EHS SMART-Treat™
MOVING BED BIOFILM REACTOR (MBBR) SYSTEM
COMPONENT MANUAL FOR
PRIVATE ONSITE WASTEWATER TREATMENT SYSTEMS

Environmental / Health Products & Service
P. O. Box 21
Richfield, WI 53076

Phone: (262) 628-1300
E-Mail: ken-ehs@juno.com

Update Version 3: May 2012

EHS SMART-Treat™

MOVING BED BIOFILM REACTOR (MBBR) SYSTEM

COMPONENT MANUAL

TABLE OF CONTENTS

DESIGN ASSISTANCE & ESSENTIAL COMPONENTS FOR THE SMART-Treat MBBR SYSTEM ARE AVAILABLE THROUGH EHS OR THEIR ASSOCIATES

ENVIRONMENTAL / HEALTH PRODUCTS & SERVICE contact: Ken Neu PO BOX 21, RICHFIELD, WI 53076 Phone: (262) 628-1300, ken-ehs@juno.com

I. INTRODUCTION AND SPECIFICATIONS

This Private Onsite Wastewater Treatment System (POWTS) component manual provides design and construction guidelines, inspection, operation, and maintenance information for a Small Flow Moving Bed Biofilm Reactor (Trade Name: SMART-Treat by EHS) system component. These items may accompany a properly prepared and reviewed plan acceptable to the governing unit which provides a system that is installed and functions properly. The Small Flow SMART-Treat™ MBBR system component may receive domestic, commercial/light industrial or combined influent flows and loads equivalent to 100, 000 gallons per day (or less) of wastewater equivalent in organic strength to domestic septic tank effluent. Greater flows and loads may be designed by the supplier on a site specific basis.

PRECAUTIONARY NOTE:

When HIGHER or LOWER organic strength wastewater is encountered, design calculations for system sizing must include steps that would equate back to population equivalents for domestic septic tank effluent. As a design estimate, tank sizes, air rates and biofilm carrier element surface area must be calculated based on population equivalents for domestic septic tank effluent, regardless of waste origin.

For purposes of designing SMART-Treat™ MBBR systems, these general rules apply:

- ✓ The key underlying basis for system design is to use tankage that is, for the most part, approved and readily available from a wide variety of manufacturers and vendors. The main ingredient in these aerobic wastewater treatment fixed film systems is high surface area biofilm carrier elements that will suitably function in any size or shape tank, given minimum system requirements. Therefore, the plumber and system designer should be free to select locally available tank components, purchasing only a specialized aeration system, screens, and media components from a main supplier.

- ✓ All calculations of wastewater quantity and organic strength are based on **Population Equivalents (PE)**. That is, the waste that one average adult would generate within a 24-hour period. Table A lists typical domestic wastewater concentration RANGES for septic tank effluent wastewater per person per day in the United States. Since this manual is based on organic loading per person, most calculations are given in population equivalents [Example: 1 population equivalent (pe) BOD load is equal to the organic load in pounds of BOD that a single adult person creates in one 24-hour period. That load is about 0.154 pounds of BOD_5 per day—primary treated or septic tank effluent].

  COMMERCIAL / LIGHT INDUSTRIAL OR COMBINED APPLICATIONS POPULATION EQUIVELANTS OF ORGANIC LOAD ARE TO BE TREATED AND DESIGNED ACCORDING TO POPULATION EQUIVELANTS USING THE SIZING TABLES WITHIN THIS COMPONENT MANUAL.

NOTE THAT IN MOST CASES ORGANIC (BOD) CONSENTRATION FOR COMMERCIAL/LIGHT INDUSTRIAL APPLICATIONS IS USUALLY HIGHER THAN STRICTLY DOMESTIC WASTEWATER. THEREFORE, <u>MINIMUM REACTOR TANK SIZE FOR A PARTICULAR APPLICATION WILL BE GOVERNED BY THE ORGANIC LOAD, NOT THE HYDRAULIC LOAD</u>. AN INDUSTRIAL STRENGTH WASTEWATER WILL THEN HAVE (& MANY TIMES MAY REQUIRE) A LONGER HYDRAULIC RESIDENCE TIME IN THE REACTOR TANK THAN TYPICAL DOMESTIC STRENGTH WASTEWATER. HENCE, THE ORGANIC LOAD SETS THE MINIMUM TANK SIZE REQUIRED FOR COMMERCIAL/LIGHT INDUSTRIAL OR COMBINED WASTEWATERS.

- ✓ For purposes of designing SMART-Treat™ MBBR systems for the small flow on-site industry, the standard design assumes that septic tank effluent will be the influent to SMART-Treat MBBR reactors.
- ✓ For the purpose of this component manual, typical domestic septic tank effluent has the characteristics listed in Table A. (While there is some variation in wastewater character from household to household, & community to community, these average values are used here for design purposes to cover the majority of cases. Real world, there is a range of concentrations).

Table A. – Domestic Wastewater: Septic Tank Effluent – Defined (for the purpose of this component manual)

Flow, Gallons/ person/day	Total BOD_5	Total Suspended Solids	Total Nitrogen Ammonia, Organic N	Total Phosphorus	pH
75 gallon/day 282 liters/day	200-300 mg/l Ave=247 mg/l (~ .154 #/PE/d 70 gm/d/PE)	100-300mg/l Ave= 200mg/l	40-80mg/l Ave=60 mg/l	6-12 mg/l Ave= 9 mg/l	6.0 – 9.0 Ave = 7.5 standard units

Special Note: SMART-Treat™ MBBR design for septic tank effluent is based on a conservative figure of 70 grams per day of BOD_5 versus 60 grams BOD_5 which is the typical BOD_5 generated by an average adult per day.

When designed, installed and maintained in accordance with this manual, the SMART-Treat™ MBBR component provides treatment of domestic wastewater. The effluent from the SMART-Treat™ MBBR system typically has monthly average values equivalent to or less than NSF Class I treatment of 25 mg/L for BOD_5, 30 mg/L for TSS. If influent values are appropriate, and if designed with intermittent aeration and internal recirculation to an anaerobic stage or septic tank, Total Nitrogen removal to 10-20 mg/L (or less) nitrite+nitrate-nitrogen and 15-30 mg/L for Total N (OR LESS) should be achieved. Total Nitrogen removal of 75 % or higher may be achieved with the proper amount of aeration, biofilm carrier element surface area, internal recirculation to ST and blower on/off sequencing, if necessary. Appendix C goes into more denitrification detail. Supplemental carbon could be added if needed.

Note: Detailed plans and specifications must be developed and submitted for review and approval by the governing unit having authority over the plan for the installation. Also a Sanitary Permit must be obtained from the department or governmental unit having jurisdiction. See Section X for more details.

Table 1

INFLUENT FLOWS AND LOADS

ANTICIPATED EFFLUENT QUALITY

SMART-Treat™ MBBR aerobic reactor TANK Based on population equivalent sizing of domestic septic tank effluent wastewater	
Design wastewater flow (DWF) from primary treatment tanks	Range: 375 gal/day to 100,000 gal/day (See following tables)
Monthly average value of Fat, Oil and Grease (FOG)	≤ 100 mg/L
Monthly average value of five day Biochemical Oxygen Demand (BOD_5)	≤ 247 mg/L
Monthly average value of Total Suspended Solids (TSS)	≤ 200 mg/L
Monthly average value of Total Nitrogen (TN)	≤ 60 mg/L
Design wastewater flow (DWF) from one and two-family dwellings	≤ 150 gal/day/bedroom, or 75 gpd/ person
Design wastewater flow (DWF) from public facilities (Use sizing chart to equate all design calculations back to population equivalents)	≥ 150% of estimated wastewater flow in accordance with Table 4 of this manual or s. Comm. 83.43 (6), Wis. Adm. Code
Forward flow	= Design wastewater flow (DWF)
Anticipated Effluent Quality, Domestic Wastewater Equivalent	BOD <30 mg/l, TSS < 30 mg/l, N Reduction, +80 % reduction of ammonia-nitrogen Total Nitrogen removal of 50-75% or more when designed to remove Nitrogen

Case Study: High Strength SMART-Treat™ Moving Bed Biological Reactor

Westwood Golf & Supper Club, Phillips, WI

A golf & supper club on the Phillips Chain-of-Lakes in Price County had a failing drainfield. The restaurant owner was notified under WI Dept of Commerce Statute 83, effective July 1, 2000 that restaurant wastewater is a high strength wastewater. Therefore, aerobic treatment was required. A sample of the wastewater to be treated aerobically was collected. A correction factor of +22.5 % was used to raise the organic load figure for design purposes.

The MBBR treatment system has been used worldwide to treat high-strength industrial and domestic wastes for small and large flows. Site plans and a component manual were prepared and approved, and the system was installed & started 10/28/01. After a successful startup and acclimation period, the SMART-Treat™ MBBR POWTS system has performed very well within one month of start-up; with treated water quality reported better that designed for. Sampling period was 5 months. Advantages include: economical, a very high biological surface area in a small footprint, therefore takes up less space than other systems, ease of installation and startup, and the ability to increase treatment capacity without the addition of more tankage.

Design Wastewater Flow (DWF): 4500 g.p.d, Restaurant and two 2-bedroom cabins
Design Parameters (Septic Tank Eff) Sample Collected 10/27/00. Certified Lab Results

All results: mg/l	BOD	COD	TSS	pH (su)	FOG	TKN/TN	TP
GT Eff-Anticipated	600-1200	>1500	300-500	6-9	<150	40-60/<100	8-15
GT Eff- Sampled	577	1023	242		60	104.4	16.5
Anticipated Final Eff	<25		<30			<2 / <15	

BOD Full Design Flow: anticipate 706 mg/l or 26.5 pounds/day TBOD removal122.5 %)
Total Nitrogen: If needed, ammonia reduction and total nitrogen removal to can be accomplished to <15 mg/l with additional media, increased recirculation, and/or blower on/off sequencing.

