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Small Flow High Strength Waste Gets "Super-Charged" Treatment With Good Results

A Case Study of the SMART Treat™ System

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This study examines a relatively new fixed film advanced biological treatment process technology which is energy-efficient, has a small footprint, and functions very well with high strength or typical domestic waste or nitrogen reduction applications. The SMART-Treat™ moving media process had been downsized from larger municipal & industrial wastewater treatment applications. The unique Combined Fixed Activated Sludge (CFAS) features designed into the flow path provided hybrid process performance and delivered good quality effluent to downstream processes in overloaded conditions.

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ABSTRACT

Since 2000 the Wisconsin Department of Commerce had classified restaurant wastewater as high strength waste, and is required to have advanced treatment prior to soil dispersal. In 2005, design and construction of the onsite treatment system and the restaurant occurred simultaneously in an unsewered area near growing communities. The restaurant opened for business in late July and the wastewater system began to operate in August, 2005.

Random samplings from various unit processes occurred over the following 3.5 years. Available data showed organic loading to the primary biological process which averaged 163 % of design, while flow averaged 94 % of design.

This study examines a relatively new fixed film technology that had been chosen as the primary biological treatment process. The SMART-Treat™ moving media process had been downsized from larger municipal & industrial applications. The unique Combined Fixed Activated Sludge (CFAS) features designed into the flow path provided hybrid process performance and delivered good quality effluent to downstream processes in overloaded conditions.

INTRODUCTION

For new restaurant construction, the design parameters could not be measured by the system designer. The primary biological treatment process was originally designed as a BioMicrobics FAST process followed by a fabric filter as the secondary biological process. That design train gained regulatory review and approval. However, the franchise owner requested the designer to search for other potential alternatives that might be lower cost & accomplish the treatment required.

Upon discovery of the SMART-Treat™ moving media process, the owner's and designer's decision was to replace the first stage primary treatment design in favor of the SMART-Treat™ moving media system design. Flow was estimated using flow sizing requirements prescribed by the regulatory community, with standard safety margins calculated. Wastewater strength was estimated, and thought to be sufficiently high to include most daily loads. In these situations designers may incorporate extra measures to assure proper treatment is achieved. The total treatment system consisted of 5000 gallon grease interceptor, 5000 gallon septic tank, 5000 gallon surge flow equalization, two stages of aerobic fixed film biological treatment and pump tank to soil absorption. The design flow was 3,317 gallons per day with 1250 mg/l BOD_5 wastewater concentration (182 population equivalents) at the septic tank effluent. The grease interceptor and septic tank were conservatively sized; the design hydraulic residence time to the effluent of the septic tank was about 3 days.

In this case, the primary aerobic treatment component supplier had many years of process design and troubleshooting experience in the larger municipal and industrial wastewater treatment market with fixed film, suspended growth, and combined processes. Therefore, when the restaurant application was presented, the supplier had the forethought to design in unique features which could have the ability to accomplish good biological treatment of a relatively high strength wastewater and maintain treatment if overloaded conditions existed and persisted.

This study: 1) Summarizes a relatively new fixed film treatment process, provides unique design considerations for high strength waste and the steps taken during design, construction, and operation that moderated the effects of potential organic overloads to provide highly pretreated water for subsurface recycling. 2) It also serves as an introduction to the EHS SMART-Treat™ moving media treatment system.

About Environmental / Health Products & Service and the SMART-Treat™ Process

Environmental / Health Products and Service (EHS) is the designer and supplier in the United States of the EHS SMART-Treat™ moving media system. This process is marketed and supplied nationwide to the on-site treatment community for domestic, commercial and light industrial applications. The <u>S</u>mall *Moving* <u>M</u>edia <u>A</u>erobic <u>R</u>eactor <u>T</u>reatment **(SMART-Treat™)** process is used for wastewater flows of 100,000 gallons per day or less. Environmental /Health Products and Service (EHS) of Richfield & Phillips, Wisconsin worked with Dr. Bjorn Rusten of Aquateam-Norway in the period 1996-1999 to develop the process for small flows. This process is marketed and supplied nationwide to the on-site treatment community for domestic, commercial and light industrial applications. To date, in Wisconsin there are several dozen systems designed, installed and operating successfully, including single family homes, restaurants, mobile home parks, condominiums, apartment complexes, and similar small flow applications. This treatment process is especially suited to high-strength small flow waste streams due to its large biological surface area in a small footprint, and self-cleaning media.

The SMART-Treat™ process contains several unique features which add stability and flexibility, compared with larger moving media fixed film processes used in larger municipal and industrial applications. The process involves small plastic pieces that are placed in an aerated reactor with wastewater flowing through it. Microbes inhabit the surface area of the plastic. The biofilm carrier elements move around within the tank with just enough aeration for organic pollution oxidation. The flow pattern through the reactor may be single or multiple pass fixed film, or combined with active microbes to create a hybrid system. The combination of high surface area, aeration and food allow microbes to efficiently and effectively remove wastes.

