Integrated Fixed Film/ Activated Sludge (IFAS) Technology

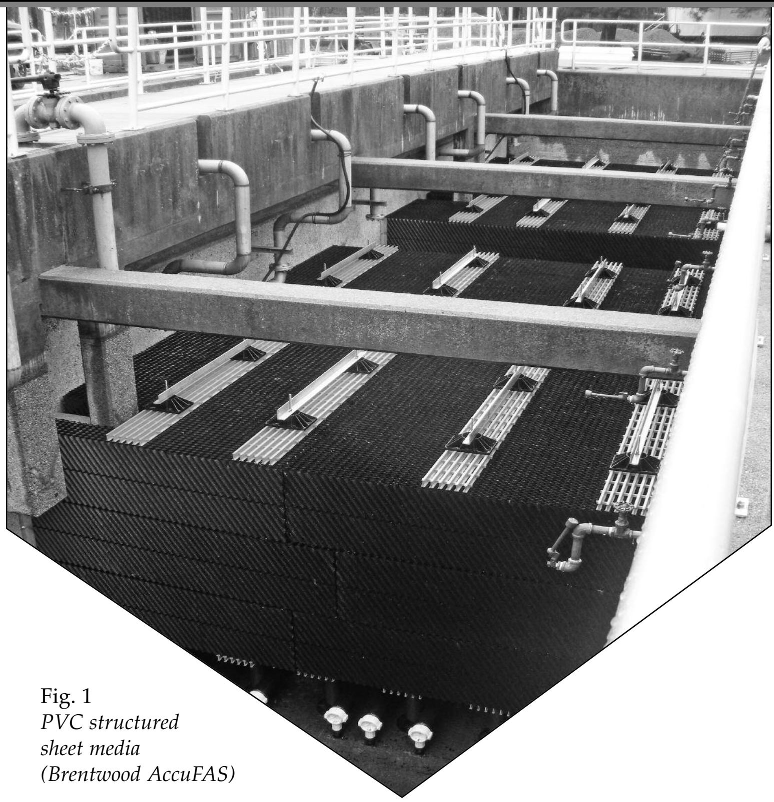


Fig. 1
PVC structured sheet media (Brentwood AccuFAS)

Integrated Fixed-film Activated Sludge (IFAS) Technology provides for additional biomass within a wastewater treatment facility in order to meet more stringent effluent parameters or increased loadings without the direct need for additional tankage. Industry practice for upgrading wastewater treatment plants usually focuses on increasing the bioreactor volume to provide the additional bacterial population required to meet the system kinetic needs. However, designers often encounter clarifier solids loading limitations that put an upper limit on the amount of biomass that can be carried in the suspended growth system. IFAS systems allow for the additional bacterial population to exist on a fixed surface, thereby eliminating the need to increase the suspended growth population.

IFAS systems add the benefits of Fixed Film systems into the suspended growth Activated Sludge process. Activated Sludge has process flexibility and provides a high degree of treatment. Fixed Film processes are inherently stable and resistant to organic and hydraulic shock loadings. Placing Fixed Film media into Activated Sludge basins combines the advantages of both of these approaches.

Evolution of IFAS Technology

The use of Submerged Fixed Film technology in the biological treatment of wastewater has been in practice for well over 60 years. Early work included the "Contact Aeration" process used in the 1930's and 1940's. At that time, asbestos panels were vertically suspended over a perforated pipe aeration grid. The process was staged with intermediate clarifiers, did not have return sludge capability, and the total Hydraulic Residence Time (HRT) was typically 1.7 to 3 hours.

This process was stable and responded well to load fluctuations without significant operator attention. However, without a Return Activated Sludge (RAS) provision, it lacked the range of control associated with Activated Sludge processes. Also, the fixed panels did not facilitate oxygen diffusion, good mixing, or energy efficiency. Eventually, this concept gave way to Activated Sludge practices.

In the following decades, hundreds of installations employing Submerged Fixed Film were introduced internationally, although relatively little work was done in the US. The small footprint and ease-of-operation of Submerged Fixed Film systems were the primary benefits driving the use of this technology.

In the 1980's and 1990's, work began in the US on the integration of Fixed Film and Activated Sludge technologies. Because of today's increasingly stringent effluent requirements, high cost of tank expansion, and reduced funding options, IFAS technology represents an attractive solution for wastewater applications requiring additional treatment capacity or increased biological nutrient removal, both in the United States and internationally.

