THE SMARTER WAY TO TREAT

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Abstract

The paper highlights innovative ways to improve decentralized advanced treatment processes which reduce equipment components, vastly reduce maintenance, improve energy efficiency, and allow for intelligent decision making. An integrated fixed-film Moving Bed Biofilm Reactor (MBBR) treatment system was developed which is able to operate via a single blower to provide all aeration, mixing, and pumping processes powered by the single air source. These revolutionary smart systems have innovations in technology with very few mechanical or electrical moving parts below water, only where required. A comparison of tank volume required for moving media treatment system versus stationary media treatment system is shown. A case study describes a staged combination of aerated fixed film media and mixing equipment which uses accumulated air to agitate without aerating. The same air-accumulating equipment with modifications is used in pumping in a controlled fashion, which eliminates the need for flow meters and underwater electrical pumps and mixers. The case study features a new and unique combination of equipment used to both remove high strength organic matter to extremely low concentrations (89-98 % removal) and reduce nitrogen 59% to near 80%. This paper describes installation, operation, and maintenance advantages which are additive and may tend to collectively favor an economic advantage over competitive processes in some cases.

KEYWORDS: SMART-Treat®, high-strength, biofilm, MBBR, PointWatch, MegaBubble®, nitrification, denitrification, energy efficiency, low maintenance

Introduction

The objectives are to show:

- A new combination of technologies which were installed, operated and fine-tuned
- Achievement of treatment levels lower than state regulations
- Achieved within smaller tankage than alternative systems
- Ultimately providing cost advantages to the installer, customer, and maintainer.

The Moving Bed Biofilm Reactor (MBBR) fixed film wastewater treatment process, developed in the early 80's in Norway, has been widely accepted worldwide and features high surface area small plastic biocarriers in an aerated reactor with wastewater flowing through it. The MBBR process has historically been known to decrease wastewater treatment plant footprint because of the high fixed film surface area per unit volume, as reported by Rusten and Paulsrud (1987, 1996) and Rusten, and Ødegaard (2007).

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The reactor volume, whether in an aerobic, anoxic, or anaerobic stage, is completely mixed. The biofilm lives on small plastic pieces freely swimming within the reactors. The movement of the plastic pieces creates its own biofilm sloughing action. Due to the self-cleaning nature of the media and a separate biosolids settling zone, settled waste biosolids recycle to primary settling zone with the movement of the water through the system. The aerobic reactor zone itself never needs solids removal, as many stationary fixed film processes do. Rusten and Neu (1999) and Rusten et.al, (2000) indicated 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. Likewise, the MBBR process may be designed to remove nitrogen from the fluid stream as reported by Rusten and Ødegaard (2007)

For the onsite water recycling industry, the SMART-Treat® MBBR process is used for wastewater flows of up to 100,000 gallons per day or around 200 pounds BOD or less. Since 2001, dozens of small scale MBBR systems were designed, installed, and are currently operating successfully. It is essential for proper technology transfer to occur when a relatively different method of treatment is introduced. Communication and education regarding the technical specifications set forth for siting, installation, and operation and maintenance of these advanced wastewater treatment systems will be handled via a SMART-Treat network to be established throughout North America. The idea is to have a central communication hub and regional teams to serve the on-site treatment community for domestic, commercial and light industrial applications.

System sizing using an engineered design modeling software program is done for the specific carrier element used. The filling ratio 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, as well as anticipated future expansion. Organic loading per 1000 ft^2 of biological surface area is the primary sizing criteria. The MBBR design can be customized for each application, never having to overdesign tankage or surface area unlike many fixed film processes. In general, the MBBR design can be modularized, providing expediency and simplicity of design—within a general set of design parameters. Figure 1a shows sketches of the moving media system. Figure 1b shows a close-up view of healthy aerobic biomass on a biofilm carrier element from a municipal treatment system.