The Private On-Site Wastewater Treatment System (POWTS) SMART-Treat™ component operation consists of typical septic tank (and grease interceptor when needed) for primary solids separation, aerobic reactor tankage, secondary (biological) solids separation, and effluent discharge to usually subsurface destinations for final disposal. Up to 70 % (or more) nitrogen reduction can be achieved with specific engineering techniques for nitrogen reduction. For larger flows, surface discharge may be applicable under permitted conditions.

One of the important advantages of the moving bed biofilm reactor is that the filling fraction of biofilm carriers in the reactor may be subject to preferences, which provides much flexibility in system design. Tank sizes and amount of carrier elements are sized based on effluent treatment requirements, anticipated future treatment needs, and expansion goals, if known. The filling of carrier elements in the reactor may be decided for each case, based on degree of treatment desired, organic and hydraulic loading, temperature, and oxygen transfer capability. For many applications, the biological surface area for treatment per cubic foot of reactor volume has 2 - 4 times more biological surface area per sq. ft. than typical stationary fixed film processes offer.

The reactor volume is totally mixed and consequently there is no dead space or unused space in the reactor. Due to the self-cleaning nature of the media, the aerobic reactor never needs solids removal, as do other competitive stationary fixed film processes. Figure 1 shows sketches of the moving media system. Figure 2 shows a close-up view of healthy aerobic biomass on a biofilm carrier element taken from a municipal open tank configuration.

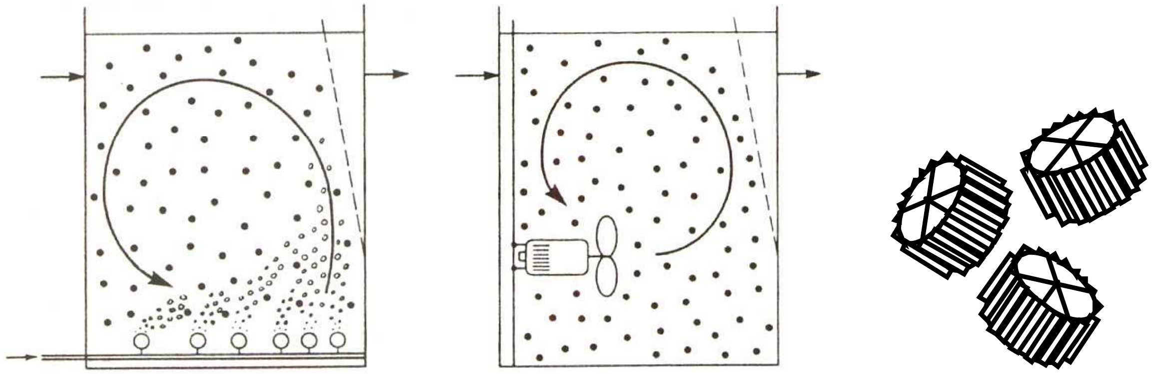


Figure 1. Moving Media system, Aerobic and Anoxic modes, typical Biofilm Carrier Elements.

SMART-Treat™ Treatment Capabilities

The moving media system reduces biological oxygen demand, total suspended solids, and nitrogen as ammonia-nitrogen or total nitrogen. Supplying oxygen to the media in the wastewater stream reduces BOD_5 using aerobic microbiological action. Total Suspended Solids are reduced through settling and filtration. Nitrogen as ammonia-nitrogen is reduced by aerobically converting ammonia to nitrite and nitrate. When specifically designed for Total Nitrogen reduction, the system is capable of converting nitrite and nitrate to nitrogen gas by a variety of means. For larger flows, and very low effluent total nitrogen, a supplemental carbon source or additional anoxic stage(s) may be appropriate, dependent on site specific conditions and influent water quality such as the carbon to nitrogen ratio.

Fecal coliform and Total Phosphorus reduction is possible with additional passive (non-mechanical) or active (mechanical) system components. Phosphorus removal can be accomplished chemically, if needed. The only small flow UV disinfection product approved in Wisconsin is distributed by EHS.

Figure 2. Full-scale Moving Media wastewater treatment plant for a municipality.

Table 1 shows some of the domestic wastewater treatment design characteristics for SMART-Treat™ systems up to 1000 population equivalents.

Table 1. SMART-Treat™ for larger Domestic Septic Tank (primary treatment) Effluent flows, BOD_5 removal only.
(Alternate sizing tables available for ammonia and total nitrogen reduction)

Population Equivalents	Q, Gal /day	Tank Size, Min. gallons	Min. Hydraulic Retention Time, Hrs.
100	7500	838	2.5
125	9375	1000	2.5
250	18,750	2100	2.5
500	37,500	4175	2.5
750	56,250	6250	2.5
1000	75,000	8250	2.5

Uses of the SMART-Treat™ system
This relatively new small flow fixed film wastewater treatment process may be used in new construction or to upgrade small or larger activated sludge or fixed film systems. The process has gained the favor of major engineering firms around the world because it is economical, reliable, and easy to install and operate, compact, and is highly flexible with regard to influent hydraulic and organic loads. This process can be easily integrated into a variety of different stages of infrastructure development to treat domestic, industrial or combined flows. To date, this process has been used for a variety of flow sizes in both domestic and industrial treatment.

