrification, nitrifying filters are used to convert ammonia to nitrate. Denitrification filters may then follow and provide reduction of the incoming nitrate to nitrogen gas, which dissipates to the atmosphere, thereby removing the nitrogen from the water stream. Configurations using these tertiary filters can achieve effluent ammonia concentrations below 0.5 mg/L and total nitrogen values below 3.0 mg/L. This configuration has been used successfully in many treatment facilities, including the Tahoe-Truckee Sanitation Agency (T-TSA) plant in Truckee, CA.

Moving Bed Biofilm Reactor (MBBR) technology is also a compact process using microorganisms contained within a fixed film on small plastic carriers. This system has been employed since the early 1990's for the removal of carbon and nitrogen in municipal wastewaters. Veolia's AnoxKaldnes™ biofilm carrier technologies have been used in over 50 municipal wastewater plant installations in the US and many more around the world.

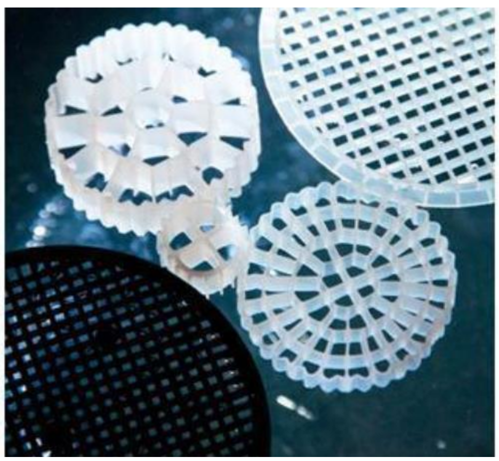

Figure 4: AnoxKaldnes™ MBBR Biofilm Carriers

These two individual Veolia fixed film processes have been successfully combined to create the next evolution of BAF technology, which is called BIOSTYR® DUO. This innovation uses the two different media layers to increase the total surface area available for biological treatment in the same overall BAF reactor volume and footprint. Much higher loadings of pollutants can be treated with this configuration, whose target applications are for secondary treatment immediately following primary clarification. This configuration has undergone extensive pilot scale testing and is beginning to be installed in full scale facilities around the world.

TERTIARY BIOSTYR® SYSTEM CONFIGURATION AT TAHOE-TRUCKEE SANITATION AGENCY

T-TSA's discharge requirements are very stringent to preserve the pristine nature of the Truckee River and Martis Creek. T-TSA's facility must meet total nitrogen (TN) limits of 3.0 mg/L on an annual average basis and 2.0 mg/L over the summer months (May 1st through October 31st).

The influent temperature of the facility's wastewater typically varies from 7°C to 20°C and the influent flow rate typically varies from 11,300 to 30,300 m^3/d (3 to 8 MGD). T-TSA selected the BIOSTYR® system to accomplish its objectives.

T-TSA commissioned a full-scale BIOSTYR® nitrification and denitrification BAF system in August 2006, which was installed following an existing pure oxygen activated sludge plant. The system was designed to treat a maximum weekly flow of 45,400 m^3/d (12 MGD), down to TIN concentrations of 2.0 mg/L and 3.0 mg/L for summer and winter periods, respectively. Process performance is analyzed using online analyzers and automatic samplers. A simplified schematic of the full-scale system is illustrated in Figure 5.