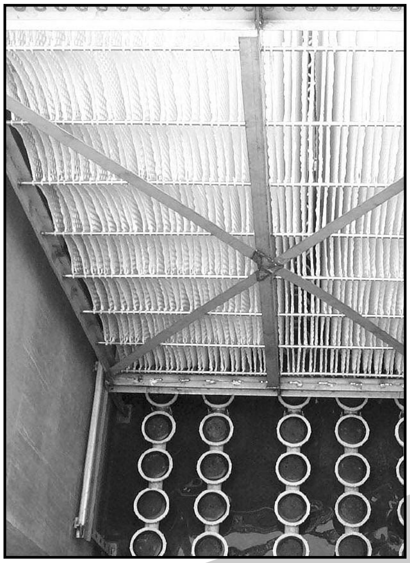


Fig. 2
Fabric media module

IFAS Process Benefits

Higher "Effective" MLSS without Higher Clarifier Solids Loading

IFAS systems can increase the effective MLSS in an aeration basin by as much as 3000 mg/l. The additional biomass can offset the need for additional aeration basin capacity. Furthermore, IFAS systems can also be designed to specifically "off-load" clarifiers by shifting an appropriate portion of the bacterial population to the fixed film. This is particularly effective in applications with limitation on the clarifier solids loading, which often limits the MLSS content of the aeration basins.

Enhanced Nitrification

The fixed biomass increases the Sludge Retention Time (SRT), promoting better nitrification compared to simple suspended growth systems. During cold weather and where lower compliance limits are imposed, the added biomass improves the performance of nitrifying plants, or even allows non-nitrifying plants to nitrify. Recent research indicates that autotrophic bacteria tend to grow more readily on fixed-film surfaces than in a suspended growth environment.

Resistant to Organic and Hydraulic Shock Loads

Biomass populations in IFAS aeration basins are not susceptible to washout during hydraulic surges as they are in suspended growth systems without IFAS because they are fixed in place. Additionally, the fixed biomass acts as a source of seeding to help return the system to normal operations quickly after such a surge. System nitrification is also restored faster since a large mass of nitrifiers is retained on the fixed-film. The fixed-film component continues to provide treatment while the mixed liquor suspended solids inventory is rebuilding. This can mitigate or prevent permit excursions, depending upon the amount of fixed-film biomass in the system. The depth of biomass provided on fixed film also resists organic shocks better than does suspended biomass.

Improved Process Stability

By increasing the bacterial population (**M**icroorganism) with the fixed-film component for a given loading (**F**ood), the **F/M** ratios are lowered. Alternatively, loadings may be increased while maintaining F/M ratios. Typically, lower F/M systems are more stable than higher F/M systems.

Improved SVIs

In various studies and discussions with practitioners, it has been noted that the Sludge Volume Index (SVI) improves and has less variation when IFAS upgrades are implemented. The continual sloughing of the fixed film component into the suspended growth environment is the key to this characteristic. Reductions in SVI values of 25-40% have been reported in the literature. Improved SVIs allow for a more concentrated Return Activated Sludge (RAS), thereby reducing the return sludge flow requirements, saving power, and improving process control.

Reduced Sludge Production

IFAS system studies and reports from owners and engineers consistently demonstrate reduced sludge production. Studies indicate that reduction in sludge production or wasting rates is expected where F/M ratios are reduced, or where the waste sludge solids concentration is higher.

Types of IFAS Systems

There are a number of different approaches to IFAS implementation but the various configurations fall into one of two basic types: "dispersed media" entrapped in the aeration basin, and "fixed media", such as structured sheet media or knitted fabric media, fixed-in-place in the aeration basin.

Dispersed Media IFAS Systems

Dispersed media systems may use porous sponges or plastic finned-cylinder shapes that are suspended or float (depending upon material density) in the activated sludge tank. These dispersed IFAS systems provide for excellent mixing and high surface area but can be expensive to implement (additional equipment is required to retain media) and operate over time. Sponges and non-compressible suspended media types will exhibit surface area loss due to abrasion and require yearly replenishment.