Unique design features can be incorporated into the SMART-Treat ™ process design to increase performance:

- The surge flow equalization tank may be aerated with a separate blower.
- A portion of treated water with biosolids from the SMART-Treat™ aerobic reactor may be recirculated to the EQ/surge flow tank.
- Some active settled biosolids from the bio clarifier may be recirculated to the EQ/surge flow tank. This creates an activated sludge pre-treatment zone upstream of the fixed film SMART-Treat™ reactor and elevates the SMART-Treat™ reactor into a Combined Fixed Film Activated Sludge reactor (CFAS).

MATERIALS, METHODS & DESIGN RATIONALE

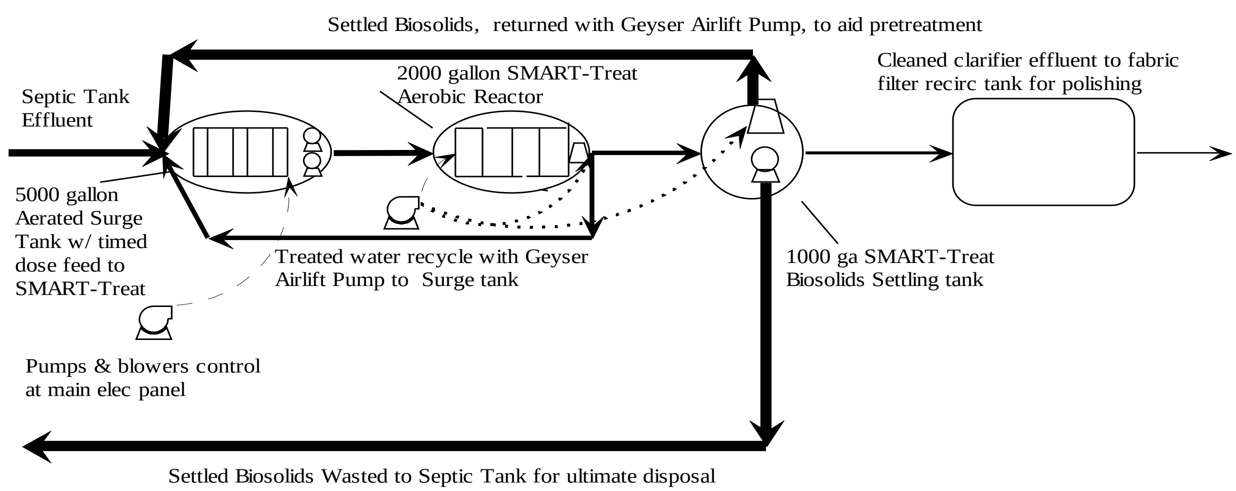
For this high strength waste application, the primary aerobic treatment goal was to reduce 1250 mg/l to 200 mg/l BOD_5 prior to the textile filter as secondary treatment. The textile filter was to reduce the pollution load further before subsurface dispersal of cleaned effluent. Unique design features were incorporated into the EQ tank, which carried over and bolstered SMART-Treat™:

- Aeration of the surge flow equalization (EQ) tank, full or part-time

- The capability to recirculate a portion of the aerobic reactor effluent to the EQ tank for repetitive treatment
- Recirculation of active biosolids settler microbes to the EQ tank to activate the EQ tank as a pre-treatment stage. This action allowed the EQ tank to be a pretreatment zone, and created a Combined Fixed Activated System at the SMART-Treat™ tank.

These features required another blower to be incorporated into the EQ tank design. An air distribution grid was also placed in the EQ tank and the additional blower energized the EQ tank into first- a pre-aeration zone, and then into a pretreatment zone with the activation of the moving media aeration reactor recycle and biosolids recycle from the Biosolids settler. These internal recycle flows within the SMART-Treat™ system created hybrid Combined (or Integrated) Fixed Activated Sludge (IFAS or CFAS) treatment. Biological treatment occurs:

- With thin, active fixed film biomass (attached to biofilm carrier elements) and
- Suspended growth biomass (coming from the aerated EQ/surge flow tank, as well as the biomass developed in the reactor liquid or sloughed microbes from the biofilm carriers).



Proposed Restaurant WW Treatment Flow Diagram
(septic tank effluent to fabric filter influent) Environmental / Health Products & Service
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Figure 3. SMART-Treat™ portion, Process Flow Diagram - Restaurant Treatment System.

With a moving media system, the entire aeration reactor is used. An aeration grid near the bottom of the reactor adds compressed air and provides water movement. Biofilm carrier elements are added to the aerated reactor. The movement of the aerated water moves the plastic media around in the entire volume of the tank. No solids are ever deposited in the reactor tank bottom. The biofilm carrier elements are prime surfaces for healthy microbe attachment, and yet are self-cleaning due to continuous movement with aeration.