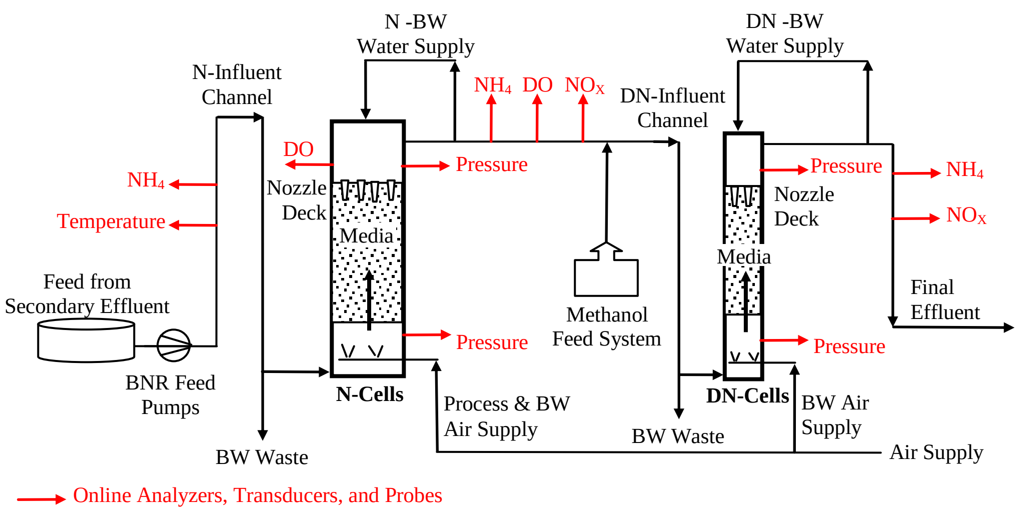

Figure 5: T-TSA System Schematic

The full-scale system has eight (8) parallel nitrification cells and four (4) parallel denitrification cells. The nitrification and denitrification cells contain floating media (polystyrene beads) held in place by a concrete deck with nozzles that allow only the liquid stream to pass through. The nitrification cells are fed with secondary effluent pumped to a common nitrification cell influent channel. The nitrification cell effluent is gravity fed to the denitrification cells through a common influent channel. Each nitrification and denitrification cell is normally backwashed after a cell has been in filtration mode for a specific number of hours. The cells are also backwashed automatically if the maximum headloss set point is reached.

The depth and area of the media in each nitrification cell are 3.2 m (10.5 ft) and 87 m^2 (940 ft^2), respectively. T-TSA nitrification cells are rotated into service based on NH_4-N loading conditions. Loading is determined using an influent flow meter and an influent online NH_4-N analyzer. The nitrification effluent NH_4-N concentration is constantly monitored using an online NH_4-N analyzer.

The depth and area of the media in each denitrification cell are 2.5 m (8.2 ft) and 65 m^2 (704 ft^2), respectively. The four denitrification cells are rotated into service based on NO_X-N loading. Methanol is dosed upstream of the denitrification cells in a common influent channel. The methanol is dosed into the stream using metering pumps and a submersible chemical induction mixer. The dosing rate is calculated based on the denitrification influent NO_X-N and DO concentrations and is trimmed based on the denitrification effluent NO_X-N concentration.

TERTIARY BIOSTYR® SYSTEM PERFORMANCE AT T-TSA

As originally reported by Holloway, et al (2008), the full-scale system has been fully operational and receiving secondary effluent since October 2006. Through the first two (2) years of operation, the average TIN loading to the full-scale system was 370 kg/d (820 lb/d), with minimum and maximum TIN loadings of 140 kg/d (310 lb/d) and 950 kg/d (2100 lb/d), respectively. The temperatures over this same duration ranged from 7.1°C to 19.7°C with an average of 12.3°C. Table 1 summarizes the average influent and effluent nutrient and solids concentrations for the nitrification and denitrification systems during this initial two year operating period.

Table 1: T-TSA Pollutant Concentrations During Initial 2 Years of Operation

Constituent	Nitrification Concentrations, mg/L [a]
Influent NH_4-N Effluent NH_4-N	10 – 34 < 0.5
Average Influent TSS Average Effluent TSS	9.6 6.8
Average Influent COD Average Effluent COD	44 37
Influent Organic Nitrogen-N Effluent Organic Nitrogen-N	1.4 – 3.9 1.5 – 2.5
Constituent	**Denitrification Concentrations, mg/L [a]**
Influent NO_X-N Effluent NO_X-N (Summer) Effluent NO_X-N (Winter)	8 – 30 < 2.0 < 3.0
Average Influent TSS Average Effluent TSS	6.8 4.3
Average Influent COD Average Effluent COD	37 36
Influent Organic Nitrogen-N Effluent Organic Nitrogen-N	1.5 – 2.5 1.5 – 2.2

[a] Ranges and averages based on daily composite samples collected over approximately two years.