Fixed Media IFAS Systems

Fixed media systems can be implemented with either flexible fabric media or PVC structured sheet media. The flexible fabric materials are typically attached to rigid frames that are placed within the activated sludge tank. Fixed media systems based on PVC structured sheet media offer an excellent combination of high performance and low cost without the concern of redworm predation often found in fabric media based systems. PVC structured sheet media are designed to maximize fluid mixing performance and oxygen transfer through the biomass on the media wall.

TYPES OF IFAS MEDIA

FIXED-IN-PLACE TYPES	ADVANTAGES	DRAWBACKS
PVC Structured Sheet Media	• Simple to install • Low initial cost • No material losses	• May foul if rag removal is inadequate
Fabric Web-type	• Simple to install • No material losses	• Prone to redworm blooms • May foul if rag removal is inadequate
DISPERSED TYPES	**ADVANTAGES**	**DRAWBACKS**
Polypropylene Finned Cylinders	• Excellent mixing • High surface area	• Media losses (washout or abrasion) • Aeration devices and screens may foul • Difficult to maintain aeration system
Sponges		

IFAS Applications

IFAS technology has been incorporated into municipal/industrial wastewater facilities for both new construction and upgraded plants in many variations of suspended growth systems. When included in new plant design, reduced tank volumes result. New tanks must be designed to incorporate fixed or dispersed media and additional auxiliary screens should be added if a dispersed IFAS media reactor is chosen.

Similarly, in retrofit applications, increased treatment capacity may be realized, along with the other benefits of fixed film type processes. The existing aeration capacity needs to be evaluated to determine whether it is adequate for the increased BOD removal and biomass respiration expected with the higher level of treatment performance associated with IFAS. Media installation needs to be planned carefully to ensure that the existing basins can accommodate the fixed media modules or dispersed media systems.

TYPICAL IFAS SYSTEM APPLICATIONS	
Application	**IFAS Benefits & Design Considerations**
Increase plant capacity while providing same treatment level	• Additional biomass on fixed media increases "effective" MLSS necessary to treat additional flow
Improve existing treatment performance in existing process configuration at same plant capacity	• Biomass on fixed media provides improved process stability and resists organic or hydraulic surges that can disrupt process efficiency • Biomass on fixed media provides improved cold weather nitrification
Provide additional nutrient removal through modified process to meet new effluent permit at same overall plant capacity	• Portions of existing aerobic zones can be partitioned into anaerobic or anoxic zones for advanced BNR treatment • IFAS added to remaining aerobic zone increases Solids Retention Time (SRT) to a level needed for nitrification and allows for conversion to advanced process

IFAS Process Design Considerations

Biomass Effective Area

The enhanced treatment provided by IFAS is related to both the amount of biomass growth on the media surface and the activity of the biomass. Although it would seem that the amount of biomass should be directly proportional to the measured surface area of the media, this approach can be misleading. It is the effective area that is most important. No matter which design tool is used to size IFAS media requirements, model parameters must be well calibrated to ensure that the model represents the effective surface area performance of the IFAS media system selected.

In dispersed systems, the apparent surface area can be very high but overgrowth of the biomass on the porous media limits the diffusion of oxygen and nutrients to the bacteria. Also, abrasion from the normal tumbling action of the media in the reactor can remove the slimes from the surface, further reducing the effective area.

In fixed systems, the bacteria can grow outward from the fixed surface, thus keeping the effective surface area constant (Fig. 3). Dedicated aeration diffuser grids underneath fixed media systems creates a unique shearing pattern along the "smooth" fixed surface, promoting thin biofilm/boundary layers for enhanced oxygen transfer efficiency and effective nitrification.

IFAS System Design Considerations

Primary Treatment

All IFAS systems, whether based on dispersed or fixed media, require adequate preliminary treatment design and operation. Primary clarification or fine screening will prevent ragging and material build-up on the media in the aeration basin and clogging of the dispersed media and retaining screens.

Aeration Supply

Sufficient oxygen must be available to satisfy the demand of the additional biomass to oxidize BOD and ammonia. Accordingly, the blower capacity may need upgrade in order to supply oxygen for the increased treatment. In many retrofitted plants, excess oxygen transfer capabilities exist and require little or no modifications. Data indicates that fixed media increases oxygen transfer efficiency by increasing bubble retention time. Nonetheless, maintaining conventionally established parameters will provide a safety factor, unless site-specific oxygen transfer testing indicates otherwise.

