Overcoming Hydraulic Limitations of the Integrated Fixed-Film Activated Sludge and Moving Bed Biofilm Reactor Process

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In 2011, more than 600 moving bed biofilm reactors (MBBRs) were operational in 50 different countries. Approximately 20 systems incorporating an integrated fixed-film activated sludge (IFAS) process were operational in 2011, 15 of which exist in the United States. Similar design standards are applied to MBBR and IFAS process mechanical components. Each of these process mechanical components influences the hydraulic throughput of MBBR and IFAS systems. There are six IFAS systems that have been subject to a hydraulic failure that resulted in plastic biofilm carrier loss; however, hydraulic failures are an engineering problem that can be solved. While hydraulic failures that result in plastic biofilm carrier loss have occurred in less than 1 percent of the known existing MBBR and IFAS systems, the failures were public. Potential negative public perception may perpetuate utility reluctance to implement this technology. Examples of IFAS process that have lost plastic biofilm carriers due to hydraulic failure, hydraulic failure mechanisms (which resulted in plastic biofilm carrier loss), and design features for overcoming hydraulic limitations inherent to the IFAS (and MBBR) process are described.

The MBBR, illustrated in Figure 1, includes one, or a series of, submerged and completely mixed biofilm reactor(s), followed by a liquid-solids separation unit (e.g., sedimentation basin, dissolved air flotation, or ballasted flocculation). Moving bed reactors can be operated as a two- (anoxic) or three- (aerobic) phase systems with buoyant free-moving plastic biofilm carriers that require energy (i.e., mechanical mixing or aeration) for uniform distribution throughout the bulk phase (McQuarrie and Boltz, 2011; Boltz et al, 2010).

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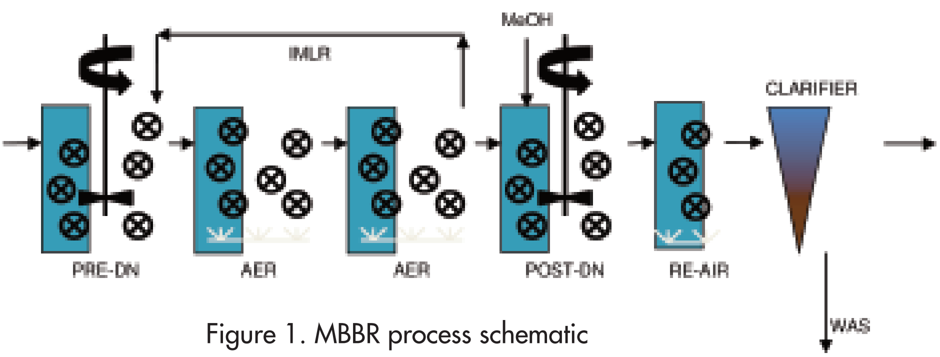

Figure 1. MBBR process schematic

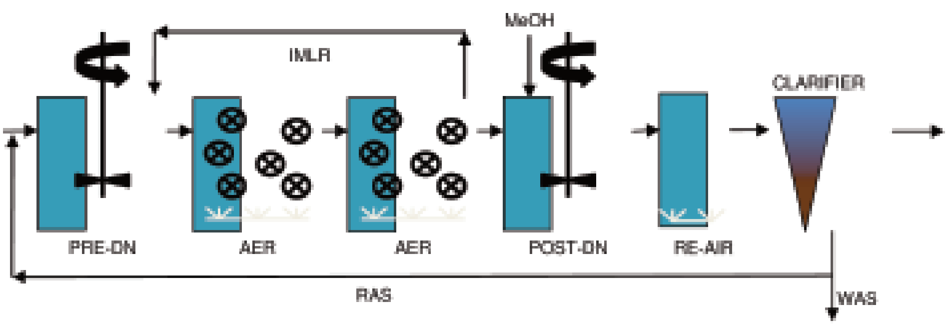

Figure 2. IFAS process schematic

Features typical of a MBBR include:

- Continuously flowing biofilm reactor with biofilm compartment only
- No MLSS accumulation; therefore, amenable to a variety of liquid-solids separation unit processes
- Processes:
    - o Carbon oxidation (BOD_5 removal)
    - o Nitrification
    - o (Pre- and post-) denitrification
- More than 600 installations in 2011

The IFAS processes, depicted in Figure 2, combine suspended growth and biofilm compartments in a single bioreactor. Most IFAS applications are for nitrogen removal where free-moving plastic biofilm carriers are added to one or two aerobic bioreactor cells to enhance system capacity for nitrification. In these systems, nitrifiers grow selectively in the biofilm and oxidize ammonium (provided the operational condition results in nitrifiers washing out of the suspended growth compartment), while the suspended biomass

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largely removes soluble and particulate organic matter and facilitates denitrification in the anoxic zone(s). The short solids retention time (SRT) typical of IFAS processes (e.g., three to five days) can also encourage the development of a substantial population of phosphorus accumulating organisms (PAOs) in the suspended growth compartment, which is responsible for biological phosphorus removal, especially if a dedicated anaerobic zone is included in the process.