The surface area of the carrier elements in bulk pack = 151 square feet per cubic foot. However, this surface area is reduced per volumetric measurement when the media is added to a reactor tank. The media fill fraction more typically is 40-67 %. At 67 % reactor fill fraction, biological surface area is about 101 sq. ft. /cu ft. Sloughed biomass & water flows through an outlet screen. The screen retains media within the reactor while treated water and biosolids flow out. Biosolids are settled in a compartment or tank, wasted to the septic tank for ultimate disposal (or recycled in the hybrid CFAS mode) while clear water flows to downstream processes or discharge.

For this restaurant application, the SMART-Treat™ reactor itself was comprised of a 2000 gallon aerobic reactor and 1000 gallon SMART-Treat™ biosolids settler. [*Note that as a point of reference, the prior design proposed a much larger tank for the FAST system---over 11,000 gallons. An interesting analogy for size comparison is the approximate difference between one (1) liter and one (1) gallon.]* Even with smaller tank size required, design biological surface area was approximately 19,500 square feet, 129 cubic feet of biofilm carrier elements, or about 48.3 % tank fill fraction. Organic loading at that media fill volume was 1.77 lbs. BOD_5 per 1000 square feet of biological surface area. Maximum media fill volume is 70%. For this application there is room to accommodate additional biological surface area for microbes—which accounts for added treatment capacity---without tearing up landscaping to add more treatment tanks.

To achieve the hybrid SMART-Treat™ CFAS process, the aeration reactor and biosolids settler recycle flows were activated, powered by patented energy efficient Geyser airlift pumps that used a very small quantity of air from the aerobic reactor blower to recirculate water and some biosolids. The microbes from the biosolids settler then "activated" the EQ tank, as the aerated EQ tank became a pre-treatment zone. The pretreated mixture enters the SMART-Treat™ reactor, which then becomes a Combined Fixed Activated Sludge (CFAS) reactor. The combination of the aeration reactor and biosolids settler recycle flows super-charged the treatment as compared to the traditional single-pass moving bed models.

Case Study Design Rationale

The rationale supporting the decision to change from stationary fixed film to moving media fixed film treatment is provided. Stationary media envelopes come in several "densities" or surface areas per unit volume. There are several different manufacturers. Generally, standard plastic materials are shaped into corrugated or a combination of flat and corrugated sheets. Trickling filters and bio towers use this type of media. These packaged bundles of media vary in dimension and are placed in tanks. Microbes grow on the surfaces of these sheets and remove wastes from the water. The media can be mostly submerged, water pumped up from the bottom of the media envelope within a pipe and distributed on the surface of the media via a standard airlift pumping action, as air is forced into the water. This is a down flow stationary bundle fixed film treatment system which also has a bit of sloughed biosolids recycling within it. However in most cases the biosolids settle to the tank bottom and must be removed periodically.

The media can also be packed in tanks in the air phase, where water is pumped onto the top of the media, water and air mix and water trickles down the media. The water and sloughed biosolids are collected and a portion is recirculated to the top of the media where it trickles down the media again. A standard trickling filter with plastic media is a prime example of this type of stationary fixed film process.

Water Environment Federation's (1998) MOP 8, "Design of Municipal Wastewater Treatment Plants" lists surface area of bundles from 27 to 45 square feet per cubic foot. For comparative purposes, and given this qualified reference, general assumptions can be made and estimates provided of the potential different media configurations used for different applications, such as:

High Strength Waste: 30.5 sq. ft. /cu ft.
Domestic Waste, BOD removal: 36 sq. ft. / cu ft.
Nitrification/Denitrification applications: 42 sq. ft. / cu ft.

The surface area available for biological growth can be compared to moving media on a volumetric basis. Organic loading may also be compared. Table 1 shows the relative volume of media needed at a specific organic loading, organic loading defined as pounds BOD_5/day per 1000 square feet of media biological surface area. For this comparison, it is assumed a high strength waste of 34 pounds BOD_5/day & organic load of 1.77 pounds BOD_5 applied per day per 1000 sq. ft. of biological surface area. Therefore, 19,209 sq. ft. of biological surface area is needed.

Table 2. Volumetric Stationary vs. Moving Media Comparison, High Strength Waste

	Media Density Sq ft/ cu ft	Number of cu ft needed	Equivalent gallon volume of media	Equivalent gallon volume at 66% media fill in tank	Proposed treatment vol, w/ biosolids
Stationary Media	30.5	648.3	4850	7348 gal	11,000 gal
SMART-Treat, Biofilm Carrier Elements	151 (bulk density)	127.2	952	1442 gal	3,000 gal
Volume ratio difference:					3.66 : 1

The selection of this process at this installation was made in part, because it required 3.66 times less tank volume (the approximate difference in size of 1 liter versus 1 gallon). The result was savings on capital equipment cost due to the smaller tank size requirement. Conversely, the same tank volume as required by stationary media in the initial design could have held over three (3) times more SMART-Treat™ biological surface area. For this application the smaller footprint was selected, $ 15,000 saved in material cost, and several hundred dollars in lower installation cost to install smaller tankage. *It should be noted that the cost of the features which enabled the CFAS process (EQ aeration grid, EQ blower, and airlift internal recirculation pumps for the EQ tank recirculation flows) was also included in the SMART-Treat™ system cost.* At this installation, there was adequate area for larger tanks. In summary, the SMART-Treat™ moving media system is ideal for applications with limited area due to its small footprint.