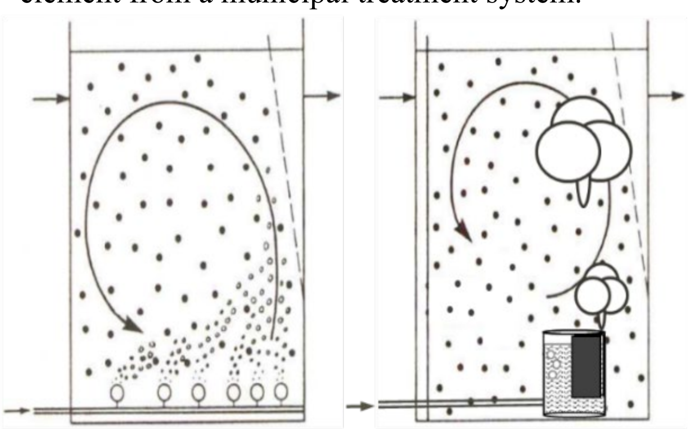

Figure 1a: Aerobic and Anoxic MBBR reactors with carriers moving within tanks

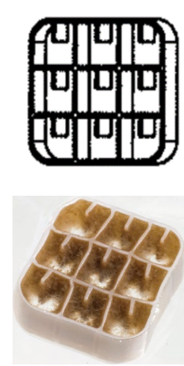

Figure 1b: Typical MBBR carriers

For many MBBR treatment applications, the biological surface area for treatment per cubic foot of reactor volume has more biological surface area per volume than typical stationary fixed film processes as reported by Ødegaard, Rusten and Siljudalen (1999)

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Onsite Moving Bed Biofilm Reactors have many positive advantages

Neu and Rusten (1998) pointed out that since MBBRs have 200-400% more biological treatment surface area per unit volume as static or rotating treatment systems, it has begun to gain favor in the US due to the smaller volume requirements and low maintenance requirements. Table 1 shows a comparison of required tank volume for the moving media treatment process versus a stationary fixed film process.

Table 1. Volumetric Stationary vs. Moving Fixed Film Biological Surface Area Comparison High Strength Waste, 3317 gallons per day (gpd), Influent BOD = 1250 mg/l

Media Type	Media surface ft^2/ft^3	Ft^3 required	2/3 volume filled (gal)	Treated volume with Bio-Solids separation
Stationary Media	30.5	648	7348 gal	11,000 gal
Biowater BWT-X Moving Media	198 ft^2/ft^3 bulk 131 ft^2/ft^3 active	100	1135 gal	2,100 gal

Notes in reference to Table 1:

- Volume ratio difference: MBBR Media vs Stationary Media
    - 5.2:1 Bulk Density; 4.3:1 Working Density
- Stationary media requires ample space between media layers and towards tank bottom to allow microbe attachment & settling without clogging. Moving media supports thin active self-cleaning biofilm; the entire tank devoted to biological treatment w/o settling.

As shown by Neu (2009) the MBBR process can be used for existing system upgrades or new construction where a small compact footprint is required and comparable systems are too large or cost prohibitive. MBBR systems can be used for small or large activated sludge or fixed film treatment systems, which then create integrated fixed activated sludge (IFAS) systems. Rusten, McCoy, Proctor, and Siljudalen (1998), Rusten, et.al. (2003) and Rusten and Ødegaard (2007) pointed out that MBBR systems are highly flexible with regard to influent hydraulic and organic loads, and can be easily integrated into a wide variety of and stages of infrastructure development to successfully treat domestic, commercial, industrial or combined domestic, commercial or light industrial flows. MOP 8 (WEF, 1998) also refers to MBBR design and operation.

Upgrade of the biological treatment capacity can occur with relative ease when the need arises for larger flows, heavier organic loads, or better effluent quality. A typical plant upgrade consists of the simple addition of biomedia, where it can take only minutes to increase the biological surface area without added tankage or excavation. An example of this scenario is a condominium originally outfitted to SMART-Treat MBBR in 2002, then in 2012, nine additional bedrooms were added. The MBBR reactor tank and air supply were adequate for the increased flow and load. It took 2 days to obtain the sanitary permit to upgrade for higher capacity of treatment and only 15 minutes to add the additional biological surface area required—by simply adding a few dozen cubic feet of carrier elements into the existing aerobic reactor through the manway.