Features typical of an IFAS system include:

- Biofilm and suspended biomass compartments
- A majority of moving bed applications in North America use IFAS due to existing wastewater treatment (WWT) infrastructure, which primarily utilizes the activated sludge process.
- Implementation of the IFAS process is primarily triggered by a need to improve nitrification or total nitrogen removal.
- IFAS is warranted when there are site constraints at an existing clarifier coupled activated sludge-based wastewater treatment plant (WWTP) or the technology lends itself to an economic advantage.

Chronology of MBBR and IFAS Systems

Figure 3 illustrates a timeline indicating the chronology of MBBR and IFAS system development. In addition to major technological milestones, a parallel timeline that indicates IFAS systems that have failed hydraulically resulting in plastic biofilm carrier loss. Moving-bed reactor hydraulic failures that resulted in plastic biofilm carrier loss occurred after 300 moving-bed reactors had been successfully operating without hydraulic failure.

Case Studies: Hydraulic Failures Resluting in Media Loss

Hydraulic failures (of which the authors are aware) that resulted in plastic biofilm carrier loss have occurred in less than 1 percent of existing moving bed reactors. However, the reported failures described all occurred in IFAS systems. The limited hydraulic failures that resulted in plastic biofilm carrier loss became a matter of public concern, and were exposed through media outlets such as the Internet and local newspapers. According to anecdotal evidence, the hydraulic failures have generally occurred during system construction. Consequently, operational conditions inconsistent with the design mode of operation may have been prevalent, and process instrumentation may not have been online. Therefore, under these circumstances, limited information exists to describe the conditions that ultimately resulted in the hydraulic failure and biofilm carrier loss.

Five case studies illustrating hydraulic failures that resulted in plastic biofilm carrier loss from IFAS processes are evaluated, including: (1) Broomfield, Colo.; (2) Raisio, Finland; (3) Groton, Conn.; (4) Hooksett, N.H.; and (5) Mamaroneck, N.Y.

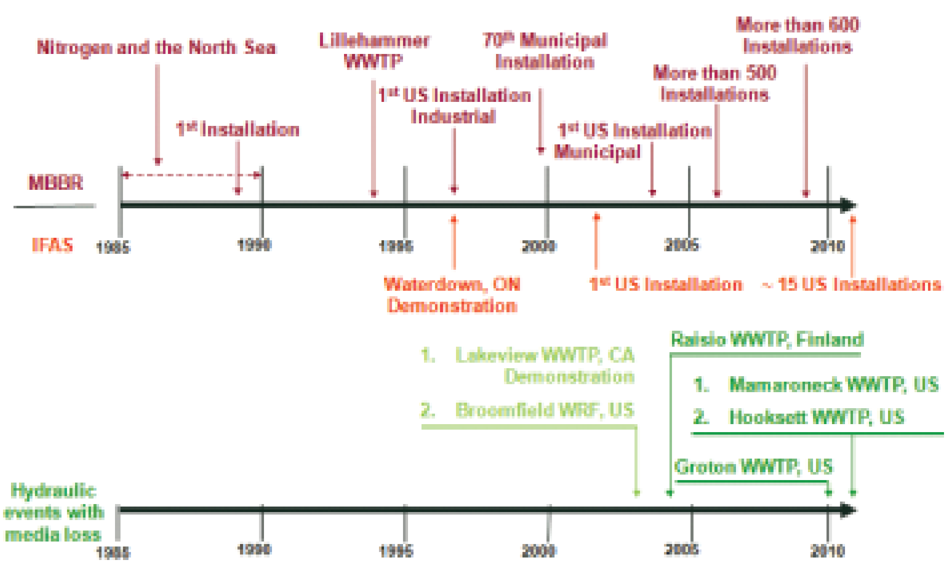

Figure 3. Chronology of MBBR and IFAS systems, including hydraulic failures

The case studies are based on press record, and a limited technological evaluation of the respective systems. The intention of conducting case studies is not to fully evaluate the individual systems, nor is it to make inferences about the party that is responsible for the respective system hydraulic failures and biofilm carrier loss. Rather, the intention is to identify general mechanisms of hydraulic failure and biofilm carrier loss and recommend generally applicable design protocol to avoid such a hydraulic failure and biofilm carrier loss in moving bed reactors such as the MBBR or IFAS processes. While the following cases are not explicitly evaluated and described, it should be mentioned that free-moving plastic biofilm carrier processes located in (1) the Region of Peel (IFAS), Canada; (2) Varkaus, Finland; (3) Vihti (MBBR), Finland; and (4) Laufäcker, Baden, have also experienced hydraulic failure that resulted in carrier loss. Hydraulic failure at the Region of Peel wastewater treatment facility, for example, resulted from excessive water approach velocity and inadequate plastic biofilm carrier retention screen design.

