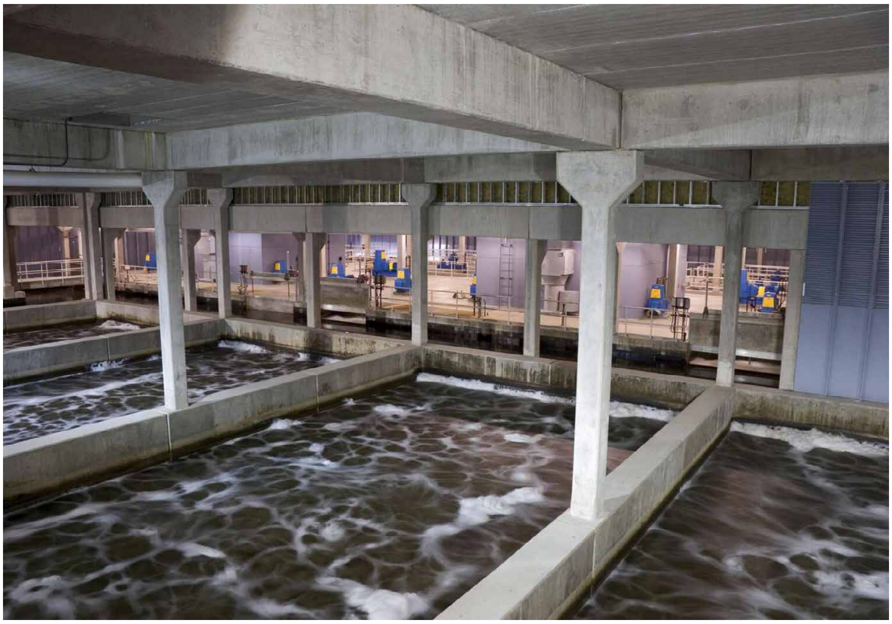
EFFECTIVELY USING BAF TECHNOLOGY IN COLD CLIMATES FOR HIGH LEVEL NITROGEN, TSS REDUCTION

By **John He**, **Glenn Thesing**, **Hong Zhao**, **Rich DiMassimo**, **Luke Wood**, **Louis Ortenzio**, **Mark Drake**, **Mathew Edds**, **Meg Hallowed** and **Pia Prohaska**



Top view of typical BIOSTYR cells.

Biological active filters (BAFs) are the most successfully and widely used biofilm-based nitrification or nitrification and denitrification system for simultaneous NH_4-N oxidation, NO_X-N reduction, and suspended solids removal through the media bed. BAFs, operating either in down-flow or upflow hydraulic conditions, have evolved from a biological nitrogen removal (BNR) treatment option to a fully mature and accepted biological wastewater technology.

The key distinguishing characteristic of the BAF process is that the microorganisms live in a biofilm attached to a media surface, rather than being freely suspended in the wastewater. The solid surface is fixed in space with the wastewater flowing over it in media beds. The media bed has a very high specific area (> 1,000 m^2/m^3) and relatively low void space (35% – 40% of porosity).

This allows the process to develop and maintain a large biomass population per unit volume for biodegradation of carbon, ammonia and nitrate. This ensures that filtration and clarification can achieve very low effluent TSS (less than 10 mg/L). Hydraulic retention times (HRTs) can be extremely low when support media of high specific surface area are utilized. For example, both downflow with sunken media and upflow with floating media, BAFs with a specific surface area greater than 1,000 m^2/m^3 can give HRTs of less than two hours for complete BNR.

The biofilm-based BAF process has a few distinct advantages over conventional activated sludge (CAS) technology for nitrogen removal. Accumulation of biofilm attachment on media surface eliminates volume constraints imposed by a settler, so the physical footprint is significantly smaller than a clarifier-coupled CAS system.

Simultaneous ammonia removal or NO_X-N reduction on media surface, with TSS removal through pores and interstitial void spaces in the media bed, eliminates the need for a separate liquid-solids separation unit. The presence of a large population of biofilm prevents washout of microorganisms. This allows substantial BNR even at HRTs well below those that would cause washout in a CAS bioreactor.

Thus, the performance of BNR removal is always guaranteed, regardless of water temperature. Finally, nitrogen stripping and re-oxygenation of mixed liquor prior to entering the secondary clarifiers are not required, so re-aeration is not mandatory for the tertiary post-denitrification system.

BAF technology has been successfully in use for at least two decades for BNR. But, it is commonly believed that it is not possible to achieve ultra-low substrate concentrations, especially ammonia and nitrate concentrations in the effluent, due to the mass transfer limitation across the mass transfer layer and within biofilm. Design, upgrade, and successful operation of complete nitrogen removal to achieve less than 1.0 mg/L TN, with HRTs ≤ 2 hours in cold climates (≤ 10°C), has not been previously demonstrated in the field.