Results: Up to 30 samples were taken during the first 5 months, field and lab tests were conducted (state-certified labs: City of Phillips WWT Plant & Environmental Task Force Lab, Stevens Point, WI)

	BOD5, mg/l	TSS, mg/l	TKN, mg/l	NH3-N, mg/l	NO3-N, mg/l	Temp-C	pH	DO,mg/l
GT Eff	**1619**	**540**	**78**	**46.7**	**--**	**14.6**	**5.3**	**0.5**
ST Eff	**164**	**125**	**--**	**--**	**--**	**9.8**	**6.9**	**0.4**
Final	**16.2**	**14.5**	**2.5**	**0.5**	**8.3-10.5**	**7.0**	**7.1**	**5.4**
% Rem	**99.0**	**97.3**	**96.8**	**93.4**	**--**	**--**	**--**	**--**

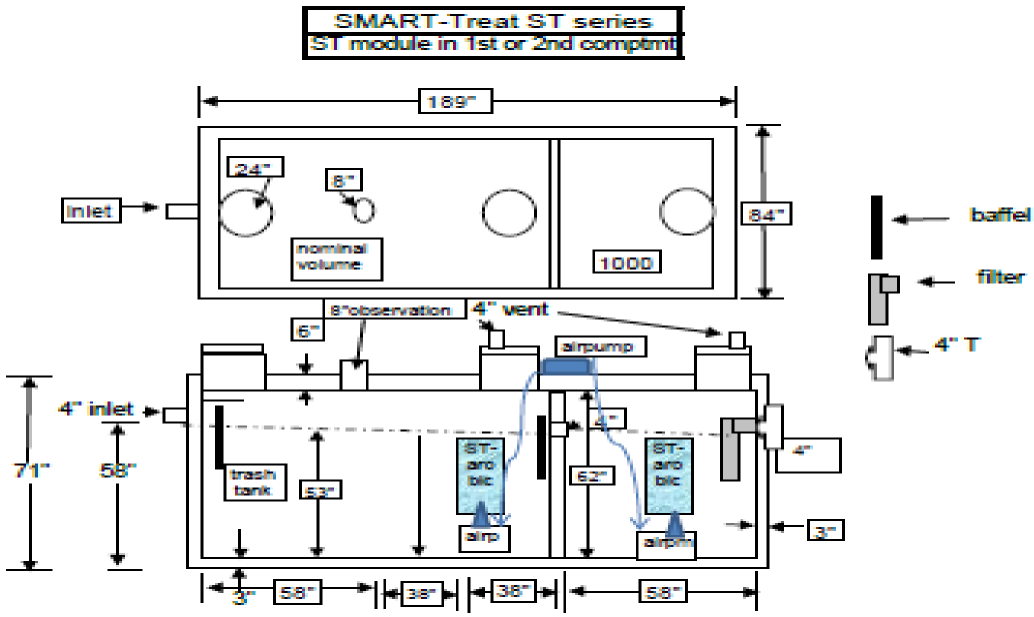
Low STE values from solids removal / recirculation from clarifier, resulting in 85 % Total Nitrogen Removal, with 5 minute pumping of clarifier solids to Septic Tank each 6 hours.

System Rejuvenation/Renovation

EASY Upgrade & Retrofit Options for Existing Septic System or Holding Tank to Aerobic Treatment with the SMART-Treat™ Moving Media Process

Two methods are available:

I. Use the SMART-Treat™-ST series self-contained insert, example in the drawing:



A New Product----The SMART-Treat ST series module

Adding air changes the microbe life in the septic tank from "no air" or anaerobic, to "with air", or aerobic. These microbes are much more efficient and reduce wastes faster.

Aerobic microbes grow and populate the several hundred square feet of surface area on the thousands of biofilm carrier elements within the SMART-Treat module that mix with injected air as they clean wastes in the water.

The end result is cleaner water going into the soil in the drain field. Cleaner water in the drain field may clean up or renovate the drain field, & could make the drain field or mound last longer.

Contact Ken at EHS for pricing and availability.

The most convenient way to convert an anaerobic septic system to a fixed film moving media system is to add a self-contained SMART-Treat ST-series module to the septic tank. One module is designed for a typical 3-bedroom home. The treatment level for this septic tank insert device is typical of---or may be better than competitive models and may match treatment of full-scale units at times. For additional bedrooms or duplex housing units, another module could be added.

<u>General Range of Specifications:</u> Only 2 Components: 1-SMART-Treat-ST module, 1-air pump. Diameter: 12 ", Height: 37", Weight: 35#, Material: HDPE corrugated plastic, w/ weighted base, Integrated 4" course bubble diffuser, with built-in air supply line, media: HDPE biofilm carrier elements that move throughout module, Water circulation: 0.25 " Inlet holes 1' from bottom allow water in, outlet holes 3' from top allow water out. Media retention screen at top of module.

<u>SMART-Treat™ ST series Installation guidelines:</u>

- **<u>Location of the ST module:</u>** It is best to install the SMART-Treat™ ST module in the 2nd compartment of a 2-compartment septic tank AFTER pumping the entire tank. Locate ST module a sufficient distance away from the baffle/outlet area of the tank—so as not to disturb floating solids separation.
    - Note: in a septic tank with only one compartment or a tank with only one manhole, it is possible to use the SMART-Treat ST module. Place the module in the most logical location to reduce as much as possible the mixing and solids separation disturbance caused by rising air bubbles from the module.
- Attach tubing or piping to the air line.
- Attach non-biodegradable rope to the rope loop secured to the module
- Lower the unit to the tank floor using the rope loop and supplemental non-biodegradable rope or wire. (Secure excess rope to manhole/riser side for future use if the ST module needs to be removed from the tank at a future date)
- Secure tubing or pipe through riser using proper plumbing techniques; bring to surface.
- Air pump is usually a self-contained diaphragm blower (similar to fish tank air supply) with enough air volume to provide air for aerobic treatment for one 3 bedroom home. Blower is110 volts, 88 watts. The air pump may be mounted inside of a building up to 100' away. Most installers prefer to place the air pump close to the treatment zone.
- If the air supply is located outdoors, a blower enclosure is highly recommended.
- EHS can supply the blower base and enclosure, if requested, with additional cost to the base price. If an enclosure is provided for weather protection, place the blower base, blower and enclosure in an elevated position (8-12" above grade—a 12" riser section or concrete blocks are examples) to reduce weather-related water and snow effects. P*rotect the blower and enclosure from being covered by snow---to the point of potential blockage of air. If blower is starved for air, it could overheat and damage the blower.*
- After blower is mounted, connect plumbing, electrical. Place the blower into operation.
- **NO Recurring COST!!!**-- **NO NEED for microbe or enzyme refills.** The **LARGE microbe surface is the key.** Abundant microbes live on their moving media homes & remove wastes 24/7-- 365days/yr.

SMART-Treat™ ST series Operation & Maintenance:

<u>Operation:</u> When water in the tank reaches the normal level, the biofilm carrier elements will move throughout the interior of the module. Water in the clear zone with biodegradable food will be drawn into the intake ports located in the lower portion of the module. The rising air and moving media will mix with the water. Microbes will grow and attach to the LARGE surface area provided on the biofilm carrier elements and the module corrugated walls. Treated water and excess biosolids exit the module through upper module effluent ports. Carrier elements are retained inside of the module---top retention screen, intake and effluent ports allow water and biosolids in and out, carrier elements are retained inside of the module. The continuous (24hr/d, 7d/wk) cycling of water into and out of the module provides aerobic treatment and cleaner water to the drainfield than conventional anaerobic septic tank treatment. Excess microbes settle in the bottom of the septic tank and are removed with periodic septic pumping maintenance cycles.
<u>Maintenance:</u> Check, clean, replace blower filter at prescribed intervals as recommended by the blower manufacturer. If the module is moved as a result of septic pumping maintenance, relocate module to optimum location. Module may be removed for inspection of intake/ effluent ports. Air supply longevity is in the range of 3-5 years or longer (typ.) with continuous 24/7 operation.

II Installation of a separate aerobic treatment tank for flows larger than 12 pe: Another method to renovate an existing system if there is sufficient area to do so is to install another tank in between the septic tank / trash tank & drainfield, for flows larger than 6 bedrooms or 12 population equivalents. The existing septic tank acts as primary solids separation.

A convenient way to make this conversion is for the plumber / excavator to install an approved one or two-compartment precast tank downstream from existing septic tank.
Single Compartment aeration, with integrated SMART-Treat™ biosolids filter: A small precast tank such as a 320 gallon Wieser Concrete tank (or similar) could be installed downstream of ST, upstream of pump tank. This tank would serve as the aerobic reactor, complete with air grid, biofilm carrier elements and element screen, independent blower with blower housing. The cleaned water would pass through a SMART-Treat bio-filter with removable element (for cleaning) prior to flowing to the pump tank.

Double Compartment, aeration and biosolids settler, for flows > 12 population equivalents: The conversion of a 2-compartment precast tank would consist of the aerobic SMART-Treat ™ MBBR reactor (1st compartment) and a settling zone (2nd compartment). Inside of the two-compartment tank an air distribution grid (supplied by EHS) can be installed and secured in the 1st compartment. EHS will also supply a media strainer at the outlet of the 1st compartment, and of course, the media or biofilm carrier elements. EHS will supply a blower and the central electrical control panel. The blower will be linked by the plumber to the air distribution header by conventional PVC pipe. The 2nd-compartment of the tank will become the biosolids settling zone. A mechanical or airlift pump, supplied by EHS, will be installed in this compartment by the plumber. A solids return line will be built by the plumber from the pump to the septic tank, so that biosolids can be returned to the septic tank for storage and disposal. If a mechanical pump, it will be wired to the main electrical control panel, with automated operation 1-2 times per day to remove solids. If an airlift pump, it will operate in a continuous or intermittent mode, powered with air from the main air blower, or if desired, from its own "fish tank-type" air supply. An intermittent "spurt" of liquid will be returned to the septic tank.
Existing septic systems or holding tanks can be converted quite simply to aerobic treatment systems under the proper conditions. Other unused underground or above-grade tankage could be converted to an aerobic treatment system with the SMART-Treat™ MBBR process. In these situations, there are several key essential features that must be present for the system to function properly. Generally, the sizing criteria in this component manual should be followed as closely as possible. Sizing criteria is based on POPULATION EQUIVALENTS. Note the conditions for population equivalents regarding flow and organic load in the tables provided. Since each upgrade / retrofit situation is unique, some general guidelines are provided:

Upgrade two-compartment septic tank or septic tank/pump tank to aerobic treatment.