Broomfield, Colo.

The Broomfield Water Reclamation Facility in Broomfield, Colo., consists of preliminary treatment (fine screens and grit removal), primary treatment, advanced secondary treatment, and disinfection. Reclaimed municipal wastewater requires secondary effluent filtration. Primary treatment is achieved with sedimentation. Advanced secondary treatment, including biological phosphorus removal and total nitrogen control, is achieved with an IFAS-based A2O process. Secondary clarifiers are used for liquid-solid separation. Secondary effluent flows to an ultraviolet disinfection unit process. Following disinfection, the treated effluent may be discharged to Big Dry Creek. Alternatively, secondary effluent is pumped through sand filters prior to entering the reclamation system. Solids removed by primary clarification are thickened in the sedimentation basins, while waste activated sludge is thickened with dissolved air flotation units. The thickened sludge is reduced and stabilized in anaerobic digesters.

The Broomfield facility was the first in the United States to utilize IFAS technology. A snow melt/storm event in 2002, during construction of the IFAS improvements, resulted in bulk-liquid containing plastic biofilm carriers to overflow process tanks. Ultimately, it was determined that the cause of the hydraulic failure was an under-sized pipe connecting the bioreactor and secondary clarification units. Lost plastic biofilm carriers were discharged to the Big Dry Creek, where they settled on the creek bed. After replacing the under-sized bioreactor effluent pipe and recovering lost plastic biofilm carriers, the facility has been operational without hydraulic failure since 2002.

Raisio, Finland

The Raisio Wastewater Treatment Plant in Raisio, Finland, uses a liquid-stream treatment process consisting of preliminary treatment (screens and grit removal), primary treatment, and advanced secondary treatment. The system was designed to process a combination of municipal and food-industry wastewaters. Primary clarifiers were designed to accommodate metal salt and polymer dosing to achieve chemically enhanced primary treatment. Advanced secondary treatment was achieved with a four-stage Bardenpho process that incorporated IFAS (with free-moving plastic biofilm carriers) in the aerobic zone. The supplemental carbon source methanol was fed to the post-anoxic zone to promote denitrification. The secondary clarifiers were also designed for metal salt and polymer dosing to achieve chemically enhanced clarification. Treated effluent was discharged to the Baltic Sea. During wet-weather flows, screened and de-gritted wastewater could bypass the

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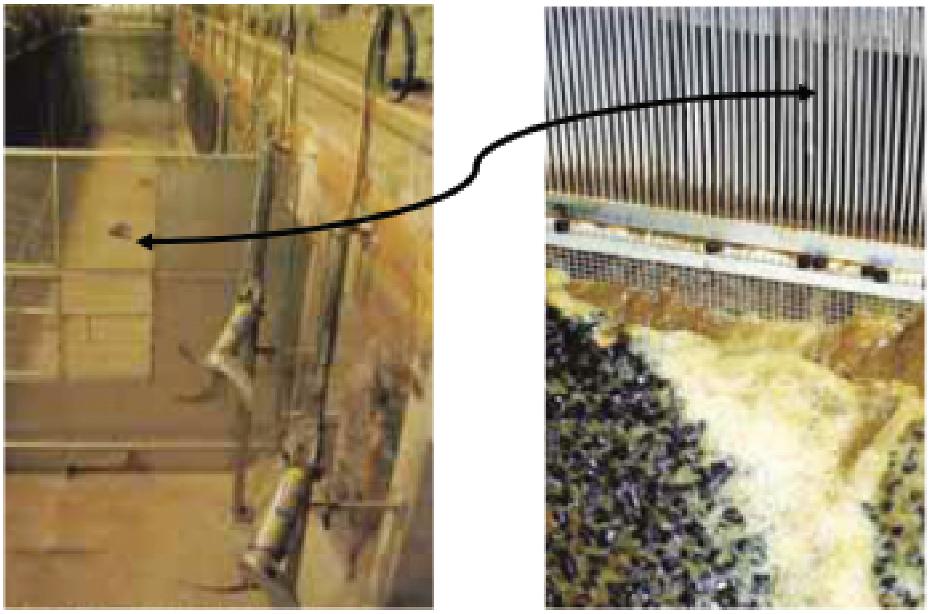

Figure 4. Flat-screen walls at each end of the aerobic IFAS zone of the Raisioplant Bardenpho process (left). Improvement to the originally designed flat-screen wall following an initial hydraulic failure that resulted in carrier loss from the Raisio plant (right).

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main wastewater treatment process where the wet weather stream was processed by dissolved air flotation. The screened, de-gritted, and clarified (via flotation) wet weather flow was then combined with the treated main-stream effluent prior to being discharged into the Baltic Sea. Solids removed from the process by primary and secondary clarification units were compacted by gravity thickening and dewatered by centrifuge.