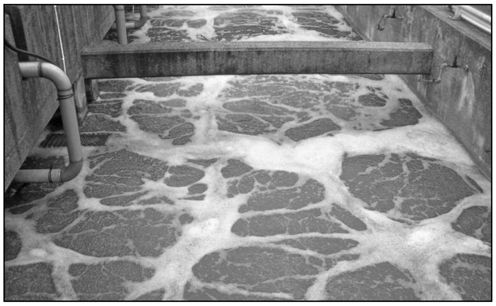


Fig. 4 *Aerated IFAS basin*

Proper mixing is required for solids suspension, substrate transfer, and oxygen diffusion. Dispersed media, such as sponges and polypropylene cylinders, are suspended by the flow induced by the aeration system. Most dispersed media systems require a roll pattern commonly provided by coarse bubble diffusers. Mixing should not be too vigorous or biomass could be eroded from the media. Fixed media systems typically use fine bubble diffusers placed underneath the fixed media towers to create distributed airlift pumping through the media and a recirculating fluid flow between media towers. Systems should be carefully designed to ensure adequate mixing velocity in order to avoid solids buildup on the basin floor.

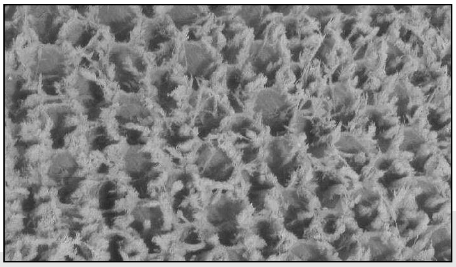


Fig. 3 *Fixed media sample showing extended growth*

Hydraulic Profile & Volume Displacement

For dispersed media systems, the volume displaced by the media can impact the HRT and should be considered when sizing the aeration basins. Also, the screen used to retain the media will increase head loss in the aeration basin. For fixed media systems, hydraulic profile impact and basin volume displacement are not significant since the void/volume ratio is in excess of 95%.

Equipment Access

IFAS installations should be designed to allow for access to aeration diffusers, mixers and valves in order to provide periodic maintenance. In dispersed media IFAS systems, provisions need to be made for the collection, removal, and storage of floating media during basin maintenance. Spare basins represent potential sites for storage. For fixed media IFAS systems, access to aeration equipment should ideally be possible without moving media modules.

Other System Considerations for Dispersed Media

Media Mobility

The mobility of the media is a major design and operational consideration for dispersed media IFAS systems. Retention screens are required to keep the media in the aeration basin and these screens can often bind with organic growth or rags or they can concentrate inert solids in the aeration basin. Dispersed media also tends to collect in the downstream portion of the tank and must be airlifted back to the front of the reactor.

Solids Buildup

Sponges eventually build up solids to the point where they can settle and accumulate in the bottom of the basin. Periodically squeezing the sponges reduces the buildup.

Abrasion Loss

Sponges also exhibit material loss due to abrasion and require regular replenishment. Literature indicates a 1 to 2% per year replacement rate, with some reports indicating as much as 10% per year.

Other Systems Considerations for Fixed Media

Breakage

Although fixed media systems require virtually no ongoing maintenance following the initial installation, a robust support system is required to hold the fixed media in place to ensure many years of service under the harsh conditions of an activated sludge aeration basin. Inferior support structures can result in damage to fixed media modules.

Fouling

A fine screen with a pore size of 3mm (less than 1/8") is highly recommended for wastewater pretreatment before entering an IFAS treatment area.

Economic Considerations

While direct economic comparisons between different treatment processes can only be made on a case-by-case basis, some general statements can be made regarding IFAS vs. Activated Sludge (AS) and different IFAS approaches:

IFAS vs. Conventional AS

- For new installations, IFAS systems will generally require less tankage and therefore have less capital cost than a conventional AS system.
- For retrofits of existing AS systems to address increased capacity or improved BNR, IFAS systems represent a cost-avoidance associated with the additional tankage that would otherwise be required for additional AS capacity.
- IFAS systems require little or no additional operational costs or operating staff over conventional AS.