Essential Elements-(Two-Compartment Septic Tank):

- 1st compartment should meet the minimum septic tank sizing requirements of the manual for BOD reduction only or BOD reduction plus ammonia removal/nitrification.
- *VERY IMPORTANT*: When using a two-compartment tank as a SMART-Treat™ MBBR reactor, the divider between compartments should be sealed well enough to NOT allow passage of biofilm carrier elements from one compartment to another. The compartments do not need to be airtight. However, any spaces between floor, walls or cover should be less than ¼ inch in width be prevent

carrier elements from escaping out of the intended compartment. Manufactures have brought the compartment divider up to meet the cover, using the same sealing material as is used between the cover and outer walls. Another method of sealing is to insert a flexible plastic sheet in the wet concrete of the compartment wall, from outer wall on one side to outer wall on the opposite side of the tank. The plastic sheet is slightly higher than the bottom of the top cover. When the top cover is put into place, the cover touches and slightly deflects the flexible plastic sheet, thus making a relatively tight seal between compartments.

- 2nd compartment will be converted to a SMART-Treat™ MBBR aerobic treatment tank. It should meet the minimum sizing requirements of the manual for BOD reduction only or BOD reduction plus ammonia removal/nitrification.
- An aeration grid and a media screen need to be purchased and installed in this compartment.
- The proper amount of media must be purchased and installed (dumped or poured) in the converted SMART-Treat™ MBBR reactor.
- A small solids settling tank can be installed just downstream of the septic tank.

Where a 2-compartment tank would act as aeration chamber (1st compartment) and a biosolids settling tank (2nd compartment), corner fillets could be installed for flat-bottomed compartments. These fillets could reduce the potential for biosolids accumulations in the corners of flat-bottomed tanks.

- An airlift pump or conventional submersible pump could be installed to return solids on an intermittent timed basis to the septic tank for eventual disposal.
- All or a portion of the biosolids can also be returned to the SMART-Treat™ MBBR tank. This would create a hybrid fixed film / suspended growth process and would create endogenous respiration, which would aerobically digest biosolids, ultimately reducing biosolids disposal volumes.
- For single family homes or duplexes, an option available might be a settling chamber that could be inserted into the manhole which would have inclined plate separator media which would encourage most of the solids to settle within the chamber, where an airlift or conventional pump would dispose of them in the septic tank. In the event a settling chamber was installed, the inlet to the chamber would need inlet hole size to comply with 0.20 inch or less inlet opening to keep the biofilm carrier elements from entering the settling chamber. This would eliminate the need for any additional screening in the aeration compartment.
- Another option as a substitute for the biosolids settling zone in domestic applications up to 12 pe is biosolids reduction with a SMART-Treat™ Bio-Solids Filter. This filter could be placed at the outlet end of the SMART-Treat aerobic reactor, but more typically just down stream from the outlet end of the aerobic reactor in the surrounding earth. The filter components are composed of a Catch Basin with removable bucket strainer filled with the same or similar media as the media moving inside of the aerobic reactor. It is 12 inches in diameter. The Catch Basin is part of the flow path, downstream from aerobic treatment tank, upstream of the drainfield or pump tank to soil dispersion. This catch basin has a REMOVABLE basket. The use 1-2 cubic feet of the same media as in the aerobic treatment zone will act as a filter for biosolids. Cleaned on a regular six-month interval with maintenance contract, this device may serve as a substitute for the recommended settling zone for treatment systems up to 12 population equivalents.

  The biosolids filter option would reduce cost of the entire treatment system. However, as with any filter system that is not self-cleaning, this filter would need to be cleaned on a regular basis, typical interval 6-18 months. A service maintenance contract is required.

Essential Elements-(Septic Tank/Pump Tank):

- Septic tank compartment should meet the minimum septic tank sizing requirements of the manual for BOD reduction only or BOD reduction plus ammonia removal/nitrification.
- A pump chamber would be inserted into the manhole. The effluent pump would be mounted inside the pump chamber where it would be positioned and floats set to allow multiple short pumping cycles, minimizing water level change to 5-6 inches water level fluctuation during pumping cycle (for example, 50-65 gallons in a 4'x4'x4' = 500 gallon tank). The inlet to the chamber would need inlet hole size to comply with 0.20 inch or less inlet opening to keep the biofilm carrier elements from entering the pump chamber. This would eliminate the need for any additional screening in the aeration compartment. A "Sim-Tech" type bristle brush screen could act as a secondary screening device.
- These pumping chambers usually allow a bottom settling zone, which would be maintained on a scheduled basis. Alternatively, an airlift or conventional pump could be installed to remove solids to the septic tank for disposal.
- The remainder of the pump tank compartment will be converted to a SMART-Treat™ MBBR aerobic treatment tank. It should meet the minimum sizing requirements of the manual for BOD reduction only or BOD reduction plus ammonia removal/nitrification.
- An aeration grid and a media screen need to be purchased and installed in this compartment.
- The proper amount of media must be purchased and installed (dumped or poured) in the converted SMART-Treat™ MBBR reactor.

Caution should be used regarding entry of any enclosed space, especially in the case of wastewater, where oxygen could be low and toxic gases could become high enough to cause injury or death.

Installation of new tankage would be safer and easier from an aeration diffuser installation standpoint, but may be slightly more expensive than retrofit of existing tanks to aerobic treatment. However, retrofit to aerobic treatment can certainly be accomplished, using most any size tank. The tank could be converted to an aerobic treatment reactor from other uses, no matter what dimensions of the tank. However, it should be water –tight and in reasonably good condition.

New SMART-Treat™ MBBR component tanks can be added to any existing POWTS system. In fact, the SMART-Treat™ MBBR system will be one of the, if not the most compact footprints that are available. This is especially true in larger system applications because of the tremendous amount of surface are for biological growth than with almost any other system (over 133 square feet of biological attachment surface area per cubic foot of tank reactor volume, when 70% media fill level in tank).

Preliminary Treatment Tank Volume

Domestic: Primary Settling
Commercial / Light Industrial: Fat / Oil/ Grease Interception and Primary Settling.

Note: As a general guideline, the majority of the sizing of these tanks is left up to the plumber (or design engineer for larger systems). The general guideline usually allows 25 –35 % of daily DWF as primary settling volume for domestic systems, and 27-75 % of daily DWF volume as grease interceptor and primary settling volume for commercial / light industrial flows. The table below shows this guideline as recommended minimum tank volumes for various flows.

Table 2 -- Tank Volume, Minimum Gallons
Primary Settling (Domestic) and
Primary Settling + Fat, Oil & Grease Interceptor (Commercial/Light Industrial)

Flow, gpd	Septic tank solids separation, Domestic	Septic tank solids separation compartment, Commercial	Grease Interceptor Tank Commercial	Hydraulic Retention Time (HRT) Hours, Minimum Domestic/ Commercial
<1875	500	500	1000	6 / 18
1876-4725	1250	1000	1750	6 /13.2
4726-7050	2000	1200	2000	6.4 / 10.2
7051- 9375	2500	1500	2250	6 / 9.0
9376-13125	3750	1650	2500	6 / 6.6
13126-18750	5000	2000	3500	6 / 6.6
18751-37500	10000	4000	5500	6 / 6
37501-46875	12,500	5000	7000	6/ 6
46876-100000	Use standard industry grease removal and primary settling guidelines. Use individual equipment manufacturers for sizing, price quotations.			

<u>Special Tank, Media, & Air Volume Sizing Notes:</u>

- Where appropriate, interpolation of sizing values between the two closest sizing sets is appropriate, because in most cases, values are proportional to population equivalent intervals. In other words, sizing for 35 pe (an unlisted chart sizing row) would be the mid-point between the listed values for 30 and 40 pe.
- The SMART-Treat MBBR component manual is based on Kaldnes model K-1 biofilm carrier elements, 151 sq ft / cu ft bulk volume. Other carrier element manufacturers are available since this component manual was initially approved, with variations in surface area above and below the K-1 media. This manual will maintain surface area tables with K-1 media as the standard. For any given application, initial surface area determinations will remain the same. Variations of media volume needed shall be based on surface area determined by this manual, and then adjusted to the volume of carrier elements needed, based on the ratio of surface area per unit volume. As an example, EHS uses Biowater Technologies BWT-X media with a surface area of 198 sq ft/cu ft. The ratio is 0.76 : 1. Therefore, to determine the volume of BWT-X media to be used, multiply component manual K-1 volume by 0.76. If 100 cu ft K-1 carrier elements were called for by the sizing table, only 76 cu ft of BWT-X media are needed, to equal same surface area.