The Raisio plant was subject to several hydraulic failures that resulted in plastic biofilm carrier loss before being shut down in 2007. The plastic biofilm carriers have a propensity to float and cause foaming when they are first placed in a process tank, especially when the tank is filled with clean water (McQuarrie and Boltz, 2011). The first Raisio plant hydraulic failure, reported by Arvaja (2004), occurred in 2004 during system startup. A combination of inadequately designed flat-screen walls (which were too low) and foaming caused the plastic biofilm carriers to overflow the flat-screen and bioreactor walls. Plastic biofilm carriers spilled into corridors that surrounded the bioreactor, but a majority of the carriers flowed over the flat-screen walls and into downstream secondary clarifiers. Approximately several hundred cubic meters (of the plastic carriers) flowed into the secondary clarifiers, but only ten cubic meters of these plastic biofilm carriers were officially lost into Raisio Bay and, ultimately, the Baltic Sea (Rantanen and Huhtamäki, 2005). Remedial action taken by the system manufacturer in response to this first hydraulic failure was to heighten the flat-screen wall. Figure 4 depicts the originally designed flat-screen wall, and the screen applied to heighten the flat-screen wall.

Subsequent hydraulic failures resulted from broken plastic biofilm carrier fragments (which were smaller than the screen openings) fouling the flat retention screen. When fouled, the flat-screen wall had significantly reduced hydraulic throughput, which caused hydraulic failures and resulted in plastic biofilm carrier loss. The plastic biofilm carriers were broken by post-anoxic zone mixers and during the process of transferring them from the secondary clarifiers to the IFAS zone. Remedial action taken by the system manufacturer following these subsequent hydraulic failures included replacing the flat plastic biofilm carrier retention screens with cylindrical screens. The use of cylindrical screens in aerobic IFAS zones in now generally accepted design criteria (Boltz et al, 2010).

Figure 5. Plastic biofilm carrier retention screens at the Groton facility before (left) and after (right) a storm event and their structural failure

Figure 6. Plastic biofilm carrier clean-up along the New England coastline (March 2011)

Groton, Conn.

The City of Groton Water Pollution Control Facility in Groton, Conn., consists of preliminary treatment, primary treatment, secondary treatment, and disinfection. Primary treatment is achieved with sedimentation; secondary treatment is achieved with a Modified Ludzack Ettinger (MLE) process. Secondary clarifiers are used for liquid-solid separation. Secondary effluent flows to a chlorine contact basin for disinfection. Following disinfection, the treated effluent is discharged to the Thames River. Solids removed from the process by the primary and secondary clarifiers is thickened, and reduced and stabilized in anaerobic digesters.

A Groton facility improvements project to incorporate the IFAS process experienced biofilm carrier loss for the third time in March 2010. The series of hydraulic failures occurred during a two-year period, approximately, and each was the result of biofilm carrier retention screen failure. The first failure resulted from the screen ends caving in, allowing plastic biofilm carriers to flow through circular orifices core drilled in the screen containing wall(s) to the secondary clarifiers. The end was a screen plate that was tack welded to the outside of the cylindrical biofilm carrier retention screen. The tack weld resulted in end cap structural instability. A proper cap weld is located inside the cylindrical screen perimeter to provide required structural support. Ultimately, each biofilm carrier retention screen was removed and the welds were reinforced on the ends before the system was placed back into service.

A unique design feature of the biofilm carrier retention screens was the ability to extract the submerged screens from the bioreactor by guide rails, as depicted in Figure 5. The second loss of plastic biofilm carriers most likely occurred when the cylindrical screens were dislodged from their fixed position by aeration that exerted excessive uplift forces on the media retention screens. The biofilm carrier retention screens were constructed with "structural support fins" on the cylindrical screens exterior rather than inlaying structural supports on the screen interior. As a remedial action, clips were installed on each screen to lock them in place. If a clip is removed, the screen may be lifted out of the basin for inspection or cleaning.

The third media retention screen failure, which occurred in March 2010, was the result of severe flooding which adversely impacted numerous wastewater treatment facilities in Connecticut and Rhode Island. However, instantaneous flow measured at the Groton facility when the hydraulic failure occurred did not exceed the media retention screen design hydraulic loading rate. Nevertheless, the water surface elevation in the IFAS bioreactors rose rapidly. It is plausible that hydrostatic pressure created by a rapid rise in water surface elevation caused the screens to collapse, as depicted in Figure 5. However, screen blinding by plastic biofilm carriers may have contributed to the rapid rise in water surface elevation. Plastic biofilm carrier retention screens must be designed to withstand a load exerted by hydrostatic pressure when the process tank is full. Plastic biofilm carriers flowed, with the effluent wastewater, into the Thames River, and, ultimately, into Long Island Sound. Rows of plastic biofilm carriers began appearing in the wrack line along the island's beaches following the March 2010 failure (Voskamp, 2010).

Hooksett, N.H.