Cost Comparison of Various IFAS Systems

- Dispersed systems require expenditures for additional components, such as media-retaining sieves, air knives, and/or pumps for sponge regeneration.
- Rather than solely using the media specific surface area as a means of comparing various IFAS approaches, a true capital cost comparison of different IFAS media systems should look at the cost of removing a given NH_3-N load.
- The cost of removing a pound of NH_3-N is determined by dividing the media cost per unit volume ($\$/ft^3$) by the specific nitrification rate (lbs. per ft^2/day) and the media specific surface area (ft^2/ft^3). Based on the best available today, the treatment cost per lb. of NH_3-N removed per day in a fixed media IFAS system is approximately 1/3 less than the treatment cost per lb. of NH_3-N removed per day in a dispersed media IFAS system.

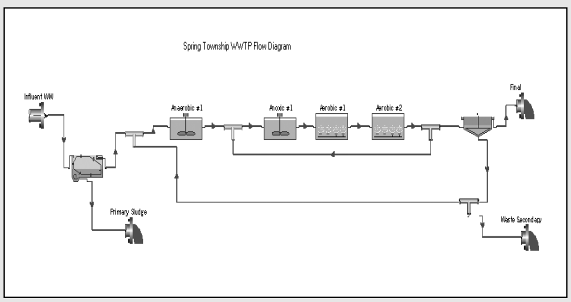
$$\text{Treatment Cost per lb. of } NH_3\text{-N Removed per Day} = \frac{\text{Media Cost per Unit}}{\text{Nitrification Rate} \times \text{Specific Surface Area of Media}}$$

Process Modeling Software

Simulation software constructed according to IWA ASM models and incorporating sophisticated biofilm modules for IFAS configuration are now widely recognized and used as powerful and accurate wastewater treatment process modeling tools.

After intensive calibration studies are conducted specifically for a given IFAS media system, these models can be used with great confidence as preferred methods for designing IFAS systems for various wastewater treatment applications. Pilot studies with the actual media at the treatment facility are often used to develop site-specific design criteria and calibrate the model for an optimized process design with the highest confidence

Based on the needs of a specific design, existing or proposed basins can be configured into discrete anaerobic, anoxic, and aerobic zones and modeled with a desired media fill to achieve the required removal of BOD, ammonia, TN and TP. Influent characteristics such as flow, BOD, TSS, Ammonia, alkalinity, etc. are needed as inputs in order for BioWin to estimate the IFAS media requirements for an enhanced treatment or an increased flow capacity.



BioWin 3.0 ™ process modeling diagram courtesy of EnviroSim Associates LTD., Ontario, California

Kinetic Method

The kinetic design approach uses empirical ammonia removal rates to size IFAS media requirements. Reported nitrification rates for different media are summarized in the table below. Because the nitrification rates are significantly dependent on the ammonium-N, dissolved oxygen (D.O.), and BOD concentrations, the kinetic method should be used with caution as it will only provide an estimate of the amount of media required to achieve the enhanced treatment.

Kinetic Method Results

MEDIA TYPE	SPECIFIC REMOVAL RATE (kg NH_3-N/1000 m^2/day)	MEDIA SPECIFIC SURFACE AREA (m^2/m^3)
Floating Sponge	0.4-0.8	75-350
Floating Plastic*	0.4-0.8	150-350
Fabric Web**	0.15-0.25†	100
Structured Sheet**	0.55-1.15	160

* Investigation of Hybrid Systems for Enhanced Nutrient Control, Water Environmental Research Foundation, 2000.
** Brentwood Industries Research
† Equal to 4.5-6.0 lbs/1000 ft^2 physical web surface/day

Equivalent MLVSS Method

A simple method of estimating the amount of media needed for a given application is to consider the additional amount of biomass needed to achieve a required improvement in treatment in a conventional activated sludge process. The amount of media necessary to support the growth of that amount of biomass can then be derived by knowing the typical amount of biomass growth on a given media type.

While acceptable for estimating purposes, this method does not account for the effectiveness of the biomass grown on a given IFAS media system nor does it account for influent wastewater characteristics, temperature, or recycle flow rates that complex software models use to accurately predict overall treatment effectiveness.