The nitrification stage typically converts approximately 98% of the influent NH_4-N to NO_X-N, and the denitrification stage converts approximately 95% of the influent NO_X-N to N_2-N. The COD concentration through the denitrification stage remains relatively constant, indicating that the majority of the methanol is consumed through the denitrification stage. Figures 6 and 7 illustrate NH_4-N and NO_x-N removal rates as a function of applied rates at temperatures greater and less than 10°C.

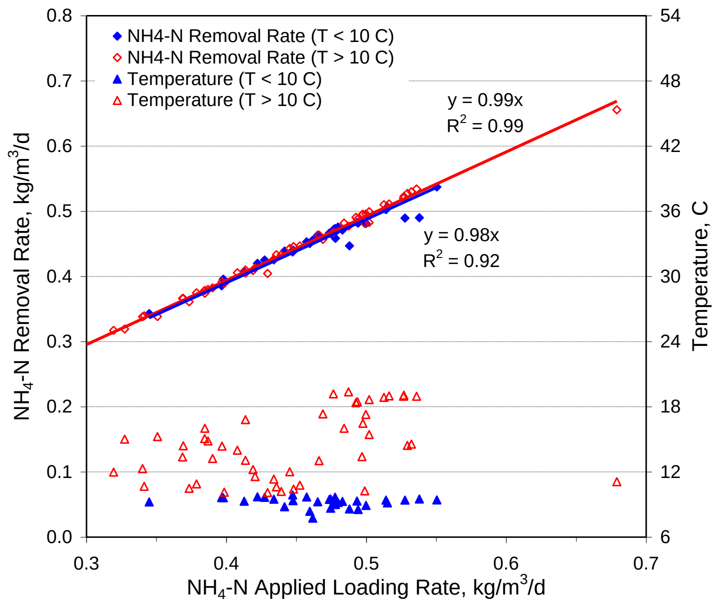

Figure 6: NH_4-N removal rates

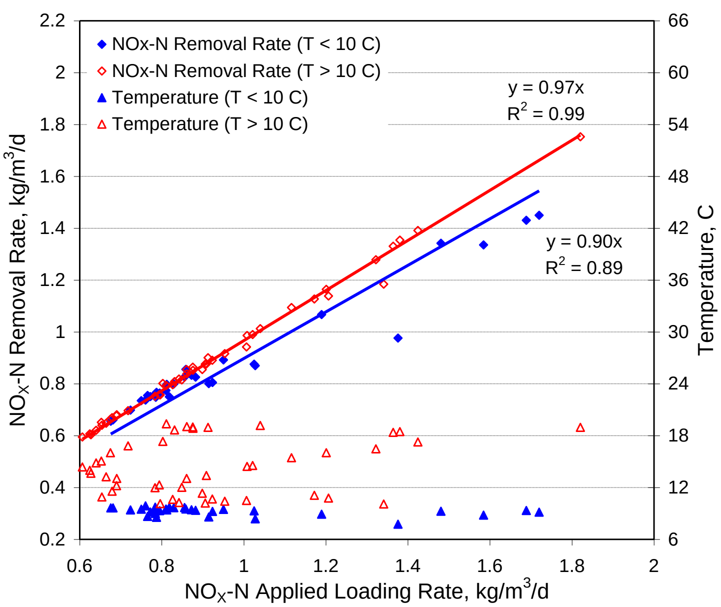

Figure 7: NO_x-N removal rates

The initial 2 years of operation confirmed the effectiveness of the BIOSTYR® system to achieve very low effluent NH_4-N and TIN concentrations across high and low temperatures. The full-scale system achieved average overall TIN removals of greater than 93% with maximum removals of 99%. The full-scale TIN removal is comparable with that achieved by the Viikinmäki wastewater treatment plant (Fred and Kiiskinen, 2005), and NO_x-N is removal is consistent with the denitrification demonstrated in other tertiary denitrification systems (Pearson, et al, 2008). A subsequent look at effluent performance over a later two year period further confirms the nitrogen removal capabilities of the system.