Recent Developments

Unique design features have been incorporated into the process to increase performance and ease of maintenance. One example is to incorporate pulsed air pumping and mixing. The science and mechanism behind the unique combination of this equipment combines aeration, anoxic mixing, and pumping with one low pressure air source.

Recent developments in the MBBR treatment process:

- The aeration headers, mixers, and internal recirculation pumps have no moving parts.
- For the MegaBubble® mixers and pumps, air simply accumulates in an accumulation chamber. When the chamber fills to a critical point, the entire volume of air is released at once in the form of a large amorphous bubble. A repetitive air accumulation and release occur as long as the device receives air flow.
- The MegaBubble pump is a pulsed air mixer that simply allows the bubble to rise through a riser pipe. Each pulse provides an approximate fixed volume per burst. This allows bursts to be metered and a flowrate to be approximated, providing an easily adjustable recycle rate without the need for flowmeters for adjusting flowrates.
- For mixing and agitation, the same metered pulses provide the right amount of mixing and can be adjusted accordingly.
- Control for pulsed air devices may be continuous or on an off/on regime, where a continuous flow of air results in intermittent large bubble events, and these may be turned on and off with a valve or separate blower as desired.
- A surge flow equalization tank may be mixed with pulsed air mixers as well (and aerated, if desired) with the main system air source or a separate blower.
- The SMART-Treat system may be configured as an integrated fixed activated sludge reactor with the use of Megabubble airlift pump recycle. These mixers and pumps may be used wherever conventional mixing and pumping devices are used, without the need for maintaining electrical equipment other than the air source which activates aeration, mixing and pumping. Very simple, easy & low maintenance.
- Operator training consists of counting air bursts from mixing and pumps, calculating air mixing or water volume pumped, and air flow valve adjustments to attain desired mixing intensity or airlift pumping rate. After initial settings, only minor adjustments as needed for the desired mixing/pumping regime. Typically, no further adjustments are needed.
- Mixing intensity and pumping rates are usually checked semi-annually, simple manual air valve adjustments take only minutes.

- For controlling the system, PointWatch online controls are used. PointWatch is an intuitive English based programming language, using <, >, =, commands. These can be set remotely if desired, from a smartphone. No ladder logic necessary, rules based control.
- PointWatch offers robust controls which can significantly reduce the control panel size, as many of typical relays, timers, etc., become redundant. The system has functionality that would be difficult to cost-effectively integrate into treatment systems to save time, lower costs associated with site visits. PointWatch has an easy to understand human machine interface system. It is what everyone already has in their pocket – their smart phone. Operators can remotely monitor and control all aspects of the plant, such as level, pump status, flowrates, etc. This same system provides alarms and collects data.

There is a short learning curve to become familiar with the monitoring and control concepts of the PointWatch system. A general training session of an hour can familiarize individuals with basic cell phone use knowledge. After this point, on-the-fly programming is easy, with the ability to set points or counters using simple logic, instead of ladder logic programming. This may be done remotely. In summary, all of the bulleted design upgrades vastly simplify onsite treatment, reducing maintenance, reducing equipment costs, increasing flexibility, and increasing the robustness of control.

Materials, Methods and Design Rationale

A SMART-Treat® MBBR system using MegaBubble® pulsed air mixing and pumping technology was installed in late October 2018. The owners of a small multi-unit commercial property off I-94 in western Wisconsin needed to upgrade the capacity of their failing wastewater treatment system. The existing design was less than 1200 gpd and the new design flow was 3500 gpd. The treatment load included brewery and restaurant waste, as well as mixed use facilities. The existing septic tanks included small aeration devices which did reduce organic load, but not enough to prevent a premature drainfield failure. The commercial property owners desired to maximize commercial rental area. A new advanced wastewater treatment system was necessary.