SMART-Treat™ MBBR Tank Volume, Air, & Media Requirements

Aeration Reactor Characteristics: Goal of the SMART-Treat system, domestic septic tank eff. is ≤ 25 mg/l BOD and ≤ 30 mg/l TSS after settling, and nitrification of about 80 % if wastewater temperature is greater than 50 degrees F (10 degrees C). Organic loading to the SMART-Treat™ MBBR to achieve this degree of nitrification is based on 0.00072 pounds BOD/ ft^2/day (3.5 grams BOD/ m^2/day). This would be equivalent to about 215 ft^2 (20 m^2) surface area to treat the waste of 1 person. **For larger flows, this would be equivalent to a loading rate of about 0.72 # BOD_5/ 1000 ft^2/day (3.5 grams BOD/m^2/day). If only BOD removal was required <u>(not nitrification)</u> the loading rate could be increased to 1.44 # BOD/1000 ft^2/day (7.0 grams BOD/m^2/day). If BOD removal only, the surface area and the hydraulic residence time can be cut in half. Table 3 only shows typical BOD influent values. Table 4a shows tank size and biological surface area for BOD REMOVAL ONLY. Table 4b shows tank size and biological surface area for BOD REMOVAL + NITRIFICATION (ammonia removal @ 80% reduction).**

<u>Table 3.</u> Population Equivalents, Flow and Influent BOD loading (with nitrification) at 0.00072 pounds BOD/ft^2/day (3.5 grams BOD/m^2/day). Table 3 is based on Domestic Septic Tank Effluent as the SMART-Treat™ MBBR Influent. For BOD_5 higher than 300 mg/L, the population equiv. and wastewater flow must be based on 0.154 pounds BOD/day/PE.

To determine pounds of BOD/day/PE, use the following formula:

BOD Pounds/day/PE = mg/L BOD x 2.204623^{-6} lb/mg x 3.785412 L/gal x 75 gal/day/PE

Population Equivalents	Design Wastewater Flow		Influent BOD	
	Gallons/day	Liters/day	Pounds/day	Kilograms/day
6	450	1704	0.92	.42
10	750	2840	1.54	.70
12	900	3408	1.85	.84
15	1125	4260	2.31	1.15
20	1400	5300	3.09	1.4
30	2250	8520	4.63	2.1
40	2800	10600	6.17	2.8
50	3750	14195	7.71	3.5
60	4300	17040	9.25	4.2
70	5250	19870	10.79	4.9
80	5600	21200	12.33	5.6
90	6750	25550	13.87	6.3
100	7500	28390	15.41	7.0
125	9375	35485	19.26	8.8
250	18750	70970	38.52	17.5
500	37500	141940	77.04	35.0
750	56250	212900	115.56	52.5
1000	75000	283875	154.08	70.0
1333	100000	37500	205.3	93.3

Table 4a. *BOD REDUCTION ONLY*. MBBR MINIMUM tank volume, depth, biofilm carrier elements (volume, % fill, surface area)

Population Equivalents	Tank Volume Gallons (M^3)	Aerobic Reactor Water Depth, min, FT	% Tank Fill of Media (M^2/m^3)	Media Bulk Volume, FT^3 (M^3)	Surface Area, FT^2 (M^2)
6	**200** (0.75)	**3.5**	**16.1** (80)	**4.3** (0.12)	**643** (60)
10	**200** (0.75)	**3.5**	**27** (133)	**7.1** (0.2)	**1076** (100)
12	**200** (0.75)	**3.5**	**32.2** (160)	**8.6** (0.24)	**1285** (120)
15	**200** (0.75)	**3.5**	**40.5** (200)	**10.8** (0.3)	**1614** (150)
20	**200** (0.75)	**3.5**	**54** (267)	**14.4** (0.4)	**2154** (200)
30	**250** (0.95)	**3.5**	**64** (316)	**21.3** (0.6)	**3228** (300)
40	**330** (1.25)	**4**	**64** (320)	**28.3** (0.8)	**4308** (400)
50	**415** (1.6)	**4**	**64** (320)	**35.4** (1.0)	**5385** (500)
60	**500** (1.9)	**4**	**64** (320)	**42.5** (1.2)	**6462** (600)
70	**580** (2.2)	**4**	**64** (320)	**49.6** (1.4)	**7539** (700)
80	**665** (2.5)	**4.5**	**64** (320)	**56.7** (1.6)	**8616** (800)
90	**750** (2.9)	**4.5**	**64** (320)	**63.7** (1.8)	**9693** (900)
100	**838** (3.2)	**4.5**	**64** (320)	**70.8** (2.0)	**10770** (1000)
125	**1000** (3.75)	**5**	**67** (333)	**88.5** (2.5)	**13463** (1250)
250	**2100** (7.9)	**5**	**64** (320)	**177** (5.0)	**26926** (2500)
500	**4175** (15.75)	**6**	**64** (320)	**354** (10.0)	**53852** (5000)
750	**6250** (23.7)	**8**	**64** (320)	**531** (15.0)	**80778** (7500)
1000	**8250** (31.5)	**10**	**64** (320)	**707** (20.0)	**107700** (10000)
1333	**10315** (39.4)	**10**	**64** (320)	**943** (26.7)	**143565** 13330

***If tank unavailable w/ min. depth, or site restrictions may not allow tank w/ min. depth, up to 20% less tank depth is acceptable if air volume is increased 10%.**

Table 4b. *BOD Reduction + Nitrification (approx. 80% ammonia removal).* SMART-Treat MINIMUM tank volume, depth, biofilm carrier elements (volume, % fill, surface area)

Population Equivalents	Tank Volume Gallons (M^3)	Aerobic Reactor Water Depth, min, * FT	% Tank Fill of Media (M^2/m^3)	Media Bulk Volume, FT^3 (M^3)	Surface Area, FT^2 (M^2)
6	**200** (0.75)	**3.5**	**32** (160)	**8.5** (0.24)	**1285** (120)
10	**200** (0.75)	**3.5**	**54** (267)	**14.2** (0.4)	**2154** (200)
12	**200** (0.75)	**3.5**	**64** (320)	**17.0** (0.48)	**2570** (240)
15	**250** (0.95)	**3.5**	**63** (316)	**21.3** (0.6)	**3228** (300)
20	**330** (1.25)	**3.5**	**64** (320)	**28.3** (0.8)	**4308** (400)
30	**500** (1.9)	**3.5**	**64** (320)	**42.5** (1.2)	**6462** (600)
40	**660** (2.5)	**4**	**64** (320)	**56.6** (1.6)	**8616** (800)
50	**830** (3.2)	**4**	**64** (320)	**70.8** (2.0)	**10770** (1000)
60	**1000** (3.8)	**4**	**64** (320)	**85.0** (2.4)	**12924** (1200)
70	**1170** (3.4)	**4**	**64** (320)	99.1 (2.8)	**15078** (1400)
80	**1330** (5.0)	**4.5**	**64** (320)	**113.3** (3.2)	**17232** (1600)
90	**1500** (5.7)	**4.5**	**64** (320)	**127.4** (3.6)	**19386** (1800)
100	**1675** (6.3)	**4.5**	**64** (320)	**141.6** (4.0)	**21540** (2000)
125	**2100** (7.9)	**5**	**64** (320)	**177** (5.0)	**26926** (2500)
250	**4175** (15.8)	**5**	**64** (320)	**354** (10.0)	**53852** (5000)
500	**8350** (31.5)	**6**	**64** (320)	**708** (20.0)	**107700** (10000)
750	**12500** (47.3)	**8**	**64** (320)	**1062** (30.0)	**161556** (15000)
1000	**16500** (63.0)	**10**	**64** (320)	**1414** (40.0)	**215400** (20000)
1333	**20625** (78.8)	**10**	**64** (320)	**1885** (53.3)	**287130** (26660)

***If tank unavailable w/ min. depth, or site restrictions may not allow tank w/ min. depth, up to 20% less tank depth is acceptable if air volume is increased 10%.**

Table 5a. ***BOD REDUCTION ONLY.*** **SMART-Treat Air requirements, Average & Maximum for peak loading. Aerobic Reactor Average Hydraulic Retention Time (HRT)**
EHS Recommends: Always design for Peak or Max Air Flow, unless Wastewater flow is 100% equalized.

Population Equivalents	**Average Air. CFM** (m^3/hr)	**Maximum Air. CFM** (m^3/hr)	**Peak Flow Factor, Max Air @ Max WW Flow**	**Minimum Aerobic Reactor Tank Vol, gal Water Depth, Feet**	**Hydraulic Retention Time, hours @Daily WW Flow, (DWF)**
6	**1.0** (1.8)	**4.9** (8.5)	**4.8**	**200 / 3.5**	**10.6**
10	**1.8** (3.0)	**8.5** (14.2)	**4.8**	**200 / 3.5**	**6**
12	**2.0** (3.6)	**9.8** **(17.0)**	**4.8**	**200 / 3.5**	**5.3**
15	**2.6** (4.6)	**12.7** (21.4)	**4.8**	**200 / 3.5**	**4**
20	**3.5** (5.9)	**16.8** (28.4)	**4.8**	**200 / 3.5**	**3**
30	**6.5** (11.1)	**21.0** (35.5)	**3.2**	**250 / 3.5**	**2.5**
40	**5.8** (8.7)	**18.4** (31.0)	**3.2**	**330 / 4**	**2.5**
50	**6.2** (11.1)	**19.8** (33.2)	**3.2**	**415 / 4**	**2.5**
60	**7.9** (13.3)	**25.1** (42.6)	**3.2**	**500 / 4**	**2.5**
70	**9.1** (15.5)	**29.3** (49.7)	**3.2**	**545 / 4**	**2.5**
80	**9.5** (16.2)	**30.5** (519)	**2.5**	**665 /4. 5**	**2.5**
90	**10.7** (18.2)	**34.3** (58.3)	**2.5**	**750 / 4.5**	**2.5**
100	**11.9** (20.2)	**38.1** (64.8)	**2.5**	**838 / 4.5**	**2.5**
125	**13.1** (22.3)	**42** (71.4)	**2.5**	**1000 / 5**	**2.4**
250	**33.6** (57.1)	**84** (143)	**2.5**	**2100 / 5**	**2.5**
500	**55.6** (94.5)	**139** (236)	**2.5**	**4175 / 6**	**2.5**
750	**49.2** (88.6)	**123** (209)	**2.5**	**6250 / 8**	**2.5**
1000	**53.3** (110.8)	**133** (226)	**2.5**	**8250 / 10**	**2.5**
1333	**71.4** (120.7)	**178** (302)	**2.5**	**10315 / 10**	**2.5**