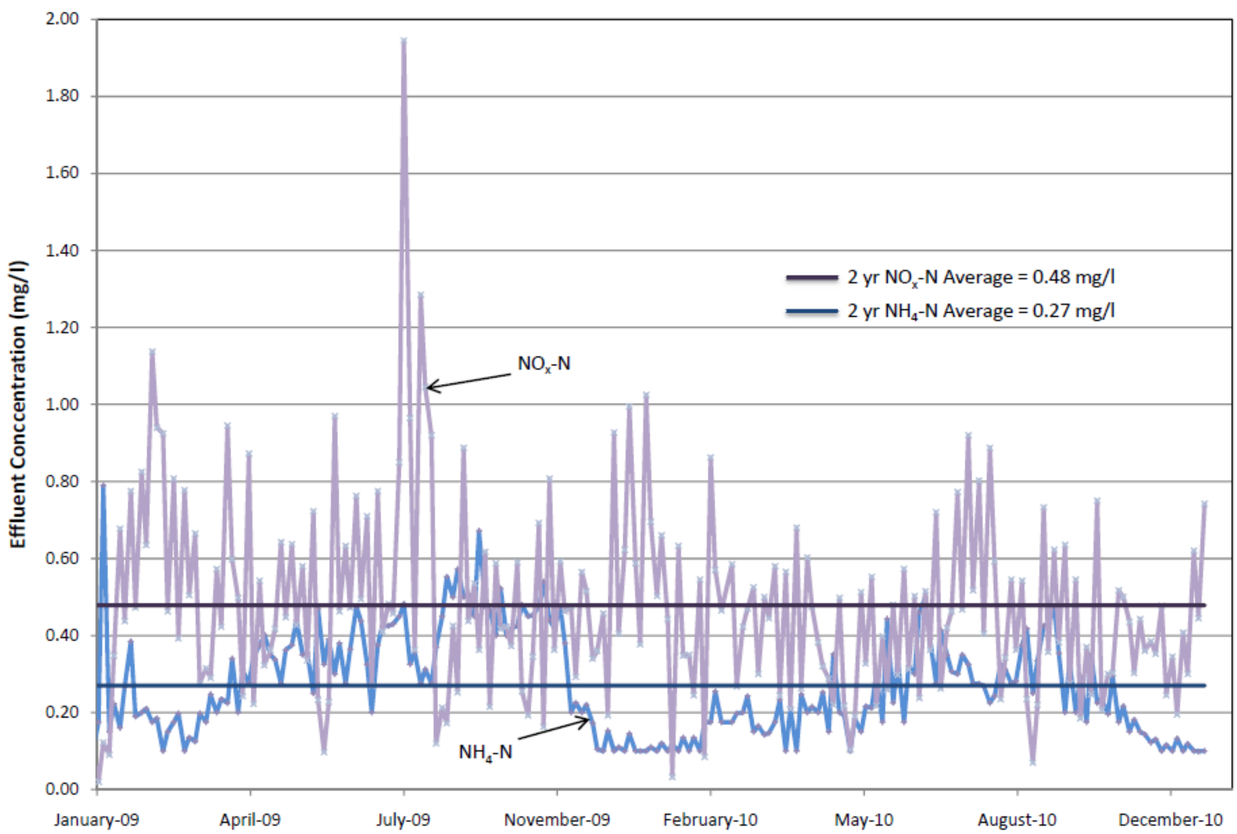

Figure 8: Additional 2 Years of Effluent Performance Data (2009-2010)

SECONDARY BIOSTYR® DUO SYSTEM CONFIGURATION AND PERFORMANCE

Pilot studies were first conducted in France in 2011 for this novel approach to secondary treatment for BOD removal and nitrification. Additional pilot studies have been conducted in Canada and the United States, and the first full scale treatment system using the technology began operations in 2014. Additional full scale treatment facilities are now under construction.

In the BIOSTYR® DUO configuration, MBBR plastic carriers are installed into the free volume located under the bed of conventional Biostyrene™ beads. This provides an incremental amount of additional surface area for biological growth and treatment that does not add to the overall system footprint or height, and adds essentially no headloss to the system. Figure 9 shows the general arrangement of the Biostyrene beads and MBBR carriers within one of Veolia's pilot systems.