For this high strength waste application, the goal is to add aerobic treatment to septic tank effluent to reduce 616 mg/l BOD to 200 mg/l BOD, 150 mg/l TSS. The effluent requirements were defined by a State of Wisconsin regulatory rule, which requires high strength waste to be reduced to typical domestic strength septic system effluent quality prior to soil treatment and absorption. Wisconsin currently does not have a nitrogen reduction regulation. However, onsite advanced SMART-Treat systems typically also reduce nitrogen—which is advantageous for the environment and people.

The primary biological treatment process was originally designed as a generic Fixed Activated Sludge Treatment (FAST) process. That design gained regulatory review and approval. However, the property owners requested the designer to search for other potential alternatives that might be lower cost and accomplish the treatment required. The owner's decision was: replace the biological treatment design in favor of the SMART-Treat moving media system design. All other parts of the system were kept the same. With minor delay for regulatory approval, the SMART-Treat® system saved the owners over $ 60,000 from the anticipated costs of the FAST design.

The original total treatment system consisted of an existing 1000-gallon grease trap, two 2000-gallon septic tanks in series, and an overloaded subsurface drainfield. The septic tanks were previously outfitted with aeration units which were undersized for the organic load. These units were scrapped in favor of SMART-Treat®.

New infrastructure upgrade included a 3000-gallon surge flow equalization tank (as originally specified for the fixed activated sludge system upgrade). The revised aerobic treatment system has three moving bed fixed film stages: BOD reduction, nitrification, and post-denitrification—in a total biological treatment tank volume of 3850 gallons, compared to the design volume of 6,010 gallons. No carbon is added, internal recirculation is achieved with a MegaBubble pulsed-air pump operated with air from the main aeration blower. The anoxic stage is mixed with MegaBubble pulsed-air mixers from the main process air source. The layout shown in figure 2.

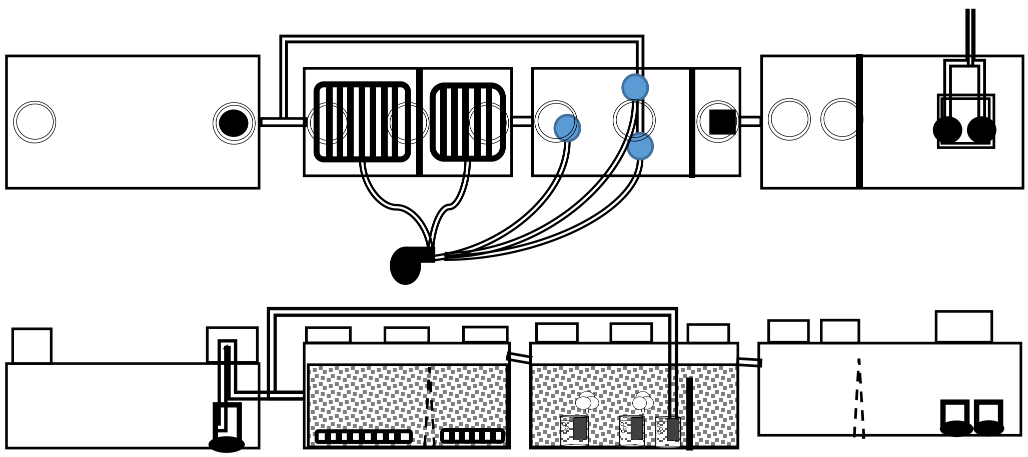

Figure 2: Layout of the W. Wisconsin system. Top view above, side view below.

The advanced system consists of two aerobic fixed film biological treatment stages followed by post-denitrification, two-stage clarification, and pump tank to new replacement soil absorption area. The biological surface area was sized for present design flow of 2350 gpd, all other system components and drainfield were sized for maximum design flow of 3500 gpd. As treatment needs increase, adding biomedia by simply pouring it into tank, will achieve biological surface area for maximum design flow.   Surface area for present design flow: 176 ft^3 Biowater Technology model X media with a surface area of 198 ft^2/ft^3 for a total protected surface area of ~35,000 ft^2 for a fill fraction of 47%. For the continuous maximum flow of 3500 gpd, the basins will be filled to 247 ft^3 of media or a fill fraction of 67%. Organic load to biological treatment remains at 0.34-0.37 lb. BOD/1000 ft^2/day. At maximum design flow and load the system is sized for 125 population equivalents at the septic tank effluent flowing to the SMART-Treat system. The design hydraulic residence time for the biological step is 26.4 hours.