Biological Surface Area & Biofilm Thickness—Static Media versus Moving Media

The idea of small flow moving media systems is to have continuously operating, non-cloggable biofilm reactors with no need for backwashing, low head-loss and high specific biofilm surface area in a small footprint, which provides a highly treated effluent, with easy, low-cost operation. As in every biofilm process, diffusion of compounds in and out of the biofilm plays a key role. Because of the importance of diffusion, the thickness of the effective biofilm (the depth of the biofilm to which the substrates have penetrated) is significant. Since this depth of full substrate penetration is normally less than 100 μm, the ideal biofilm in the moving bed process is thin and evenly distributed over the surface of the carrier. Turbulence in the reactor is important to transport substrates to biofilm and to maintain a low thickness of the biofilm by shearing forces.

Various investigations have shown that the typical biomass concentration when calculated on reactor volume is about the same as in activated sludge reactors (Rusten et al., 1994, 1995a, 1998). Since the volumetric removal rate, however, has been demonstrated to be several times higher in the moving bed process (Rusten et al, 1995a), the biomass of this process must be much more viable than in similar activated sludge processes.

The same can be said for moving media fixed film systems versus static/stationary fixed film systems. The activity of the biofilm is highest in the first 10-25 microns. Beyond that thickness of biofilm, oxygen penetration may start to become a limiting factor for viable biomass. Even if the biofilm on the protected areas of the moving media seems to fill the entire protected area, with media movement there is sufficient oxygen penetration, biofilm remains aerobic and viable, continues to grow outward, and is automatically trimmed or sheared away from the fixed film.

It is quite the opposite case with static/stationary fixed film systems, such as trickling filters, or media of similar nature in bio filters, static media envelopes in tanks or towers, where water is circulated onto and through the media. The spacing of the media layers is a very large concern due to biomass build-up and potential clogging. Even rotating biological contactors (RBC's) where media is rotated into and out of the water, have difficulty with biofilm build-up and insufficient biofilm sloughing. Some static biofilm treatment system suppliers may provide a rationale to explain the thick biofilm and may even point to supposed benefits of thick biofilm.

The truth is that biofilm thickness beyond the oxygen penetration range is simply "dead weight" and may do more harm than good in the treatment process for a variety of reasons. Two main reasons are: 1) when oxygen penetration is lacking, anaerobic processes start to take over. These anaerobic processes break down biomass into elemental forms, which can add BOD_5 back into the system, and release sulphur compounds which may encourage sulphur-utilizing microbes that are less efficient at BOD_5 removal and only take up space on the surface area meant for more viable organisms. 2) The thicker biomass, even if it uses up some nitrate, has to be accounted for in media layer spacing—otherwise biological clogging may occur, which may further inhibit treatment capability. The end result of thick biomass in stationary media systems, especially in higher strength wastewater treatment applications, may be that the layers of surface area must have more space between them. Therefore, treatment tankage must be larger, thus, higher system cost, more energy used.

High-Strength Waste Applications

The SMART-Treat™ fixed film moving media treatment system is especially suited to high strength waste applications such as restaurants or other commercial/light industrial applications. For the same tank size, moving media systems can increase surface area 2-4 times that of stationary media systems. The biofilm is self-cleaning even at high organic loadings. While competitive stationary fixed film media processes have to decrease biological surface area per cubic foot of treatment volume—due to potential clogging from thicker biofilm buildup-- the moving media system can increase biological surface area and aeration in a smaller tank volume. Thus, good treatment is accomplished at a relatively lower capital and installed cost (due to smaller tanks required and higher biological surface area), which provides a smaller footprint than static/stationary fixed film systems.

Biofilm Development & Loading Rates

With an activated sludge plant, the process of developing an active biomass begins with the growth of zoogleal bacterial floc which then becomes colonized by protozoa which feed on the free swimming bacteria to produce a clarified effluent. In the moving media process, the order of colonization seems to be reversed (Mosey, 1996). High loading rates, around 30 g COD/m^2d, produce compact bacterial biofilms, with protozoan population either absent or limited to small free-swimming protozoa and Vorticella spp. Moderate loading rates, around 10-15 g COD/m^2d promote a more "fluffy" biofilm with a rich variety of ciliated protozoa. Low loading rates (< 5 g COD/m^2d) promote very "fluffy" biofilm generally dominated by stalked ciliates.