SUMMARY OF DESIGN METHODS

DESIGN METHOD	APPLICATION OF DESIGN METHODS	FACTORS CONSIDERED IN DESIGN
Calibrated Software Model	• Various process configurations • Preliminary media sizing • Detailed final design	• Influent characteristics (e.g. pH, alkalinity, etc.) • Diffusion of substrates and oxygen to biofilm • Operating conditions (e.g. Temperature, MLSS, and D.O) • Diurnal flow if data is available
Kinetic method	• Generic media estimate • High strength NH_3-N treatment	• Specific removal rate (lbs. per ft^2/day)
Equivalent MLVSS Method	• Acceptable for estimates only	• Biomass growth per ft^2 of media

BRENTWOOD DESIGN ASSISTANCE

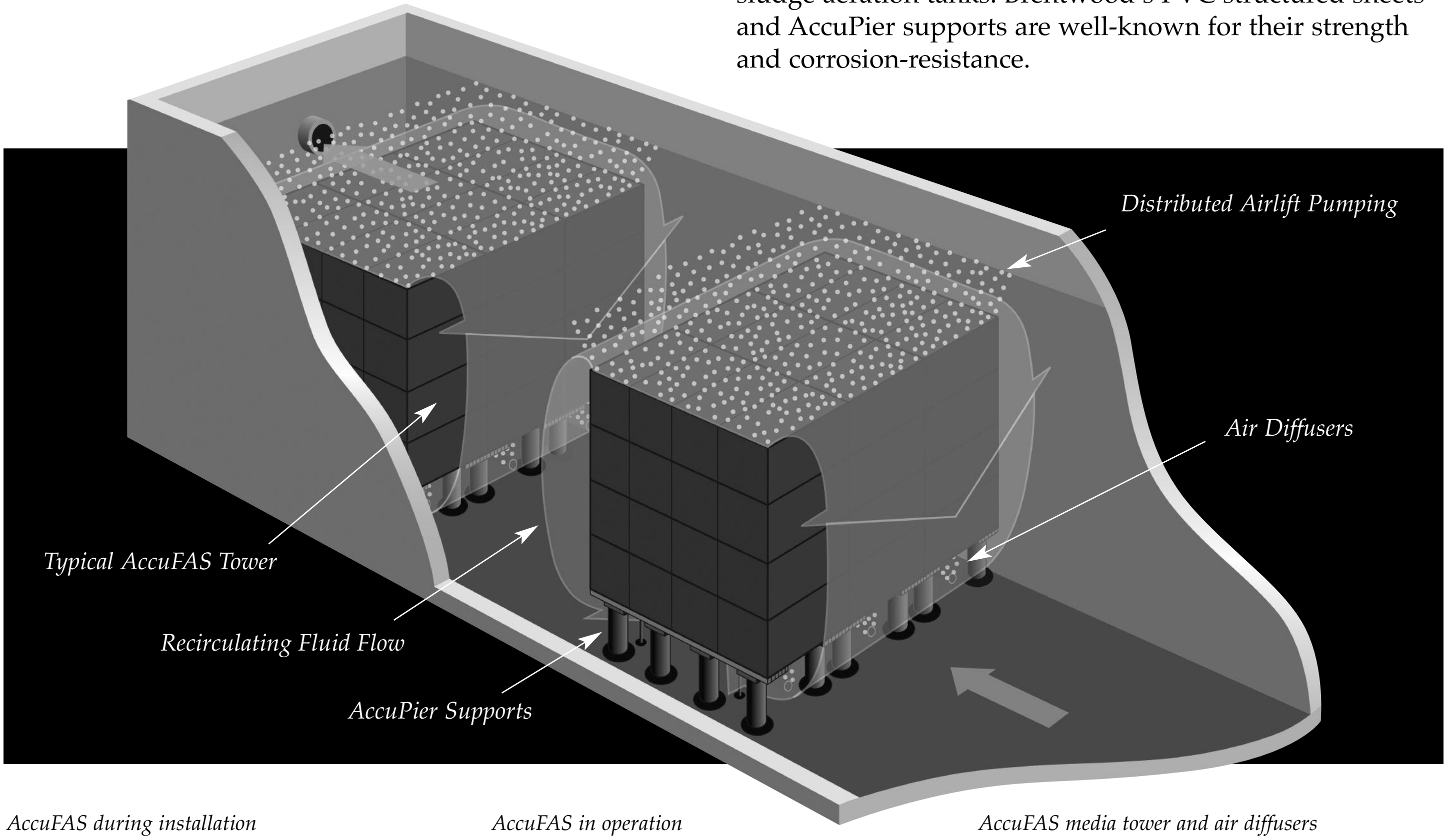
Brentwood Industries can provide complete process modeling assistance for proposed IFAS system upgrades. Brentwood uses BioWin 3.0™ modeling software from EnviroSim Associates Ltd. (Ontario, Canada) which has been widely recognized as a powerful and accurate wastewater treatment process modeling tool. BioWin 3.0 is constructed according to IWA ASM models and also incorporates a sophisticated biofilm module for IFAS configuration. With considerable BioWin calibration specifically conducted for our media, Brentwood Industries, Inc. uses BioWin with great confidence as our preferred method for designing IFAS systems for various wastewater treatment applications.