Online Control and Monitoring

PointWatch systems manufactures an intelligent monitoring and control system that is accessible via computer or a smartphone app. The very lightweight design uses a RS485 bus to run various inputs and outputs (i.e. it monitors systems, but also can output commands). This lightweight system can virtually replace a Programmable Logic Controller (PLC), leaving a control box to house only contacts and relays – which can reduce control panel costs significantly. Currently the system is set up to monitor the existing control panel and can also control pump and blower settings. It does render much of the control system redundant and adds quite a bit of functionality. (PointWatch, 2019)

Wastewater Sampling and Analysis

A state licensed laboratory (Commercial Testing Laboratory, Colfax, WI) conducted laboratory analysis of grab samples brought in from septic tank effluent and post treatment locations. Sampling was conducted using standard Environmental/Health Products & Service LLC (EHS) SMART-Treat sampling protocol published and provided to the States of Wisconsin and Minnesota regulatory agencies by Neu (2014). Initial sampling occurred in January 2019, with follow up single-grab sampling events in May, July, September, October, November 2019 and May & June 2020.) Sampling dates coincided with times personnel were in the area, since sampler personnel were normally 3.5 and 5.5 hours from the site. Samples were collected during normal business hours between 10 AM and 1 PM using a cleaned plastic tube sampling device with a ball foot valve, lifting the sampling tube up and down several times to draw water into the tube. Sampling depth was approximately 10-12 inches below the water surface in each of two sampling locations. (Due to rise in COVID cases in Wisconsin, sampling was curtailed after June, 2020)

Results

The original design was to reduce high strength waste of 616 mg/l BOD and 220 mg/l TSS to equivalent domestic strength of 220 mg/l BOD and 150 mg/l TSS before subsurface discharge. However, the SMART-Treat design is shown to achieve much better effluent quality than the prior-designed system, and in a smaller tank volume. Analysis of samples also included nitrogen species: Total Kjeldahl Nitrogen (TKN), ammonia-nitrogen, and nitrite + nitrate-nitrogen parameters, despite not being a requirement for the permit.

This case study onsite wastewater treatment plant started operation in October, 2018. The January 2019 treated effluent sampling showed appreciable decrease of BOD & TSS to 45 mg/l and 68 mg/l respectively, at the pump tank to the drain field, compared with target effluent goal. Design wastewater flow & organic load for biomedia surface area supplied at start-up was 2350 gpd, with equivalent 12 lb. BOD/day organic load to MBBR reactor stages. Table 2 shows further sampling results of seven sets of aerobic treatment influent [surge flow equalized septic (EQ tank) effluent] and treated/clarified effluent prior to subsurface discharge.

The PointWatch remote monitoring system was installed as an added feature starting in July 2019 and was not functional until September 2019. Further software and hardware upgrades were accomplished in June 2020, which allowed EQ tank flow measurements based on pump curve, total dynamic head and pump run time. The measured flow for June-September 2020 averaged 2385 gpd, or about 1.5 % above startup design flow.

Table 2: SMART-Treat lab data, multi-unit commercial property, w/ restaurant, micro-brewery.