Three plants were used in a recent study. Plant A was originally a secondary carbon removal biological activated sludge plant that had to meet total nitrogen (TN) limits of 3.0 mg/L on an annual average basis and 2.0 mg/L over the summer months. To help ensure that the stringent TN requirement was being met consistently, Plant A commissioned a full scale Kruger tertiary nitrification and denitrification (N-DN) BIOSTYR® system in August 2006.

The system was designed to treat 12 MGD secondary effluent to achieve a TN concentration less than 2.0 mg/L and 3.0 mg/L for summer and winter,

continued overleaf...

respectively, in tertiary effluent. The influent wastewater temperature typically varies from 7°C – 20°C.

Plant B was originally constructed in the 1950s and was facing the challenge of meeting its permit for total suspended solids, carbonaceous chemical oxygen demand, ammonia nitrogen, and TN. To address this challenge, Kruger's tertiary N-DN BIOSTYR was chosen. The system was designed to treat 53.6 MGD of secondary effluent from the existing high pure oxygen (HPO) plant to achieve advanced wastewater treatment standards and produce less than 0.5 mg/L NH_4-N, and less than 1.0 mg/L NO_x-N in tertiary effluent on a monthly average basis. Minimum design water temperature during the winter is 10°C.

Plant C was also a secondary carbon removal CAS system with trickling filters and aeration basins. Due to short solids retention times of less than two days and low water temperatures, the existing secondary CAS was incapable of oxidizing NH_4-N and meeting the new TN limits of 3 mg/L. In order to meet the TN requirements, Plant C chose Kruger's tertiary N-DN BIOSTYR system and upgraded its existing secondary carbon removal only CAS plant to an advanced municipal wastewater treatment plant. This provided tertiary-level BNR and TSS removal.

The system was designed to treat 14.2 MGD of secondary effluent from the existing CAS plant to achieve advanced wastewater treatment standards and produce less than 3 mg/L TN in effluent, with approximately 2.0 mg/L of the total represented by refractory dissolved organic nitrogen (RDON).

NITRIFICATION PERFORMANCE

Operation data from Plants A, B, and C tertiary N-DN BAF plants indicated that there is a correlation between applied NH_4-N volumetric loading rate (VLR) and NH_4-N removal rates. At temperatures less than 10°C, the NH_4-N removal rate increased linearly with applied NH_4-N VLR less than 40 lb/1,000 ft^3/day.

At temperatures around 20°C, the NH_4-N removal rate was directly proportional to applied NH_4-N VLR, with applied NH_4-N VLR less than 55 lb NH_4-N/1,000 ft^3/day. In these ranges, the NH_4-N removal rate increases as applied NH_4-N VLR increases, and it is a first order reaction with respect to applied NH_4-N VLR.

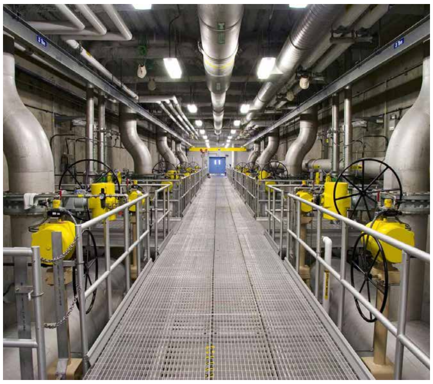
The applied NH_4-N VLR cannot be increased indefinitely. At a temperature equal or less than 10°C, once applied NH_4-N VLR exceeds the 40 lb/1,000 ft^3/day, the NH_4-N removal rate has reached a plateau. This represents a zero order biofilm in which the NH_4-N removal rate does not increase as applied NH_4-N VLR increases. In other words, NH_4-N removal rate is not limited by the bulk

NH_4-N concentration. But rather, it is limited by the rate of oxygen transfer to the biofilm.

DENITRIFICATION PERFORMANCE

Operation and performance guarantee data from Plants A, B, and C also indicated that denitrification performance is good and consistent for post-denitrification, as long as the flow distribution condition is acceptable; sufficient external carbon source is available; and/or unexpected media bed clogging does not occur very often. HRTs in the post-denitrification BAF can be as short as 20 minutes. In addition, eliminating oxygen transfer relieves the biggest limitation on the sludge volume loading rate (SVLR).

Thus, SVLR can be much higher than for aerobic biofilm processes. The full-scale results from Plants A, B, and C indicated that monthly average NO_x-N concentration has been consistently lower than 0.5 mg/L at applied NO_x-N sludge loading rate (SLR) as high as 80 lb NO_x-N/1,000 ft^3/day.