RESULTS

State licensed laboratories conducted laboratory analysis of grab samples brought in from various sample locations. Sampling was conducted using standard test protocols. Sampling occurred from October, 2005 to February, 2009. Not all sample locations listed were sampled at every sample event.

Samples were analyzed by state certified laboratories using standard methods for water and wastewater. Besides BOD analysis, COD, TSS, FOG, and ammonia-nitrogen parameters were observed. The focus for this paper is wastewater flow and organic loading. Other parameters are reported but not elaborated upon. Temperature of the wastewater in the aerobic reactor was checked on several occasions and ranged from 65 to 80 degrees F. pH was in the 6.5-8.5 SU range. Dissolved oxygen in the SMART-Treat™ reactor varied between 1 and 2.5 mg/l, dependent on temperature and organic concentration. Due to diligent maintenance at the grease interceptor, Total Fat, Oil, and Grease (FOG) was below 100 mg/l at the influent to the SMART-Treat™ system for the majority of analyses. Table 3 shows water use (equivalent wastewater flow) and Table 4 shows BOD_5 analysis and loading.

Water Usage: A water meter recorded water use for the restaurant. Water use is generally equivalent to wastewater flow at this facility, so it is assumed that water use per day generally equates to wastewater generated and treated per day. Start-up of the wastewater treatment system occurred in August, 2005. Note that in October, 2005 and in July & October of 2006, daily water use per day exceeded design wastewater flow of 3,317 gpd.

Table 3. Water Usage- at the Restaurant, July, 2005 to April, 2007

Date	**Amount (gallons)**	**Ave Daily Gal/day**
July 2005	221,600	2,462.2
October 2005	417,100	4,634.4
January 2006	194,900	2,165.6
April 2006	146,700	1,630.0
July 2006	406,900	4,521.1
October 2006	478,400	5,315.6
January 2007	203,400	2,260.0
April 2007	177,900	1,976.7
Ave Water Use		**3121**
% of Hydraulic Load		**94% of Design**

Table 4. Restaurant Wastewater, Laboratory Analysis: October, 2005 to February, 2009

Grab Sample BOD_5, mg/l:	**Septic Tank Eff**	**SMART-Treat Eff**	**% Removal**
Oct, 2005	>714	136	> 81
Nov, 2005	1,180	140	88.2
Dec, 2005	792	190	76
Feb, 2006*	951	490	49
May, 2006*	651	286	56
Aug, 2006*	3,190	255	92
Nov, 2006*	7,680	>787	< 90
Oct, 2008 **(CFAS fully implemented)**	1,280	114	92
Feb, 2009 **(CFAS fully implemented)**	1,876	68	96
* Intermittent blower operation			
Actual BOD conc. (mg/l) & % red.	**2,035**	**274**	**86.6%**
Design BOD conc. (mg/l) & % red.	**1,250**	**200**	**84 %**

These two tables provide insight into the *Design Load* of the wastewater treatment system at the subject restaurant, compared to the *Actual Hydraulic and Organic Loads*. It is significant to note that the primary aerobic reactor system achieved higher than design removals for the observation period—when in fact it received on average more than 150% of design organic load. Overall organic loading of septic tank effluent BOD_5 to the SMART-Treat™ system on a quantitative basis for the data available was 153 % of design load. (More at times). The available data shows organic load concentration was approximately 163% of design, while hydraulic load averaged 94 % of design. On a quantitative basis, design BOD_5 load to the primary aerobic reactor was 34.6 lbs. /day, actual BOD_5 load averaged 53 lbs. /day.

Table 5 shows accumulated data averages for various parameters analyzed for locations within the treatment train. *All results are in mg/l.* The number inside the parenthesis is the number of samples tabulated to depict averages during the period October 2005 to February 2009. The data reflects grab samples at various locations along the treatment train.

Table 5. Laboratory data—Sample locations within the treatment system, 10/05 to 02/09
All results are mg/l units. Parenthesis ( ) indicate number of times grab sampled at each location

Septic Tank Inlet	Septic Tank Outlet	EQ Tank	SMART-Treat Clarifier	Dose Tank
Total COD				
6595 (4)	4929 (7)	------	670 (11)	181 (11)
Total BOD_5				
6503 (4)	2035 (9)	410 (2) [1] 30 min settled	194 (11) [2]	78 (11) [3]
FOG				
140 (4)	94 (7)	36 (1)	6.2 (10)[4]	3 (12)
Total Suspended Solids				
8531 (4)	1606 (9)	4579 (3)	290 (13)	84 (12)
Ammonia-Nitrogen				
34.5 (2)	41.8 (5)	22 (1)	19.8 (12)	5.0 (10)[5]

Sample dates were: 10/12, 11/23, 12/28 in 2005, 1/20, 2/28, 5/3, 6/12, 8/30, 11/21 in 2006, 6/12/2007, 5/1, 7/28, 10/16 in 2008, 2/10/2009 (14 sampling events)