Date	**Parameter**	**Surge Flow EQ tank (septic tank effluent) mg/l**	**Pump Tank (Aerobically Treated) mg/l**	**% Reduction**
01/27/19	BOD	-	45	-
	TSS	-	68	-
05-08-19	BOD	1360	20	97%
	TSS	364	36	84%
	TKN	117	17.9	85%
	NH_3-N	83.8	7.6	91%
	NO_3-N	-	6.4	79% TN
07/26/19	BOD	858	20	98%
	TSS	67	17	75%
	TKN	87.3	15.3	82%
	NO_3-N	-	20.8	59 % TN
09/20/19	BOD	473	3	99%
	TSS	138	10	93%
	TKN	65.1	6.6	90%
	NO_3-N	-	7.6	79% TN
10/16/19	BOD	340	8	98%
	TSS	94	19	80%
	TKN	52.3	11.5	78%
	NO_3-N	-	<0.1	79% TN
11/05/19	BOD	367	< 2	99%
	TSS	237	6	97%
	TKN	77.5	4.9	94%
	NO_3-N	-	18.6	70% TN
06/23/20	BOD	747	8	99%
	TSS	730	22	97%
	TKN	97.3	11	89%
	NO_3-N	-	27.9	60% TN
11/02/20	BOD	-	<2	-
	TSS	-	11	-
	TKN	-	1.6	-
	NO_3-N	-	15.9	-
		Average Of Six Influent And Effluent Sample Sets		
May '19	**BOD**	**690**	**<10.5**	**>98**
–	**TSS**	**275**	**18**	**93**
June '20	**TN**	**83**	**25**	**70**

Table 2 Note:

- It is assumed that there is no nitrate in the septic tank effluent, so Total Nitrogen at the influent to aerobic treatment is organic/ammonia-N. Total Nitrogen reduction is calculated by subtracting the sum of the aerobically treated nitrate and TKN from septic tank effluent TKN, then dividing by the septic tank effluent TKN value. Example:

- 7/26/19 87.3 – (15.3+20.8) / 87.3 = 0.5865, rounded up = 59% Total Nitrogen reduction.

Effluent laboratory data appears consistent throughout the period. Acknowledging the limitation of sampling during winter weather and of the Covid-19 pandemic, and working with the available flow and laboratory data, if it is assumed that 4-month measured average flow was about equivalent to startup design flow for the prior 12 month period (May 2019-May 2020), and laboratory sampling results were also equivalent to averaged results from the sample sets analyzed, then calculations can be made for organic loading in pounds per day for BOD and TSS from May 2019 through September 2020. As stated earlier, design target values for influent to aerobic treatment were 616 mg/l BOD and 220 mg/l TSS. When start-up design flow is used for calculations, actual SMART-Treat influent BOD averaged 13.5 pounds or 113% of design, SMART-Treat influent TSS averaged 5.4 pounds or 126% of design. Consistent with anticipated SMART-Treat treatment capability, Total Nitrogen reduction over the six (6) sample sets was 70% even when the treatment system was overloaded and not specifically designed for significant nitrogen reduction. High carbon load and recycle aided TN reduction.

Discussion

With reference to this case study, the situation which prompted the wastewater treatment upgrade was the need for a better method of wastewater disposal. The existing drainfield had failed, likely due to being too small for the high strength waste load and inadequate amount of treatment. The SMART-treat small flow onsite moving media wastewater treatment system is well suited for treatment of high strength wastewater prior to subsurface dispersal. Although the plumbing contractor who installed the system is only 10 miles from the treatment site, a remote monitoring system was installed as an early alert system in the event of pump or blower maintenance needs or failure. The system location is not readily visible from the majority of property tenants and a nearby freeway has a constant flow of traffic, so visual and audible warnings are missed. The remote monitoring system was also needed because the system owners and maintainers are not in the immediate area. The system owner was the primary stakeholder for equipment selection . Plumbing contractors and system designers also need to be educated regarding alternatives.

As is typical of many commercial and light industrial wastewater flows, organic and solids loadings may vary widely from day to day. For this case study, TSS and BOD of the septic tank effluent (aerobic treatment influent) had a wide range, which the microbes on the moving bed biofilm reactor were able to treat quite well. Average BOD & TSS reduction for the six sample sets was 98 % and 93 % removal, respectively. Trends and averages are better indicators of total system performance than individual daily results.

The reasons why the treatment system exceeded treatment goals and produced excellent nitrogen removal were:

- The biological surface area of the MBBR was over 35,000 ft^2 at present wastewater flow and load, and will be 49,000 ft^2 at design load. (Comparable stationary media surface area would have been around 16,000 ft^2 at full design load). At full design load MBBR has over 300 % more microbe surface area to treat wastes.