The Hooksett Wastewater Treatment Facility in Hooksett, N.H., consists of preliminary treatment (fine screens and grit removal), advanced secondary treatment, and (chlorine) disinfection. Advanced secondary treatment consists of biological phosphorous removal (anaerobic zones), pre-denitrification (anoxic zones), and nitrification (in two zones that contain free-moving plastic biofilm carriers). Secondary clarifiers are used for liquid-solid separation and were designed for metal salt and polymer dosing to achieve chemically enhanced clarification. Secondary effluent flows into a chlorine contact process for disinfection. Waste activated sludge is pumped to aerated sludge holding tanks prior to dewatering with a belt filter press. The dewatered sludge is hauled by truck to a compost facility. Treated effluent is discharged to the Merrimack River.

According to the New Hampshire Department of Environmental Services (NHDES), on March 6 and 7, 2011, an unpermitted discharge from the Hooksett facility caused by a blockage within the treatment system occurred. The blockage resulted in a release of approximately 250,000 to 300,000 gallons of inadequately treated wastewater and approximately 25 percent of the installed plastic biofilm carriers (approximately 65 m3) at the facility site. A significant, but unknown, number of the plastic biofilm carriers were discharged to the Merrimack River. A heavy rain event caused high wastewater flow influent to the Hooksett facility. The wet weather wastewater flow likely caused the IFAS system hydraulic failure and the loss of plastic biofilm carriers from process tanks into the environment. The plastic biofilm carriers used in this system may have blinded the retention screens when a slug of wet-weather flow forced the plastic biofilm carriers to accumulate around the screens. None of the screens, however, were damaged as a result. Plastic biofilm carriers, referred to as "sewage discs" in local media reports, were found along the New England coastline extending from Hooksett, N. H., to Cape Cod, Mass. (Brooks, 2011; Guilfoil, 2011). Cleanup efforts from this event are depicted in Figure 6.

The incident described above occurred overnight when the facility was not staffed. Since this incident, the facility has installed measures to prevent loss of plastic biofilm carriers. An alarm system, which was under construction during the incident, is now installed and fully operational. In the event of high wastewater levels, operators are notified and pumps are shut down. In addition, all drains and overflow features from the facility property are screened to retain any plastic biofilm carriers. There have been no hydraulic incidents since March 2011, including during the tropical storm Irene, which had more rainfall than the March 2011 storm (Russo, 2011).

Mamaroneck, N.Y.

A hydraulic failure that resulted in plastic biofilm carrier loss occurred during start-up of

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an IFAS system at the Mamaroneck Wastewater Treatment Plant, in Westchester County, N.Y. A peak hydraulic event resulted in plastic biofilm carriers migrating upstream and out of a retrofit IFAS system where they entered the influent stream of a secondary tank that had not yet been retrofitted as an IFAS system. Plastic biofilm carriers were then able to freely flow from the effluent of the not yet retrofit IFAS tank. None of the IFAS equipment or tanks were damaged in the incident. As with other hydraulic failures, this event became highly publicized as a cleanup was required along portions of the Long Island Sound coastline. Kreisman and Marszalek (2011) reported that rings, which started showing up on local beaches and washed in by the hundreds, possibly thousands, had not yet been used, but they had already been placed into sewage treatment tanks, from the fierce rains that washed them into the Sound. Since the event occurred, the retention screens within the aeration basins have been redesigned to improve the hydraulic through-put. Figure 7 depicts the Long Island Sound coastline cleanup.

Figure 7. Plastic biofilm carrier cleanup on the Long Island Sound coastline following a hydraulic failure and biofilm carrier loss from the Mamaroneck plant MBBR process (March 2011)

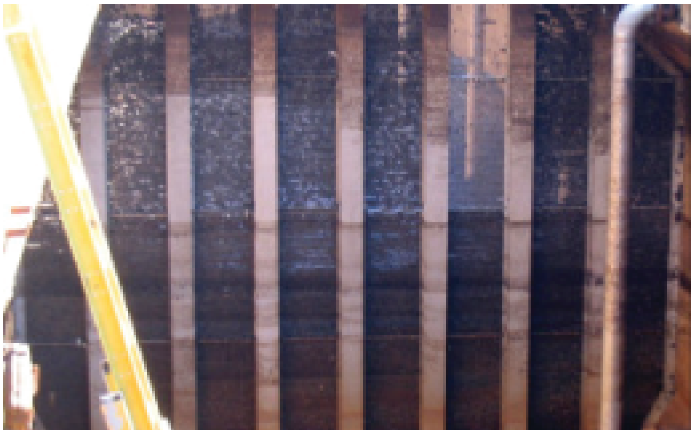

Figure 8. Plastic biofilm carrier retention flat screen with carriers lodged in screen openings

Materials And Methods

Recently publicized failures of moving bed reactors such as MBBR and IFAS systems that have resulted in carrier loss have common features such as system response to excessive hydraulic loading. The hydraulic characteristics of moving bed reactors are typically measured by approach velocity and screen hydraulic loading rate. The methods by which plastic biofilm carrier retention screens typically fail are identified.