Table 5b. ***BOD Reduction + Nitrification (approx. 80% ammonia removal).*** **SMART-Treat Air requirements, Average & Maximum for peak loading, Aerobic Reactor Ave HRT.** **EHS Recommends: Design for Peak or Maximum Air Flow, unless WW flow is 100% equalized.**

Population Equivalents *	Average Air. CFM (m^3/hr)	Maximum Air. CFM (m^3/hr)	Peak Flow Factor, Max Air @ Max WW Flow	Minimum Aerobic Reactor Tank Vol, gal Water Depth, Feet	Hydraulic Retention Time, hours @Daily WW Flow, (DWF)
6	**1.3** (2.1)	**6.4** (10.7)	**4.8**	**200 / 3.5**	**10.6**
10	**2.2** (3.7)	**10.6** (17.8)	**4.8**	**200 / 3.5**	**6**
12	**2.6** (4.2)	**12.8** (21.4)	**4.8**	**200 / 3.5**	**5.3**
15	**3.3** (5.7)	**15.9** (26.7)	**4.8**	**250 / 3.5**	**5**
20	**4.4** (7.4)	**21.0** (35.5)	**4.8**	**330 / 3.5**	**5**
30	**6.5** (11.1)	**21.0** (35.5)	**3.2**	**500 / 3.5**	**5**
40	**8.7** (14.8)	**27.8** (47.4)	**3.2**	**660 / 4**	**5.3**
50	**10.3** (18.5)	**33.0** (47.4)	**3.2**	**830 / 4**	**5.3**
60	**13.1** (22.2)	**41.9** (71.0)	**3.2**	**1000 / 4**	**5.3**
70	**15.2** (25.9)	**48.8** (82.9)	**3.2**	**1170 / 4**	**5.3**
80	**20.0** (34.0)	**50.1** (85.2)	**2.5**	**1330 / 4.5**	**5.3**
90	**22.5** (38.3)	**56.3** (95.7)	**2.5**	**1500 / 4.5**	**5.3**
100	**25.0** (42.6)	**62.6** (106.4)	**2.5**	**1675 / 4.5**	**5.3**
125	**27.8** (47.3)	**69.5** (118.2)	**2.5**	**2100 / 5**	**5.3**
250	**55.6** (94.5)	**139** (236.3)	**2.5**	**4175 / 5**	**5.3**
500	**88.8** (191)	**222** (377)	**2.5**	**8350 / 6**	**5.3**
750	**84** (143)	**210** (357)	**2.5**	**12,500 / 8**	**5.3**
1000	**88.8** (150.9)	**222** (377)	**2.5**	**16, 500 / 10**	**5.3**
1333	**119**	**296**	**2.5**	**20,625 / 10**	**5.3**

*** Interpolate air requirements based on proportioning between listed P E figures.**

Air Distribution Piping within the SMART-Treat™ Aerobic Reactor

General comments:
The air distribution piping is manufactured to provide even air distribution throughout the entire tank bottom. Aeration holes of 4 mm min size (3/16" diameter is common) are placed evenly at bottom of 1.5-2.0" dia. pipe to create course bubble aeration. Distance between holes: 8-12"on the pipe length, laterals are 12-15" apart. As of April, 2012, the pipe distribution manifold is placed on cement blocks at the corners (and in the center, if needed). Expanded plastic sleeves cover the pipe at places where the pipe rests on the block—and NOT blocking air flow. At each of those locations a cast hollowed concrete block is set on top of the plastic sleeve and presses firmly on the concrete base block underneath. The concrete block/sleeve placement across the air header holds the air header in place, with no chance of moving or floating. Table 5-C is shown as a general guide to show air volume with pressure in a clean environment. It is NOT meant to depict air flow in a wastewater and biological mass environment. If inert material accumulations and biomass buildup over time, the listed orifice size could be ½ the diameter as listed. For example, if 3/16 " holes were placed in the aeration pipe, over time at 40 " water depth , the narrowing of the hole may only allow1.5 CFM vs. 3 CFM if new. To destabilize mass at air holes, several on/off blower cycles/yr may assist to keep aeration openings optimum.

Table 5-C. Airflow through an Orifice, CFM

Pressure, Inches H_2O	Orifice Diameters								
	1/8	3/16	1/4	5/16	3/8	7/16	1/2	3/4	1
10	0.686	1.54	2.75	4.29	6.18	8.41	11	24.7	43.9
15	0.84	1.89	3.38	5.25	7.56	10.3	13.4	30.3	53.8
20	0.97	2.18	3.88	6.06	8.73	11.9	15.5	34.8	62.1
25	1.06	2.44	4.34	6.77	9.76	13.3	17.3	39	69.4
30	1.19	2.57	4.76	7.42	10.7	14.5	19	42.7	78
35	1.26	2.88	5.13	6.01	11.5	15.7	20.5	46.1	82
40	1.37	3.08	5.48	8.56	12.3	16.6	21.9	49.3	87.6
45	1.45	3.27	5.81	9.07	13.1	17.6	23.2	52.3	92.9
50	1.53	3.44	6.12	9.56	13.8	18.7	24.5	55.1	97.9
55	1.6	3.61	6.41	10	14.4	19.6	25.7	57.7	103
60	1.67	3.77	6.7	10.5	15.1	20.5	26.8	60.3	107
65	1.74	3.92	6.97	10.9	15.7	21.3	27.9	62.7	111
70	1.81	4.08	7.23	11.3	16.3	22.1	228.8	65	116
75	1.87	4.21	7.48	11.7	16.8	22.9	29.9	67.3	120
80	1.93	4.34	7.72	12.1	17.4	23.6	30.9	69.5	124
85	1.99	4.47	7.95	12.4	17.9	24.4	31.6	71.6	127
90	2.04	4.6	8.18	12.8	18.4	25.1	32.7	73.6	131
95	2.1	4.73	8.4	13.1	18.9	25.7	33.6	75.6	134
100	2.15	4.85	8.61	13.6	19.4	26.4	34.5	77.5	138
105	2.21	4.96	8.82	13.8	19.9	27	35.3	79.4	141
110	2.26	5.08	9.03	14.1	20.3	27.6	36.1	81.2	144

Note: Table furnished by FPZ, Inc. (a blower supplier/manufacturer company)
1 psi = 27.68 inches H_2O Discharge Coefficient = 0.65 Air Temp = 70 deg F

Table 6a. *NON EQUALIZED FLOW* Treated Water Solids Separation/ Clarification. Minimum Volume & Depth, Maximum Overflow Rate (OFR)

NOTE: For sizing of the biological solids settling tank, Use Actual Design Wastewater Flow, NOT Population Equivalents.

Wastewater Flow, Gallons/day	Min. Clarifier Vol., gallons/ Min Clarifier Depth, ft *	Peak to Average Flow Factor	Min. Clar. Surface Area, FT^2 / Max Surface Overflow Gal/FT^2/day	Clarifier HRT, hours 24 Hr Ave / At Peak Flow Factor	Population Equivalents (applicable to domestic ww applications only)
375	200 / 3.0	4.8	5 / 400	12.8 / 2.7	5
450	240 / 3.0	4.8	6 / 400	12.8 / 2.7	6
750	300 / 3.0	4.8	9 / 400	9.6 / 2.0	10
900	300 / 3.0	4.8	11 / 393	8 / 1.7	12
1125	600 / 3.0	4.8	15 / 350	12.8 / 2.7	15
1400	750 / 3.0	4.8	19 / 350	12.8 / 2.7	20
2250	750 / 3.0	3.2	21 / 350	8.0 / 2.5	30
2800	750 / 3.0	3.2	22 / 407	6.4 / 2.0	40
3750	1000 / 3.0	3.2	28 / 429	6.4 / 2.0	50
4300	1300 / 3.0	3.2	39 / 350	7.3 / 2.2	60
5250	1750 / 3.5	3.2	48 / 350	8.0 / 2.5	70
5600	2000 / 4.0	2.5	50 / 280	8.6 / 3.4	80
6750	2000 / 4.0	2.5	50 / 338	7.1 / 2.8	90
7500	2000 / 5	2.5	50 / 375	6.4 / 2.6	100
9375	2000 / 5	2.5	50 / 469	5.1 / 2.1	125
18750	4000 / 5	2.5	100 / 469	5.1 / 2.0	250
37500	8000 / 5.5	2.5	200 / 469	5.1 / 2.0	500
56250	12000 / 7	2.5	300 / 469	5.1 / 2.0	750
75000	16000 / 7	2.5	400 / 469	5.1 / 2.0	1000
100000	21280 / 8	2.5	550 / 454	5.1 / 2.0	1333

- **A 40-inch minimum depth is listed as a minimum depth for solids settling tankage. A clarifier depth range of 48 to 60 inches is more advantageous. However, in some cases, a tank may not be readily available within that range of water depth. In other cases, site restrictions may make it difficult to accept deeper tanks. Flow equalization to SMART-Treat™ aeration tankage and pumped feed with an optimum number of short pump cycles per day will reduce pump cycle volume and enhance settling. Installation of the deepest clarifier tank possible will produce optimum results. A clarifier tank selection guide follows Table 6b. A clarifier tank selection guide follows Table 6b. Appendix B lists biosolids settling tank, equalization tank, and airlift pump examples. Other tanks may also be adaptable as clarifiers and available locally, or can be shipped to your location. EHS can assist with all of your tank needs. EHS (Ken) Phone: 262-628-1300, ken-ehs@juno.com**

Table 6b. *EQUALIZED FLOW* Treated Water Solids Separation / Clarification. Minimum Volume & Depth, Maximum Overflow Rate (OFR)

NOTE: For sizing of the biological solids settling tank, Use Actual Design Wastewater Flow, NOT Population Equivalents.