- The comparable FAST system was proposed to be a single stage treatment system in 6000 gallons while the SMART-Treat system was installed as a 3-stage system in 3850 gallons aerated, or only 64% of the volume needed for stationary media.
- Main aeration blower powered anoxic pulsed mixing of stage 3 and pulsed airlift internal recirculation pumped to higher carbon stage 1 and aided treatment. Pulsed air mixing and pumping energy was negligible, an advantage with MegaBubble pulsed air mixers and pumps.
- Due to the self-cleaning nature of the moving media, a thin, healthy biofilm is promoted as pointed out by Mosey (1996). Biofilm thickness control may at times become an issue for biofilms typical of stationary sheet media or even rotating media.

In this case study, average Total Nitrogen (TN) reduction of the samples taken was 70% reduced –without the need to do so from a state regulatory standpoint. A higher microbe density, recirculation to the surge flow tank instead of first aerobic treatment tank and slightly longer hydraulic residence time may have led to even greater nitrogen reduction. Compared to some states regulations, 50 % TN reduction is an acceptable nitrogen reduction, while TN reduction to 10 or 20 mg/l is a suggested goal for some onsite systems in some states. (Colorado Department of Public Health and Environment, Minnesota Pollution Control Agency). NSF/ANSI 245 Wastewater Treatment Systems - Nitrogen Reduction addresses nitrogen reduction as well, for domestic wastewater flows of up to 1500 gallons per day. However, there is currently no public NSF guidance for nitrogen reduction in high strength waste applications.

The major driving factor which prompts equipment selection is usually total system capital cost (CAPEX) and operating cost (OPEX). This is especially true when the system owner(s) are involved in system selection. In this case system owners saved over $ 60,000 by switching to the SMART-Treat® system. The switch from competitive systems to the SMART-Treat system has occurred in the past (Neu, K., 2009) when in 2005 $ 15,000 was saved when a 3317 gpd design high strength waste stream was treated with a MBBR process rather than competitive process. The demand for more affordable onsite treatment systems with less O&M cost with the ability to produce a higher quality effluent is likely to increase in the future, as word spreads that there are lower cost options which provide better treatment with less operation and maintenance cost. For example, annual O&M cost for a biological treatment system of this 3,500 gpd design flow on an annual estimated basis is shown in Table 3.

Table 3. 3500 gpd case study plant. SMART-Treat® onsite MBBR treating high strength waste, which also achieved 70% Total Nitrogen reduction. Estimated annual O&M cost.

Item	Estimated Cost, US dollars/year
Estimated energy cost (@ $ 0.09/KWH)	$ 875
Estimated preventive maintenance & remote monitoring	$ 860
Estimated equipment replacement fund	$ 500
Estimated total long term O&M cost	**$ 2235 or $ 6.12/day**

For this case study system, minor punch list items were addressed by the installation contractor after initial construction. A PointWatch control system was added for monitoring blower, liquid level, pump status, and for sending alarms at limits to the operator. Startup punch list items included addition of several check valves to prevent siphoning from sumps. Blower filter was changed May 9. Also, adjustments were made to frequency of bubble events in anoxic mixing zone and for nitrate recycle pump. A preventive maintenance agreement is in force and on file. Review, evaluation and active fine-tuning of the system is accomplished during each 6-month interval preventive maintenance visit. After initial operational settings were established, the 6-month low maintenance interval is sufficient to keep the treatment system in peak performance mode.