THE BRENTWOOD ACCU-FAS MEDIA SYSTEM

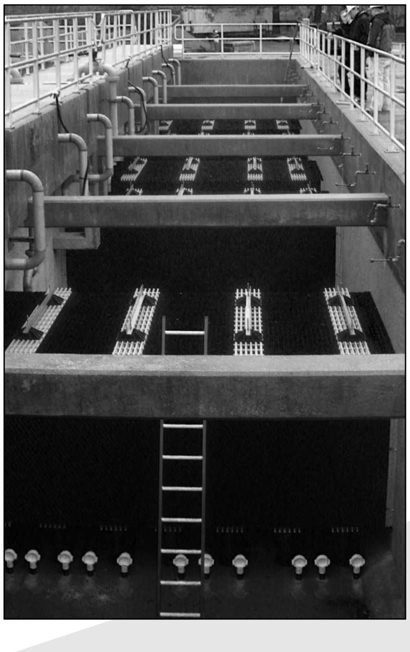
Brentwood offers the complete AccuFAS IFAS system and provides process design assistance and engineering support to ensure optimum performance. The AccuFAS system consists of "building block" media modules combined to build AccuFAS media towers within an aeration basin. These media towers are typically 8-10 ft. in height, 8 ft. long (lengthwise in basin), and span with width of the basin. The media towers are supported by a pre-engineered support system (AccuPier) manufactured by Brentwood Industries and secured to anchors in the concrete floor of the tank. Each assembly spans the width of the aeration tank in order to prevent by-passing of the mixed liquor.

Because of the critical relationship between the aeration and media in an IFAS system, Brentwood often provides an in-basin aeration package as part of the complete AccuFAS IFAS system. Diffusers mounted below the module structure provide aeration and distributed airlift pumping of wastewater through the media system. The number of diffusers will vary according to the location within the basin to account for the expected oxygen requirement profile. Diffusers are not placed in the area between the media assemblies to facilitate mixed liquor circulation.

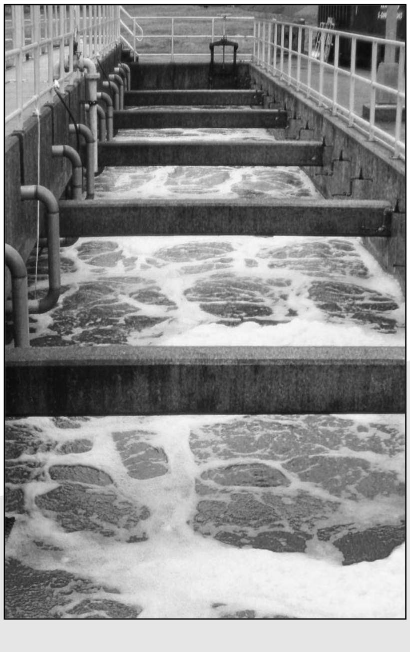
AccuFAS system components are designed for durability and long life under the harsh conditions of activated sludge aeration tanks. Brentwood's PVC structured sheets and AccuPier supports are well-known for their strength and corrosion-resistance.



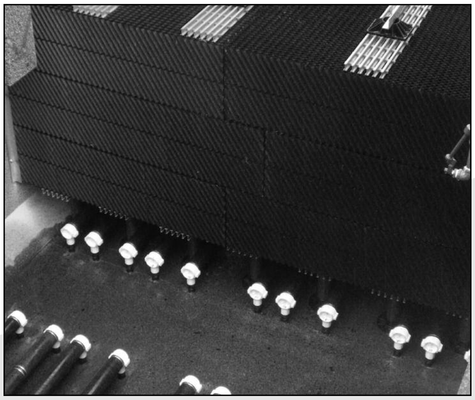
AccuFAS during installation



AccuFAS in operation



AccuFAS media tower and air diffusers



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