Wastewater Flow, Gallons/day	Min. Clarifier Vol., gallons/ Min Clarifier Depth, ft *	Peak to Average Flow Sizing Factor	Min. Clar. Surf Area, FT^2 / Max Surf ace Overflow Rate Gal/FT^2/day	Clarifier HRT, hours 24 Hr Ave / At Peak Flow Factor	Population Equivalents (applicable to domestic ww applications)
375	200 / 3.0	1.5	2 / 282	12.8 / 8.5	5
450	240 / 3.0	1.5	3 /225	12.8 / 8.5	6
750	300 / 3.0	1.5	4 /282	9.6 / 6.4	10
900	300 / 3.0	1.5	5 / 270	8.0 / 5.3	12
1125	300 / 3.0	1.5	5 / 338	6.4 / 4.3	15
1400	300 / 3.0	1.5	6 / 350	5.1 / 3.4	20
2250	300 / 3.0	1.5	10 / 338	3.2 / 2.1	30
2800	500 / 3.0	1.5	12 / 350	4.3 / 2.9	40
3750	650 / 3.5	1.5	16 / 350	4.2 / 2.8	50
4300	750 / 3.5	1.5	19 / 338	4.2 / 2.8	60
5250	750 / 3.5	1.5	22 / 356	3.4 / 2.3	70
6000	750 / 3.5	1.5	22 / 409	3.0 / 2.0	80
6750	1000 / 4.0	1.5	28 / 241	3.6 / 2.4	90
7500	1000 /4. 0	1.5	28 / 402	3.2 / 2.1	100
9375	1000 / 4.5	1.2	28 / 402	2.6 / 2.1	125
18750	2000 / 4.5	1.2	50 / 450	2.6 / 2.1	250
37500	4000 / 6	1.2	100 / 450	2.6 / 2.1	500
56250	8000 / 6	1.2	150 / 450	3.4 / 2.8	750
75000	10000 / 7	1.2	200 / 450	3.2 / 2.6	1000
100000	15000/ 7	1.2	275 / 436	3.6 / 3.0	1333

*** A 36-inch minimum depth is listed as a minimum depth for solids settling tankage. A clarifier depth range of 48 to 60 inches is more advantageous. However, in some cases, a tank may not be readily available within that range of water depth. In other cases, site restrictions may make it difficult to accept deeper tanks. Flow equalization to SMART-Treat™ aeration tankage and pumped feed with an optimum number of short pump cycles per day will reduce pump cycle volume and enhance settling. Installation of the deepest clarifier tank possible will produce optimum results. Appendix B lists biosolids settling tanks, equalization tank options, and airlift pump examples. Other tanks may also be adaptable as clarifiers and available locally, or can be shipped to your location. EHS is available to assist with all of your tank needs.**
EHS (contact-Ken) Phone: 262-628-1300, E-mail: ken-ehs@juno.com

Table 7: OTHER SPECIFICATIONS	
Treatment capability for BOD_5, TSS, Ammonia-Nitrogen and Total N **Note: Values Based on Treatment of Domestic Septic Tank Effluent with the given specifications. Deviations higher than given values may provide different results. Not applicable to commercial/ light industrial applications unless specifically designed for removals similar to domestic wastewater applications.**	Generally, ≥ 90% removal for BOD_5 and TSS, Generally, ≥80 % ammonia conversion at ww temperature ≥ 50 degrees F (10 degrees C). The SMART-Treat™ MBBR system is capable of 50- 75 % or greater removal for Total N when specifically set up for this application, which may include blower on/off manipulation and/or internal recirculation to anaerobic/ anoxic zone or septic tank of up to 200 % of forward flow.
Biofilm carrier elements Initially used Kaldnes carrier elements: Size: K-1: dia. = 12 mm, ht=8 mm K-2: dia. = 18 mm, ht = 15 mm K-1 protected biofilm growth area of about $350m^2/m^3$ (over 2,900 ft^2/yd^3) or 151 sq ft/cu ft-bulk density. Currently use Biowater Technology Carrier Elements (Specs as Appendix E)	Material: 0.96 specific gravity HDPE Shape: small cylinders or cubes, with a cross members in the inside of the cylinder or cube. Tank filling level: range: 30 - 70% (volumetric filling of carrier elements in an aerobic reactor) Surface area: BWT-X = 198 sq ft/cu ft (139 sq ft/cu ft @ 70% fill) BWT-15 = 253 sq ft/cu ft (177 sq ft/cu ft @ 70% fill) Volume displacement: Biofilm carriers @ 70% fill displace a water volume of about 10-12%.
Piping material	Meets requirements of s. Comm. 84.30 (2), Wis. Adm. Code for its intended use
Installation inspection	In accordance with Comm. 83 Wis. Adm. Code
Management	In accordance with ch. Comm 83 Wis. Adm. Code

II. DEFINITIONS

Definitions unique to this manual are included in this section. Other definitions that may apply to this manual are located in ch. Comm 81 of the Wis. Adm. Code or the terms use the standard dictionary definition.

A. SMART-Treat™ Moving Bed Biofilm Reactor (MBBR) The SMART-Treat™ MBBR process is **S**mall *Moving* **M**edia **A**erobic **R**eactor **T**reatment and uses aeration and mixing in wastewater tankage with small biofilm carrier elements. Microbes attach to the moving fixed film and treat wastewater flows from 450 to 100,000 gallons/day or more.

B. Population Equivalent refers to the waste that one average adult would generate within a 24-hour period. [Example: 1 population equivalent (PE) BOD load is equal to an organic load in pounds of BOD that a single adult person generates in one 24-hour period. That load is about 0.17 #/d and is reduced to about 0.154 pounds of BOD_5 per day in the septic tank].

C. "Recirculation rate" means the portion of the wastewater that is nitrified but prior to settling, or returned activated sludge that is delivered back into the system compared to the clarified wastewater effluent that is not delivered back into the system.

D. Biosolids Solids Settling Tank refers to the tank that treated water flows into from the MBBR aeration reactor. Biological solids settle out in this tank and are pumped to the septic tank for ultimate disposal. Clear water passes out of this tank and to subsurface disposal.

III. DESCRIPTION AND PRINCIPLE OF OPERATION

The SMART-Treat™ Moving Bed Biofilm Reactor

The Environmental/Health Products & Service SMART-Treat™ Moving Bed Biofilm Reactor (EHS- SMART-Treat™) system is a small flows treatment system of 100,000 gallons/day or less. 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 subsurface destinations for final disposal. Up to 70 % denitrification is achieved with recirculation and blower sequencing. Total Nitrogen below 10 mg/l is achieved with specific engineering techniques for nitrogen removal. For larger flows, surface discharge may be applicable under permitted conditions.

The SMART-Treat™ MBBR process uses aeration and mixing in wastewater tankage with small biofilm carrier elements to grow bacteria and treat wastewater flows. Air is mechanically compressed and distributed to the aerobic reactor tank. Oxygen in the air diffuses into the thin biofilm that naturally grows on the biofilm carrier elements. The biofilm carrier elements move at random throughout the aerobic reactor tank. As air passes through the water and past the media, the wastes in the water act as food for the microbes growing on the moving media. Cleaned water is discharged while settled biological solids are occasionally returned back to the primary solids separation zone (septic tank) for normal routine disposal along with primary settled solids.

The system reduces BOD_5, TSS, and Nitrogen as Ammonia Nitrogen or Total N. Supplying oxygen to the wastewater stream reduces BOD5. TSS is reduced through settling and filtration. Nitrogen as Ammonia Nitrogen is reduced by converting ammonia to nitrate. When specifically designed for Total Nitrogen reduction, the system is capable of converting nitrate to nitrogen gas by means of blower on/off cycling and/or internal recirculation back to the septic tank of up to 200% of forward flow. For larger flows, additional anoxic stages may be necessary.

Fecal coliform and Total Phosphorus reduction is possible with additional passive (non-mechanical) or active (mechanical) system components. However, that discussion is not directly related to the SMART-Treat™ MBBR system, and may be addressed in other component manuals. This manual addresses the primary solids separation tank, the aerobic reactor tank, and the final settling tank, and their required equipment and piping.

The basic idea was to have continuously operating, non-cloggable biofilm reactors with no need for backwashing or return sludge flows, low head-loss and high specific biofilm surface area. This was achieved by having the biomass grow on small carrier elements that move along with the water in the reactor. Coarse-bubble aeration in the aeration zone and interruption of aeration (or mechanical mixing in an anoxic/anaerobic zone) in the wastewater treatment tankage provide a highly treated effluent, with easy, low-cost operation. The biofilm carrier elements are made of 0.96 specific gravity polyethylene and shaped like small cylinders, with a cross in the inside of the cylinder and longitudinal fins on the outside. The two basic sizes manufactured by Biowater Technologies and used by EHS are described in Appendix E. To keep the biofilm elements in the reactor, a screen or perforated plate or pipe is placed at the outlet of the reactor. Agitation constantly moves the carrier elements over the surface of the screen; the scrubbing action prevents clogging.

This relatively new fixed film wastewater treatment process may be used to upgrade activated sludge or fixed film systems. 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. A brief description of this process for small commercial and domestic wastewater treatment applications will make it easier for regulatory agencies to understand the benefits of this technology and allow greater use of this technology in small flow applications.