A few results seemed not to fit typical treatment patterns (anomalies) for a few locations, so were not used in the averages. Specific reasons for anomalies are unknown. Possible reasons may be lab mix up, sample contamination, blower malfunction (insufficient aeration), or others. These results are reported here:

[1] 2130 non-settled= solids in BOD_5 test= higher BOD_5 w/ RAS biosolids to EQ tank on 6/12/06

[2] >780 on 11/21/06, 680 on 7/28/08 (electrical interruption, intermittent blower operation, possible nitrifier influence/interference in BOD_5 test)

[3] < 300 on 6/12/06 (Oct 08, Feb 09 dose tank not sampled, but BOD_5 may have been <30 mg/l)

[4] 88 on 2/12/06

[5] 72 on 6/12/06

Note: Future Clarifier BOD_5 analysis should be nitrification inhibited to avoid nitrifier influence in the BOD bottle, if nitrification occurs within the SMART-Treat™ system.

Data Analysis: Laboratory values for unit processes were tallied in columns on worksheets for each parameter, with dates and sample locations. The values were added (less anomalies) and the sum divided by the number of samplings for each parameter. Results are an average or mean result, not median. The tallied numbers above are simple averages at each location for each listed parameter.

DISCUSSION

The restaurant wastewater presented a challenge. The combination of rich American quick-food cuisine and dairy product wastewaters did present loads above design at times. It should be pointed out that initially the SMART-Treat™ reactor was operated more or less as a single pass system. Baseline data confirmed proper operation and treatment, near design loads. The three added features, previously discussed, did add treatment capability to the once-through flow process of a typical moving media system. After laboratory data established that the design loading could be exceeded at times, steps were taken to activate the features that would enhance the SMART-Treat™ moving media system. Insufficient aeration due to blower and electrical problems may have dampened performance at times. After corrective actions were taken, built-in treatment enhancers were fully activated. BOD_5 removal performance was better than design at the clarifier effluent, even though the primary aeration process was overloaded at times.

The raw wastewater had a slight whitish appearance that carried through to the clarifier tank, and even at times to the dose tank. It was not analyzed as such, but the slight milky appearance of the treated water could be residual colloidal calcium precipitate. This inert elemental form of calcium in this predominantly dairy-derived wastewater could contribute to the water color and to the suspended solids content in the effluent. Other professionals in the wastewater engineering and design business, and a few technical papers reviewed in the past seem to confirm that this slight coloration is typical and has been observed by others in larger dairy wastewater treatment applications in various part of the world. These inert colloidal solids generally do not detract from the overall quality of the treated effluent.

Operation Summary

Analysis of parameters at multiple locations had been collected for 12 months. Several other samples had been taken after the initial 12 month period. The SMART-Treat™ system provided good treatment fairly soon after start-up (within 3 months acclimation time) when BOD_5 was below the design influent levels to the process. BOD_5 was reduced to below goal in the primary aerobic reactor. This confirms design process treatment goals. Operation of the textile filter downstream of the SMART-Treat™ reactor was consistent with typical operation of that unit process. Primary aerobic treatment effluent concentration values increased when the influent organic loading was significantly above design values. SMART-Treat™ system enhancements were then fully activated to continue to provide the textile filter with near its design loading. Overall performance of the SMART-Treat™ system with CFAS additions built into the system at design in 2005 and fully activated in 2008, allowed better than target performance with overloaded conditions. As a result, the textile filter which was the recipient of the primary unit process water. displayed typical performance character.

Maintenance Summary
There were typical startup punch list items after startup. Some of these were:

- Installation of forgotten check valves on the EQ tank timed dose pumps, to prevent back-siphon into the EQ tank. The EQ tank elevation was significantly lower than the downstream aerobic process tank.
- A blower was replaced under warranty within a year due to a manufacturing defect.
- Intermittent blower operation hampered treatment in 2006 and 2007 as a result of blower thermal overload, storm event and voltage problems. The challenge was overcome by initially replacing the blower, and finally replacing the single phase blower motor with a slightly larger 3-phase motor & variable frequency drive (VFD) controller.
- The only other maintenance for the primary aerobic treatment system was a twice annual equipment inspection that included blower filter maintenance/cleaning. Maintenance on the SMART-Treat™ system appears to be very minimal.

After the blower electrical problem was solved and consistent aeration was restored, design treatment goals were reached when influent load was within design. Additional treatment capability was achieved in June, 2008 when the CFAS system was fully implemented. This was achieved by activating aerobic reactor effluent return and biosolids return streams to the aerated EQ tank on a full-time basis. Performance was enhanced (BOD_5 % removal increased) at BOD_5 loadings significantly above design BOD_5 loads. (See Table 3, 10/08 & 2/09 samplings).

The EQ tank and aeration tank combined installed blower horsepower is 3.1 HP. That equates to an average of 0.063 installed HP per pound of BOD_5 removed with the SMART-Treat™ system, aerated EQ tank included. Actual current draw was not measured, but was significantly less than the name plate full load draw. The EQ tank has a variable depth, and the primary aeration blower was not sized for maximum full load current draw. The EQ tank blower operated at 220 v., 1 phase, the SMART-Treat™ blower operated at 220 v., 3 phase. Recycle flows were airlifts powered by the main aeration blower.