Case Study Summary & Conclusions

- The SMART-Treat® process was selected after regulatory design approval versus a competing fixed film treatment process which was more expensive. Plan change approval occurred rapidly, construction commenced and operation of the system was started on time in October 2018.
- In mid-June 2020 the PointWatch remote monitoring system software was upgraded, so surge flow equalization (EQ) pump ON times could be calibrated to approximately equate to daily flow rate. Consequently. From mid-June through mid-September, flow was calculated to average 2385 gpd, or 101 % of 2350 gpd present design flow.
- Laboratory analysis of SMART-Treat influent and clarified effluent over the sampling period resulted in 99 & 96 % reduction of BOD & TSS respectively, or average of 10 & 18 mg/l BOD & TSS, compared to effluent targets of 220 & 150 mg/l BOD & TSS. If the current design flow was consistently near 100 % from October 2018 startup through mid-September 2020, and organic load was near the 7 sample set average, then overall organic loading during that time period is calculated to be 14.9 pounds BOD/day or 124 % of design—yet---very good treatment was maintained.
- TN reduction averaged 70%, range of 59-80 %. Potential reasons for great nitrogen reduction are 7.3:1 C to N ratio & recirculation. A side note is that nitrogen reduction dropped off due to lack of influent carbon load after the micro-brewery moved out in the spring of 2020. Also note that Total Nitrogen was not regulated in Wisconsin.
- Treated water with biosolids from the post-denitrification stage was recycled with the pulsed air pump to the first aerated reactor, which provided extra treatment of the high strength waste.
- The anoxic post-denitrification tank is mixed with pulsed air mixers in this low DO nitrogen reduction zone. Despite the use of air for mixing, a low dissolved oxygen concentration was maintained for adequate denitrification.
- Settled waste biosolids from the clarifier were recycled to the septic tank on a timed dose basis for ultimate disposal. Pumping not necessary to remove biosolids from aerobic tanks.
- Unique features were included in the design and added after construction in order to enhance treatment and provide ease of monitoring and control.

- The PointWatch system was installed in August of 2019, which rendered much of the control panel redundant. Remote monitoring of pump run times, blower & pump amperage readings and alarm conditions and online control of pump on/off sequencing makes operational decisions easy, eliminating unnecessary trips to the site, while still being notified if anything is wrong.
- Online graphing of data makes for easier decision making by the lead system maintenance operator and allows for decisions to be made, ultimately saving time and money.

The objectives of this SMART-Treat® upgrade case study were met:

- Using only one (1) low pressure air supply, pulsed air anoxic mixing and airlift pumping equipment was installed in addition to aeration, to achieve substantial nitrogen reduction and lower than regulation organic loading to subsurface discharge. A monitoring system was installed to remotely monitor and control/fine tune operation from afar.
- A few sets of samples were collected and analyzed at a commercial testing laboratory to prove that treatment levels are much lower than state regulations required.
- Installed biological treatment tankage is more than 35% smaller than initially planned alternative treatment tankage requirements, yet an average of 75% TN reduction was achieved. Competitive processes may have required over 300 % increase in biological treatment tank volume and related equipment to achieve equivalent treatment.
- The total cost of the new SMART-Treat MBBR system with MegaBubble pulsed air equipment enhancements ultimately provided $ 60,000 installation cost savings to the owners and system installer. The plant pumps and blower can be monitored and adjusted remotely if needed, which provides cost savings for the system maintainer. The pulsed-air technology has allowed for low maintenance because there are no electrical motors, gear reducers or other mechanical moving parts which require mandatory rebuild or replacement, other the main air blower. Cost saving is mainly from no moving parts to maintain, rebuild or replace. Service life of pulsed air mixers or pumps could be in the +40 year range.

Benefits include

- Economical treatment with savings of over $ 60,000 compared to the original specified due to a smaller footprint and lower installation cost.
- Ease of incorporation into an existing approved design.
- After initial operation set up there is minimal maintenance and simple operation.
- Efficient pulsed air pump used for recycle flow powered by the main aeration blower.
- Pulsed air mixers in the anoxic zone use air from the main process air source, which eliminates separate air source to service, maintain, replace, and save costs for separate motors to be purchased and run.
- Economical running costs, especially given the degree of nitrogen reduction achieved.

- The aerobic reactor never needs cleaning. The waste biosolids timed dose pump directs settled waste solids to the septic tank for disposal.
- Self-cleaning biological surfaces – media clogging is never an issue.
- Treatment capacity can be added within existing tankage if necessary
- Remote online monitoring and control add process reliability and security, and save O&M costs associated with travel and time savings. Only go to the site when necessary, based on remote monitoring.

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