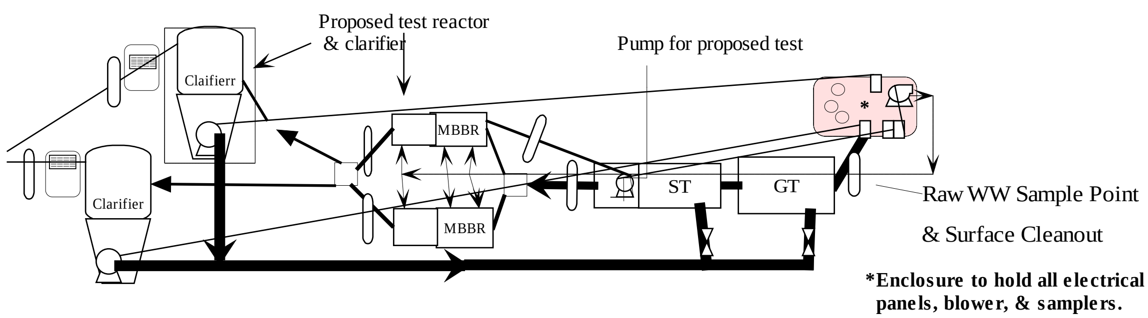
A small flow newsletter by International Association on Water Quality (1997) indicated that as small flows become more prominent and treatment requirements become more stringent, cost-effective, and efficient treatment systems need to be developed for on-site treatment and existing plant upgrades. Neu and Rusten (1997) indicated that a relatively new system that could be downsized from current municipal and industrial applications is the Moving Bed Biofilm Reactor (MBBR) process. The Norwegian Company Kaldnes Miljoteknologi (KMT), in cooperation with the SINTEF research organization, has developed the MBBR process in the late 1980's.
As of 2007, there are more than 3000 small flows units, primarily single and multi-home units and some small community systems. There are over 500 operating or planned installations in the municipal and industrial wastewater treatment areas worldwide since 1990, even some large municipal plants such as Wellington, New Zealand (population equivalent = 200,000). As of 2012 there are several carrier element manufacturers. However, EHS works with some of the originators of the technology, who maintain superior equipment and process knowledge leadership within the moving media biological wastewater treatment industry.

Almost any size or shape tank can be built or retrofitted with the MBBR process. 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. A maximum volumetric filling of about 70% of the common size BWT-X carrier elements corresponds to a specific biofilm growth area of about 139 ft^2 / ft^3. The biofilm carriers at this specific fill level displace a water volume of about 12%. The reactor volume is totally mixed and consequently there is no dead space or unused space in the reactor.

This system is ideal for small installations such as single family or multi-home clusters, mobile home parks, and small unsewered communities. It can also serve to upgrade overloaded activated sludge, trickling filter, or RBC package-type or full-scale plants, or for converting unused volumes into biofilm reactors for increased capacity or nutrient removal. This process is used to upgrade activated sludge plants by such methods as segregation of an aeration tank for use as a MBBR roughing stage, or for addition for nitrification/denitrification. This process also fills an important flow niche; that size from too large for available modular (home) systems to the flows that are just too small for package plants on the market.

As of January 2009 EHS has selected to work with Biowater Technologies, Inc. as the carrier element supplier. (Carrier element BWT-X conversion: multiply carrier element volume determined from component tables by 0.76 when calculating BWT-X media volume to be used)

Figure 2. SMART-Treat™ MBBR System for a Restaurant, w/ Q =4500gpd, BOD_5 (STE) = 706 mg/l.



IV DESIGN

A. <u>Size</u>- Sizing of the SMART-Treat™ moving bed biofilm reactor system must be in accordance with this manual and standard plumbing practice for sizing conventional septic system components.

B. Use **Tables 2, 3, 4a or 4b, 5a or 5b, & 6a, 6b to determine the various MINIMUM tank sizes to use for a specific treatment application. Septic tanks and grease interceptor tanks should be sized at or above the minimum recommended sizes. Aeration reactor tanks are sized to accommodate enough biofilm carrier element media (K-1 model media, convert to BWT-X with 0.76 multiplier) to accomplish 80 % nitrification at specified DOMESTIC SEPTIC TANK EFFLUENT wastewater strengths when the septic tank is pumped at normal intervals (less than 12 inches sludge accumulation, or every 2 years, whichever is less) and the water temperature in the reactor is 50 degrees F (10 degrees C) or higher.**

C. Biological solids separation/clarification tank must be sized to at least minimum requirements. Flat bottom settling tanks are acceptable for flows 12,000 gpd and less. For flows greater than 12,000 gpd, a sufficient sludge removal system may incorporate a specific sloping arrangement of the tank bottom, sloping down to a central point where settled biological solids could easily flow to a solids removal pump. Solids removal from the settling zone should be on a timed basis at least 1-2 times per day. Solids should be pumped to a septic tank upstream of the biological aeration tank or other dedicated tank where solids are typically and routinely removed from the treatment system.

SMART-Treat™ MBBR System Component Design – Detailed plans and specifications must be developed, reviewed and approved by the governing unit having authority over the plan for the installation. A Sanitary Permit must also be obtained from the department or governmental unit having jurisdiction.

Design of the SMART-Treat™ system component is based on the estimated wastewater flow. It must be sized such that it can accept the daily wastewater flow at a rate that will provide treatment.

Design of the SMART-Treat™ system includes four steps, which are: (A) calculating the design wastewater flow, (B) design of the pretreatment tank(s) septic tank or grease interceptor chamber, (C) design of SMART-Treat™ MBBR component tank, air flow and biofilm carrier element volume, and (D) design of the biological solids separation tank.

Treated effluent will be disposed of by normal sizing of subsurface soil absorption area or surface discharge requirements.

Step A. Design wastewater flow

Calculation of the design daily wastewater flow (DWF). To calculate DWF use formula 1.

Formula 1

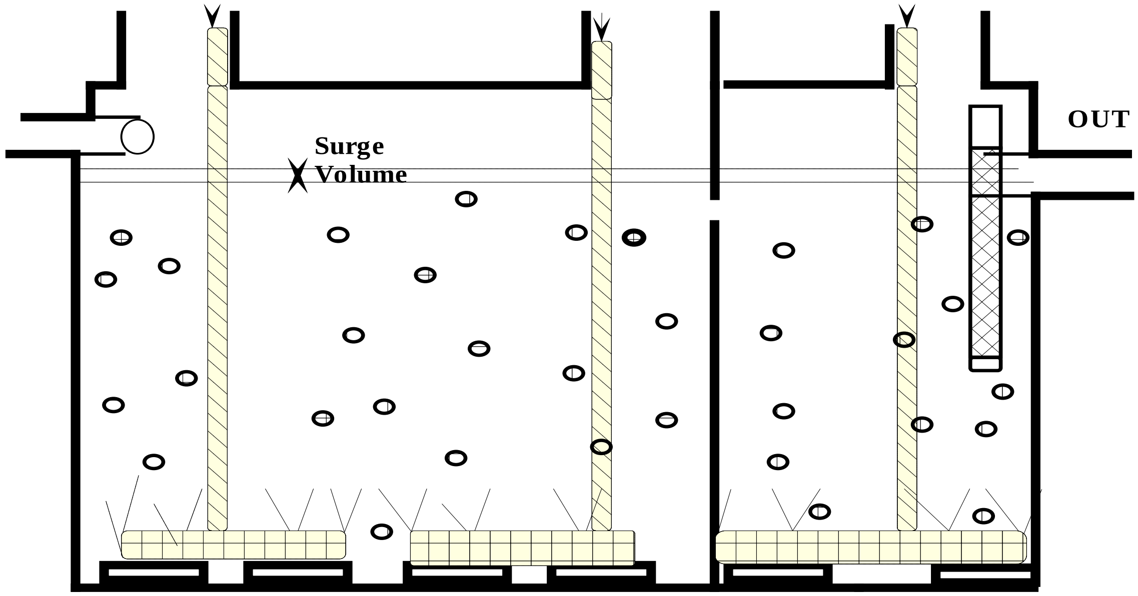
DWF = 150 gallons/bedroom/day or 75 gallons/person/day

Public facilities. Design Daily Wastewater Flow (DWF) for a public facility application is determined by calculating the DWF using formula 2. Public facility estimated daily wastewater flows are listed in Table 8. Facilities that are not listed in Table 8 are not included in this manual. Many commercial facilities have high BOD_5, TSS and FOG (fats, oil and grease), which must be pretreated in order to bring their values down to an acceptable range before entering into the SMART-Treat™ MBBR system component described in this manual.

Formula 2

DWF = 1.5 x Sum of each wastewater flow per source per day (from Table 8)

Figure 3. Cross-Section of a SMART-Treat™ Moving Bed Biofilm Reactor Aeration Reactor Tank.



MOVING BED BIOFILM REACTOR (MBBR)
(Air Distribution Header Hold-Downs not Shown for Clarity)

Typical EHS 2-compartment Aeration Reactor
(Single stage reactors typically used on domestic WW, Multi-Stage reactors on higher strength Wastewater Note that there must be a seal of less than 1/4 inch between compartments to maintain media within each compartment. Failure to adequately seal can result in shifting of media between compartments).

Table 8 **Public Facility Wastewater Flows**		
Source	**Unit**	**Estimated Wastewater Flow (gpd)**
Apartment or Condominium	Bedroom	100
Assembly hall (no kitchen)	Person (10 sq. ft./person)	1.3
Bar or cocktail lounge (no meals served)	Patron (10 sq. ft./patron)	4
Bar or cocktail lounge* (w/meals - all paper service)	Patron (10 sq. ft./patron)	8
Beauty salon	Station	90
Bowling alley	Bowling lane	80
Bowling alley (with bar)	Bowling lane	150
Camp, day and night	Person	25
Camp, day use only (no meals served)	Person	10
Campground or Camping Resort	Space, with sewer connection and/or service building	30
Campground sanitary dump station	Camping unit or RV served	25
Catch basin	Basin	65
Church (no kitchen)	Person	2
Church* (with kitchen)	Person	5
Dance hall	Person (10 sq. ft./person)	2
Day care facility (no meals prepared)	Child	12
Day care facility* (with meal preparation)	Child	16
Dining hall* (kitchen waste only without dishwasher and/or food waste grinder)	Meal served	2
Dining hall* (toilet and kitchen waste without dishwasher and/or food waste grinder)	Meal served	5
Dining hall* (toilet and kitchen waste with dishwasher and/or food waste grinder)	Meal served	7
Drive-in restaurant* (all paper service with inside seating)	Patron seating space	10
Drive-in restaurant* (all paper service without inside seating)	Vehicle space	10
Drive-in theater	Vehicle space	3
Employees (total all shifts)	Employee	13
Floor drain (not discharging to catch basin)	Drain	25
Gas station / convenience store	Patron (minimum 500 patrons)	3
Gas station (with service bay) Patron Service bay	 Patron Service bay	 3 50
Hospital*	Bed space	135
Hotel, motel or tourist rooming house	Room	65
Medical office building Doctors, nurses, medical staff Office personnel Patients	 Person Person Person	 50 13 6.5
Migrant labor camp (central bathhouse)	Employee	20
Mobile Home (Manufactured home) (served by its own POWTS)	Bedroom	100
Mobile home park	Mobile home site	200