Pipe gallery in a BIOSTYR system.

The basic relationship between applied NO_x-N SLR and NO_x-N removal rate is similar to that of the nitrification process. At temperatures less than 10°C, NO_x-N removal rate increased linearly with applied NO_x-N VLR less than 80 lb NO_x-N/1,000 ft^3 /day. At temperatures around 20°C, the NO_x-N removal rate was also proportional to NO_x-N VLR, with applied NO_x-N VLR less than 90 lb NO_x-N/1,000 ft^3/day.

TSS REMOVAL PERFORMANCE

TSS removal performance at the plants went well. Full-scale plant operation and performance guarantee testing data indicated that less than 10 mg/L of TSS concentration on a monthly average basis is achievable in a tertiary denitrification BAF with a simultaneous reducing NO_x-N (denitrification) process. Tertiary N and denitrification BAFs performed very well in terms of TSS removal.

The floating media that is retained by nozzle plates has about 35% – 40% void space (porosity) that allows TSS accumulation during the filtration phase. This provides additional filtering to ensure a low solids concentration (≤ 10 mg/L) in the tertiary BAF effluent.

continued on page 112

COMPANY PAGE

KISTERS North America
Mantech
Mil-Ram Technology
Mueller Canada
Norditech Pty.
Osprey Scientific
Real Tech
Solinst Canada
SPD Sales Limited
USABluebook
Waterra Pumps Limited

Water Quality Test Kits
Bell Flow Systems
Canature WaterGroup
Franklin Empire
Geneq
Hoskin Scientific
Mantech
Osprey Scientific
USABluebook

Water Towers
Greatario
KSB Pumps
Tank Connection

Water Use & Treatment Optimization
Aclarus Ozone Water Systems
AWI (Anthratech Western)
Bio-Microbics
Bioteq Environmental Tech.
DECAST
HydroFLOW Canada
Markland Specialty Engineering
Medora Corporation
Membrane Specialists
MS Filter Systems
Ovivo USA
SCG Industries
SciCorp International
SHAC Environmental Products
StormTrap
Trojan Technologies
Wildcat Water Technologies
Wilo Canada
World Water Operator Training Co.

Waterproofing
Aquablast Corp.
Belzona Great Lakes Holdings
Denso North America
KG Services
Nuna Innovations

Weirs
Aquablast Corp.
Aquanox Water Control Products
Bell Flow Systems
C&M Environmental Technologies
Can-Am Instruments
Claro Environmental Tech.
Flowmetrix Technical Services
Grande Water Management
Monitario Technical Services
Nuna Innovations
Protectolite Composites
Sigma Engineering
Smith & Loveless

Zebra Mussel Control
Aquafy Water Technologies
CEMATRIX
Chlorinators
Prominent Fluid Controls

EFFECTIVELY USING BAF TECHNOLOGY IN COLD CLIMATES

continued from page 61

HYDRAULIC LOADING PERFORMANCE

For the design and operation of a BAF system, one very important constraint is the maximum HLR, since excessive headloss will occur if the BAF is operating at a higher HLR. The maximum HLR was determined based upon influent TSS concentration along with biodegradable carbon concentration, either internal (plant influent carbon) or external (exogenous carbon source).

The HLR affects the operation and performance of a BAF in different ways, depending on the type of application. Generally, an increase in HLR causes increased headloss, more frequent backwashing and wasting a larger amount of treated wastewater for backwash. For a post-denitrification BAF, the more frequent backwashing due to a higher HLR has a detrimental effect on the denitrification performance. This is because of the introduction of excessive dissolved oxygen into the media bed from the air scouring process during backwash.

CONCLUSIONS

The experience with the operation of Plants A, B, and C supports the conclusion that BAF is an excellent technology for upgrading existing CAS systems, to either maintain nitrification at higher flow rates/loads or upgrade a CAS plant to meet new nitrification or total nitrogen removal requirements.

Ultra-low substrate concentrations could be achieved in biofilm BAF systems and the performance of the system is highly consistent regardless of water temperature. Undoubtedly, BAF technology has demonstrated that extremely low effluent concentrations of NH_3-N (less than 0.5 mg/L), NO_x-N (less than 0.5 mg/L) and TSS (less than 10 mg/L) can be consistently achieved at very short SRTs in cold climates (less than 10°C).

Finally, the results show that biological active filter technology is capable of achieving extremely low TSS concentrations with short hydraulic retention times.

John He is with Veolia Water Technologies. Glenn Thesing, Hong Zhao, Rich DiMassimo, Luke Wood, Louis Ortenzio, Mark Drake, Mathew Edds, Meg Hallowed, and Pia Prohaska are with Kruger Inc. (a Veolia Water Company). Email: john.he@veolia.com