Modes of Flat Screen Failure

Plastic biofilm carriers are retained in anoxic IFAS and MBBRs by flat screens. Figure 8 depicts a flat screen that has plastic biofilm carriers lodged in the screen openings. A loss of flat screen hydraulic throughput is a mode of system hydraulic failure. This can be caused by the accumulation of the plastic biofilm carriers or trash on the screen surface, resulting from excessive hydraulic loading rate or approach velocity. In addition, the absence or inefficiency of an air-scour device can contribute to the retention screen accumulation. Table 1 summarizes modes of (flat) plastic biofilm carrier retention screen failure.

Table 1. Modes of flat retention screen failures

Cause	Effect
Plastic biofilm carrier or trash accumulation on the screen surface due to insufficient screen area or excessive approach velocity	Hydraulic throughput substantially reduced and peak hydraulic flows may result in basin over flow and plastic biofilm carrier loss.
Absent or insufficient air-scour device	Plastic biofilm carrier or trash accumulation on the screen surface.

Modes of Cylindrical Screen Failures

The IFAS treatment processes utilize cylindrical screens for the retention of plastic biofilm carriers in aerobic zones. The cylindrical screens extend outward into the upward flowing air, which results in the possibility of additional modes of failure when compared to the flat retention screens. The cylindrical screens may not

Table 2. Modes of cylindrical retention screen failures

Cause	Effect
Retention screens NOT reinforced; thus subject to structural failure	Screen-wall interface integrity lost and plastic biofilm carriers migrate to downstream unit process(es)
Inadequate end-cap weld (e.g., a tack-weld to the outside of the screen rather than full internal weld)	Screen end-cap collapse, plastic biofilm carriers migrate to downstream unit process(es)
Trash accumulation due to insufficient pretreatment	Hydraulic throughput substantially reduced and peak hydraulic flows may result in basin over flow and plastic biofilm carrier loss.
Plastic biofilm carrier accumulation on the screen surface resulting from insufficient screen area, too high media fill fraction, improper depth of submergence, insufficient underneath aeration intensity, combined with excessive approach velocity	Hydraulic throughput substantially reduced and peak hydraulic flows may result in basin over flow and plastic biofilm carrier loss.

be properly structurally reinforced. If screen wall integrity is lost, plastic biofilm carriers can migrate to downstream unit processes. An inadequate cylindrical screen end cap weld, such as a tack weld to the outside of the screen rather than a full internal weld, can result in system hydraulic failure. If the end cap collapses, plastic biofilm carriers can pass through the retention screen wall. Plastic biofilm carriers or trash accumulation on the cylindrical screen surface, resulting from excessive hydraulic loading rate or approach velocity, can compromise the retention system. Hydraulic throughput is reduced, which may lead to an overflow of the bioreactor and the associated loss of plastic biofilm carriers. Figure 9 illustrates these three modes of hydraulic failure due to cylindrical screens. Table 2 summarizes modes of (cylindrical) plastic biofilm carrier retention screen failure.

Results and Discussion

It is essential to have preliminary treatment, including screening and grit removal, within an IFAS design to prevent plastic biofilm carrier retention screen blinding and the accumulation of inert material (rags, plastic, and grit) within the bioreactors. With primary clar-

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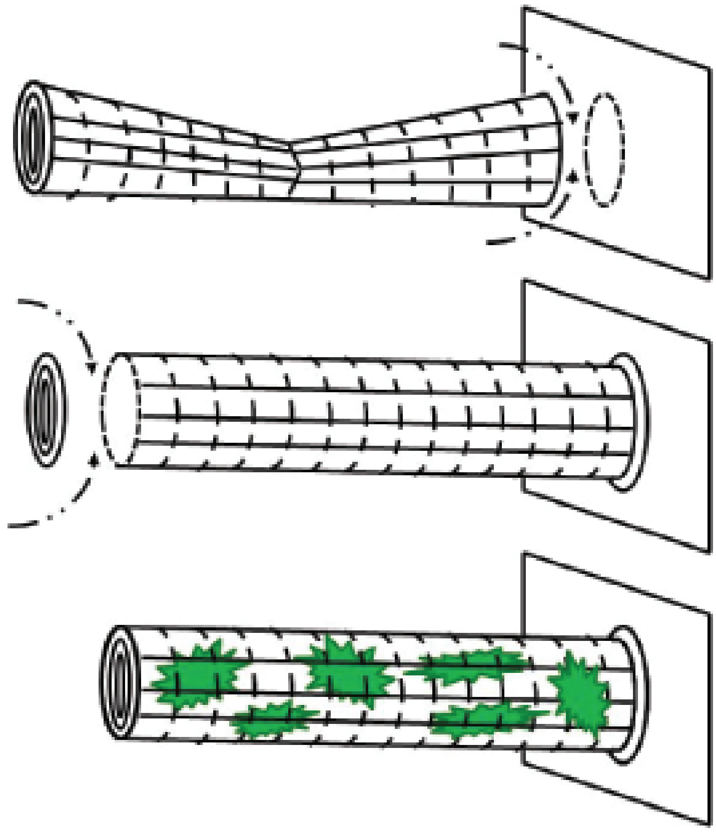