Figure 9: BIOSTYR® DUO Media

The limiting factor on a conventional secondary treatment BAF system is the COD (or BOD) load applied, typically expressed in kg COD/m^3_{media}/d or in kg COD/$m^3_{reactor}$/d. Pilot scale testing has confirmed the ability to process considerably higher loadings of pollutants for secondary treatment applications, with a particular ability to process increased carbon loading (BOD or COD). Figure 10 indicates relative performance compared to traditional BAF system design, where the red bar represents the BIOSTYR® DUO configuration, based on results of the pilot scale testing conducted (Amiel, 2014).

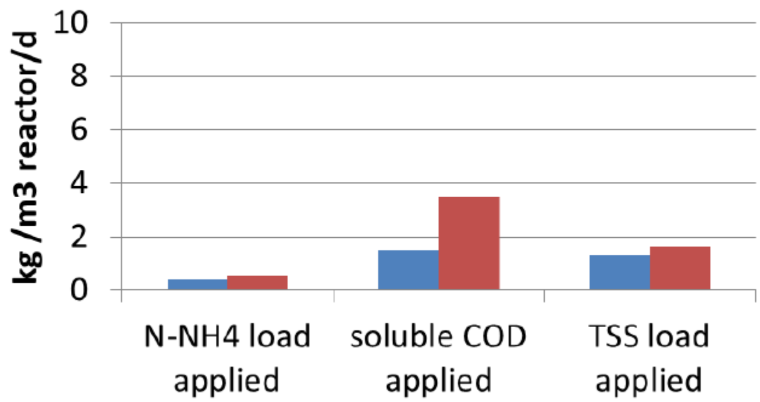

Figure 10: Relative Loading Capabilities

CONCLUSIONS

The application of BIOSTYR® BAF technology has been widely established for over 25 years in many applications. Many full scale systems, as evidenced by the performance of the T-TSA wastewater facility, have demonstrated superior tertiary nitrification/denitrification capabilities to treat to very low effluent Total Nitrogen levels, and at low influent wastewater temperatures. BIOSTYR® tertiary treatment systems are an effective means of upgrading existing pure-oxygen or other activated sludge plants to go from BOD/TSS removal only to nitrification and/or denitrification to meet new treatment standards.

Four (4) years of pilot research have shown the BIOSTYR® DUO system's capability to treat significantly higher influent loadings relative to conventional BAF technology. This increased loading capability allows BIOSTYR® DUO to be a viable secondary treatment alternative for any greenfield application or facilities with existing primary clarifiers. In addition, the use of BIOSTYR® DUO allows for much greater flexibility in needed primary treatment steps.

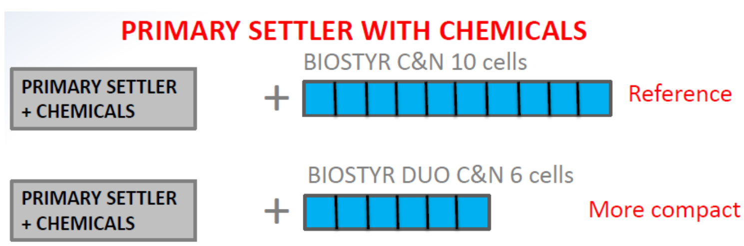

Figure 11: Conventional vs. DUO System, Equivalent Primary Treatment

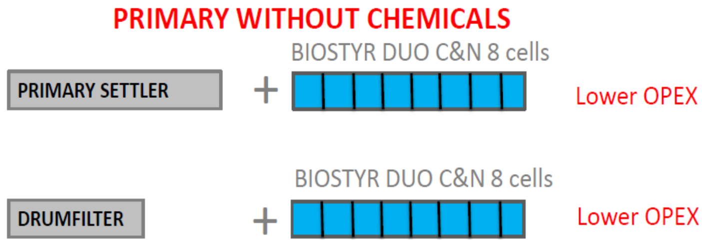

Figure 12: Conventional vs. DUO System, Different Primary Treatment

Across all applications, Veolia's BIOSTYR® and BIOSTYR® DUO provide the most compact treatment system, offering superior effluent performance, robustness and overall value to wastewater treatment facilities faced with new or tightened effluent limitations on Nitrogen.

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