Before and after recycle flows were added, the moving media biofilm was checked visually for signs of potential plugging and for biofilm thickness. Due to the vigorous movement of the media, and despite being organically overloaded (over 1.5 times organic load), the biofilm appeared active, vibrant, thin, & of a light brown or tan coloration.

Discussion of the SMART-Treat™ Moving Media Process
A more detailed description of the EHS SMART-Treat™ moving media process is presented in Appendix A. Some discussion points are relevant, relative to this case study.

SUMMARY & CONCLUSIONS

A new quick food restaurant was built in an unsewered area in a growing community in Wisconsin. Alternative processes were investigated for onsite treatment of high strength wastes. After discovery of the SMART-Treat™ moving media process, the owner's and designer's decision was to replace the initially approved first stage stationary fixed media primary treatment design in favor of the SMART-Treat™ moving media system. The SMART-Treat™ process utilized biofilm carrier elements that promoted attached growth microbes. The alternate process was rapidly approved, construction commenced in July and operation of the system was started in August, 2005. Unique features were included in the design in order to enhance treatment in the event of persistent overload conditions. These features included:

- Aeration of the EQ/surge flow tank with a separate blower.
- Treated water with biosolids from the SMART-Treat™ aerobic reactor was recycled to the aerated EQ/surge flow tank, which provided pretreatment of that high strength waste.
- Some settled biosolids from the bio clarifier were recycled to the EQ/surge flow tank, which further activated the pre-treatment zone prior to the fixed film SMART-Treat™.

With the incorporation of the Combined Fixed Activated Sludge (CFAS) treatment process, treatment was improved in overloaded conditions within the SMART-Treat™ reactor system. In the hybrid process, treatment occurs:

- With thin, active fixed film biomass (attached to biofilm carrier elements) and
- Suspended growth biomass (coming from the aerated EQ/surge flow tank, as well as the biomass developed in the reactor liquid or sloughed microbes from the biofilm carriers).

The SMART-Treat™ system with CFAS has proven to provide enhanced treatment capability when organically overloaded. This combined system was chosen because—as shown from cost saving comparison with the initial design:

- It was a more economic choice to purchase regarding initial primary aerobic equipment investment, with savings of over $15,000.

Other reasons the SMART-Treat™ moving media system was chosen include:

- Ease of incorporation into an existing approved design
- Maintenance was minimal and operation was simple.
    - For electrical requirements, the EHS SMART-Treat™ process has only one small aeration blower and one small biosolids waste pump. High efficiency airlifts for recycle flows are powered by the main aeration blower. The system operates economically, even with organic loads significantly over design at times.
- The SMART-Treat™ aeration reactor never needs cleaning. The waste biosolids timed dose pump directs settled waste solids to the septic tank for disposal.
- It has self-cleaning biological surfaces so media clogging is never an issue.
- The system had a smaller footprint and so had a lower cost to install.

- Well after installation---treatment capacity can be added within existing SMART-Treat™ tankage, rather than tear up lawns and landscaping to add aeration tanks at additional cost
- Inclusion of innovative EQ tank aeration, pre-treatment and SMART-Treat™ CFAS process features.

Most treatment processes have safeguards to withstand temporary loads somewhat above hydraulic and/or organic design. In this case, proactive innovations in the design step using the SMART-Treat™ system with CFAS has proven that the system can perform to task even when severely organically overloaded over extended periods of time. In this case it was fortunate that a treatment system was installed of the caliber to be able to consistently and adequately treat the unforeseen higher than design load without the addition of more equipment or tanks to accommodate the higher load.

It is typical that in any scale municipal and industrial wastewater treatment system, no matter what process is up front in an overloaded situation most times downstream treatment components suffer. For this small flow high strength application, the originally proposed equipment and downstream unit processes may have been exposed to serious challenges due to unexpected high organic load, which may have included:

- Potential thick biofilms that may have caused stationary fixed film media clogging,
- Potential severe overloading or clogging of the textile filter,
- Potential increased stationary surfaces or textile filter cleaning maintenance expense,
- Potential premature drain field failure due to organic overload and thick clogging mat,
- Potential treatment equipment additions to accommodate the higher than design load.

Instead, the SMART-Treat™ system with built-in features which bolster treatment has performed to task on a consistent basis Treatment achieved provided water to downstream processes with adequate load reductions, so that downstream processes functioned as intended. This study shows successful and positive wastewater recycling outcomes despite significant organic overloading at times at the primary treatment process.

Few onsite treatment processes available today may be able to fully take advantage of the features that super-charged this treatment process in this situation. However, if there are situations where these unique features can be implemented, it may increase treatment capability. Another take home message may be to install equipment or processes that have the ability to moderate unexpected overloads, and design conservatively when influent character is unknown.

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