Figure 9. Modes of cylindrical screen failure: structural collapse (top), inadequate end cap installation (middle), and plastic biofilm carrier or trash accumulation (bottom)

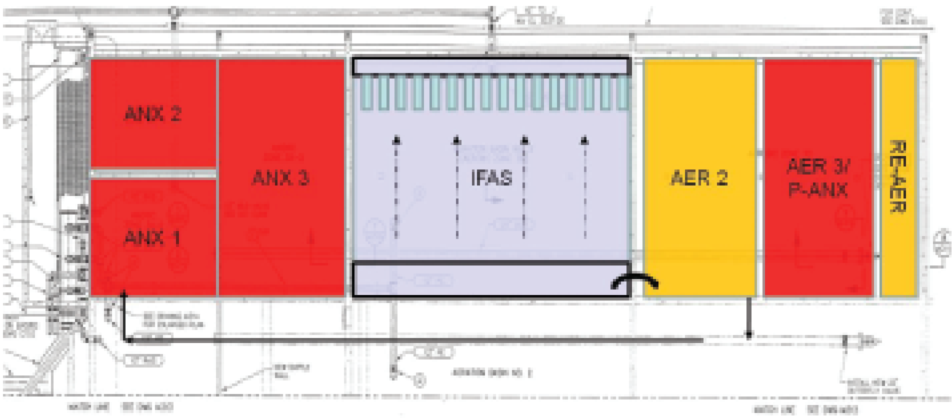

Figure 10. Redirect flow perpendicular to original basin flow scheme

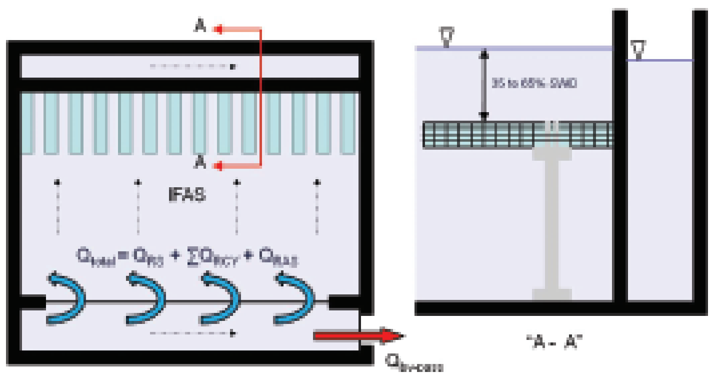

Figure 11. Wet-weather bypass around the IFAS zone
Qbypass = peak wet-weather flow directed to downstream suspended-growth reactor

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ifiers, a maximum 6-mm screen opening is required but a 3-mm screen opening is recommended for raw wastewater. Redundancy within the screening system also needs to be addressed. Some treatment facilities utilize a bypass channel with a manual bar (trash) screen as a measure of redundancy for the system. Caution should be taken with these bypass channels, as their use can result in the accumulation of rags and other inert material in the MBBR or IFAS process. Full redundancy of the 6-mm (or 3-mm) screens should be installed. Alternatively, features should be included that isolate the bypass channel and prevent the bypass stream from adversely affecting the bioreactor.

Media Retention Screen Design Criteria

Typical plastic biofilm carrier retention screen design allows for a maximum 50- to 150-mm head loss across each screen-containing wall at the peak hydraulic flow (McQuarrie and Boltz, 2011). Screen hydraulic loading rate is the flow rate applied per unit of superficial screen area (m3/m2/hr). The hydraulic loading rate is typically less than 50 to 60 m3/m2/hr under all flow conditions and includes the raw wastewater, internal mixed-liquor recycle (IMLR), return activated sludge, and in-plant recirculation streams. The plastic biofilm carrier retention screens are typically constructed of wedge wire. Perforated plate screens may be used, but the hydraulic loading rate must be reduced. Additional design criteria for the retention screens include: 1) cylindrical screen submergence of 35- to 65-percent of the bioreactor side water depth, 2) cylindrical screens with a 28 to 76-cm diameter (28-cm typ.), 3) cylindrical screens with a 2.1 to 4.9-m length (3.7-m typ.), and 4) cylindrical screens with structural support to resist forces exerted by the plastic biofilm carriers.

Design Features to Overcome Hydraulic Limitations

A number of facilities have incorporated design features to overcome hydraulic limitations inherent to the IFAS process. Typical features incorporated into full-scale IFAS designs include: 1) redirecting flow perpendicular to normal basin flow scheme, 2) bypassing wet-weather flows around the IFAS zone(s), 3) split IMLR flow using a series of pumps, and 4) process control with instrumentation to overcome hydraulic limitations.

Redirect Flow Path. Figure 10 illustrates redirection of flow perpendicular to the normal
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basin flow scheme within the retrofit of an existing conventional activated sludge basin to accommodate the IFAS process. As the mixed liquor flows from Anoxic Zone 3 (ANX 3), it enters a distribution channel which adjusts the flow path to allow the flow to cross the IFAS reactor at a path perpendicular to the normal reactor flow. If the aeration basin zone were unaltered, the IFAS zone would have a L:W = 1.5 and a 53-m/hr approach velocity. By redirecting the flow, the IFAS zone has a L:W = 0.65 and a 35-m/hr approach velocity, and both design criteria are within generally accepted tolerances.

Bypass Peak Wet Weather Flow. Typically, modes of hydraulic failure within IFAS systems are directly related to reduction of system hydraulic throughput. Peak wet weather or influent conditions dramatically contribute to this problem, especially during construction. The incorporation of a peak flow bypass around the reactor containing the plastic biofilm carriers is warranted in some cases. In an IFAS system, the bypass of wet weather flow to downstream reactors within the bioreactor is similar to the practice included within a number of conventional activated sludge and step feed wastewater treatment facilities. Whereas the bypass of wet-weather flows around a conventional activated sludge process protects the biomass inventory and allows a reduction in solids loading rates to the secondary clarification process, the bypass of wet weather flows around the IFAS zone protects the plastic biofilm carriers and retention screening systems. This practice allows the designer to maintain design criteria established for the retention screen hydraulic loading rate and approach velocity. Figure 11 illustrates an IFAS zone bypass.

*Split Internal Mixed Liquor Recycle (IMLR) Flow***.** A full-scale IFAS process demonstration project was implemented at the Hampton Roads Sanitation District James River Treatment Plant. The existing aeration basins had a high L:W = 4; therefore, the approach velocities exceeded design criteria. The IMLR flow required to meet treatment objectives was a large contributor to the forward flow. To reduce the approach velocity, two mixed liquor recirculation pumping systems where installed. Figure 12 illustrates the split IMLR pump approach to overcoming hydraulic limitations (McQuarrie et al, 2009). The downstream pump (IMLR 2) capacity was optimized to meet treatment performance requirements and to place a practical limit on the amount of recirculation from this location such that the approach velocity would remain within design criteria. The upstream pump (IMLR 1) was included within the reactor to offset the forward flow introduced into the IFAS zone (in part from IMLR 2), thereby limiting the approach velocity. This two-pump system was refined throughout the demonstration project, providing a cost-effective solution to allow for the incorporation of the IFAS system.

Process Control. The use of instrumentation and the associated process control can be utilized in part to help overcome IFAS process hydraulic limitations. As shown in previous sections, the IMLR contributes significantly to the approach velocity and hydraulic loading rate in the IFAS zone. A probe used to measure nitrate/nitrite-N (NOX-N) within the anoxic environment can be utilized to help control the IMLR flow rate accordingly. The IMLR can be operated based on a NOX-N set point established to meet treatment performance goals. This can be used to address peak hydraulic loads within the system. When the NOX-N value is low, which is typical of peak (wet-weather) hydraulic events, the IMLR can be trimmed and reduce the screen HLR.

Conclusions

Similar design standards are applied to MBBR and IFAS process mechanical components: maximum plastic biofilm carrier volumetric fill, plastic biofilm carrier retention screens, air diffuser grid (in aerobic zones), and mechanical mixers (in anoxic zones). Each of these process mechanical components influences the hydraulic throughput of MBBR and IFAS systems. The authors are aware of IFAS systems that have been subject to a hydraulic failure that resulted in plastic biofilm carrier loss. Ultimately, hydraulic failures are an engineering problem that can be solved.

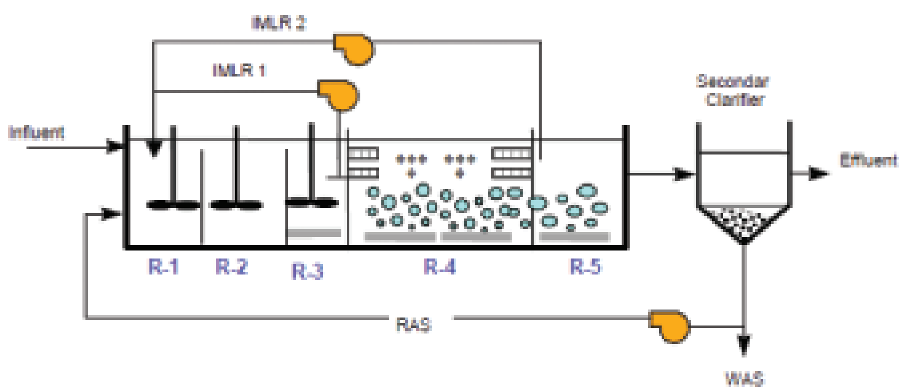

Figure 12. Split IMLR flow using a series of internal recirculation pumps

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