* = May be high strength waste

Table 8 **Public Facility Wastewater Flows** (Continued)		
Source	**Unit**	**Estimated Wastewater Flow (gpd)**
Nursing, Rest Home, Community Based Residential Facility	Bed space	65
Outdoor sport facilities (toilet waste only)	Patron	3.5
Parks (toilets waste only)	Patron (75 patrons/acre)	3.5
Parks (toilets and showers)	Patron (75 patrons/acre)	6.5
Public shower facility	Shower taken	10
Restaurant*, 24-hr. (dishwasher and/or food waste grinder only)	Patron seating space	4
Restaurant*, 24-hr. (kitchen waste only without dishwasher and/or food waste grinder)	Patron seating space	12
Restaurant, 24-hr. (toilet waste)	Patron seating space	28
Restaurant*, 24-hr. (toilet and kitchen waste without dishwasher and/or food waste grinder)	Patron seating space	40
Restaurant*, 24-hr. (toilet and kitchen waste with dishwasher and/or food waste grinder)	Patron seating space	44
Restaurant* (dishwasher and/or food waste grinder only)	Patron seating space	2
Restaurant* (kitchen waste only without dishwasher and/or food waste grinder)	Patron seating space	6
Restaurant (toilet waste)	Patron seating space	14
Restaurant* (toilet and kitchen waste without dishwasher and/or food waste grinder)	Patron seating space	20
Restaurant* (toilet and kitchen waste with dishwasher and/or food waste grinder)	Patron seating space	22
Retail store	Patron (70% of total retail area ÷ 30 sq. ft. per patron)	1
School* (with meals and showers)	Classroom (25 students/classroom)	500
School* (with meals or showers)	Classroom (25 students/classroom)	400
School (without meals or showers)	Classroom (25 students/classroom)	300
Self-service laundry (toilet waste only)	Clothes washer	33
Self-service laundry (with only residential clothes washers)	Clothes washer	200
Swimming pool bathhouse	Patron	6.5

* = May be high strength waste

Step B. Design of the Pretreatment Tankage—This section assists the designer or plumber with identifying MINIMUM septic tank and grease interceptor recommendations that will allow pretreatment prior to SMART-Treat™ MBBR treatment. Use Table 2 to determine MINIMUM tank sizes for these components. A conservative design approach may be to use local tank suppliers and select tank sizes that would exceed the minimum recommendations for these components.

Step C. Design of the SMART-Treat™ Component– This section determines the required liquid capacity and depth of the SMART-Treat™ MBBR tank or chamber, air requirements, and media requirements. Use Tables 3, 4, & 5 to determine the required liquid capacity and depth of the MBBR tank or chamber, air requirements, and media requirements, ALL BASED ON POPULATION EQUIVALENTS.

Typically, BOD reduction only applications require only one reactor stage, so a single compartment is sufficient. When wastewater is more concentrated than typical domestic strength, or if nitrification approaching 80% or higher is the goal, a two-stage reactor is required. The volume of the first stage versus the second stage is usually about two-thirds to one-third ratio, similar to standard two-compartment septic tanks or septic tank with pump chamber in one enclosure. For larger reactor volumes, or to create more stages than two, individual tanks could be piped in series. Some tank manufacturers can make or have as standard offerings multiple stage tanks.

For commercial or light industrial applications at least one sample of typical wastewater to be aerobically treated should be analyzed for the proper constituents. Sizing of the aerobic reactor should be based on real and accurate laboratory analysis, and calculated into population equivalents. Most often commercial or light industrial wastewaters contain higher concentrations of pollutant than typical domestic wastewater; so organic load should be used to calculate population equivalents. The flow most likely will be less than the flow associated with per person use on the tables, so the system size generated by organic strength converted to population equivalents governs and is the determining factor for aerobic reactor tank size, including air requirements, and media requirements.

The typical operation of a SMART-Treat™ MBBR system is as gravity feed system similar to normal septic tank operation. However, this is a miniature aerobic wastewater treatment system using fixed film biological processes to clean wastewater to achieve similar quality effluent to larger municipal systems that are designed today by leading engineering firms. Therefore, care must be given priority when operation and maintenance duties are scheduled.

Whenever water enters the system, that same quantity passes through the system and exits. When flow restriction at the effluent pipe or final filter creates a flow equalization effect, water level will fluctuate on its own, naturally.

The system can also be set up on a timed or flow-proportional basis if there is a pump tank that follows or is part of the septic tank. To determine the pump dose follow the steps below to size the dose rate of septic tank effluent into the SMART-Treat™ MBBR tank.

Determine the minimum liquid capacity of the feed pump tank or chamber.

For small flows of 1500 gallons per day or less of domestic household waste, typical operation would NOT require a feed pump tank. Rather gravity flow through the entire system should provide adequate treatment. For larger domestic waste systems or for commercial / light industrial applications and especially for erratic flow situations, a feed pump tank is required.

1. When a feed pump tank (sometimes referred to as surge tank or equalization tank) is located between the primary settling tank and the aerobic reactor tank, that tank volume should be at a minimum at least 12 % of the forward flow, or about 50 % of the primary settling zone (septic tank). The volume should equal the sum of the volumes required for the emergency cut off level + single dose volume + surge volume. The two-thirds/one-third rule applies here again for a two-compartment septic tank, where the second compartment is used as the feed pump tank.

    The minimum liquid volume of the feed pump tank or chamber is equal to 0.12 times the design wastewater flow.

    Minimum liquid capacity of feed pump tank or chamber = 0.12 x DWF

2. Determine the gallons per inch of the tank or chamber selected for feed pump tank or chamber.

    The gallons per inch of the tank or chamber equals the tank or chamber capacity divided by the liquid depth.

    Gallons per inch of tank or chamber = capacity in gallons ÷ liquid depth in inches

3. Determine the elevation of the low-level emergency pump cut off.

    The elevation of the low-level emergency pump cut off is the minimum required liquid level above base of pump as specified by the pump manufacturer.

4. Determine the volume of a single dose.

    The volume of a single dose is determined by multiplying the 2/3 of the DWF by the feed rate, then dividing by the number of doses per day. Number of doses per day must between 24 and 48.

    A. For non-recirculating systems (when denitrification or extra treatment is NOT required), single dose volume is calculated as DWF ÷ number of doses per day (24-48).

    B. When there is internal recirculation built into the system for denitrification or for extra treatment, single dose volume = 2/3 DWF x recirculation rate ÷ number of doses per day (24-48)

5. Determine the surge capacity of the feed or pump tank.

    The minimum surge capacity is determined by calculating the volume of the feed tank.

    Surge capacity = DWF x 0.12 (or other figure if feed tank is larger than 0.12 x DWF)

Determine the amount of biofilm carrier elements (media) and air volume needed for a given organic load and treatment level (effluent quality desired).

Use Table 4b to determine the volume of media to add to the reactor or reactor stages. The selection of appropriate media volume is based on population equivalents for domestic septic tank effluent. The table is based on 0.72 pounds BOD_5 applied to each 1000 ft^2 of media surface area (3.5 grams BOD_5 applied to each square meter of surface area). This loading rate assumes nitrification is needed to about 80 % reduction of ammonia. If BOD_5 removal only is needed, with no need for nitrification or denitrification, then divide the volume of media by 2, or use Table 4a to determine the amount of media needed. **Apply the media multiplier if using media different than K-1. For Biowater Technology BWT-X media, use a 0.76 multiplier.**

Use column 3 of Table 5b to determine the air requirements for treatment of the particular waste load based on lbs BOD loading. Again, the table is based on 0.72 pounds BOD_5 applied to each 1000 ft^2 of media surface area (3.5 grams BOD_5 applied to each square meter of surface area). This loading rate assumes nitrification is needed to about 80 % reduction of ammonia. If BOD_5 removal only is needed, with no need for nitrification or denitrification, there may be higher dissolved oxygen than needed. However, before air volume reduction is contemplated, contact EHS to discuss whether mixing will be affected if air rates are lowered. Recommendation is to allow higher dissolved oxygen and provide air rate listed in table.

It is standard practice to match air rate to peak flow / organic load. Therefore, use the airflow rate column **(Column 3 of Table 5b),** which shows maximum air rate at maximum flow, unless wastewater flow is 100 % equalized.

Determine the Design of the Air Distribution Headers in Aerobic Reactor Tank. Note that BOD reduction only (Table 5a) requires less air than BOD reduction + nitrification.

Note: Use Maximum Air volume requirements on Tables 5a or 5b. *It is standard practice to match air rate to peak flow / organic load. Therefore, use the airflow rate column* ***(Column 3 of Table 5a or 5b),*** *which shows maximum air rate at maximum flow, unless wastewater flow is 100 % equalized*

To design an air distribution header, estimate about 1 CFM per hole, 4 mm hole size, minimum. Calculate number of holes, geometry of aeration reactor, and build air header with lateral spacing and hole spacing to evenly distribute required air throughout entire tank bottom. Table 5-C, Airflow through an Orifice table, was placed into the component manual for information purposes. The standard airflow pattern for small flows should be equally distributed over the entire tank bottom. Standard air distribution header pipe size is 1.5 or 2 inch diameter Schedule 40 PVC, laid out in a rectangular fashion, with cross-pipes at 12 -15 inches intervals, and 12-15 inches between holes. Holes are to be drilled in the bottom of the pipe. Extreme care should be taken to debur the holes made in the PVC pipe. Hole number should be about equal to CFM delivered, sizing holes for about 1 CFM per hole. Note that biomass growth or inert material buildup around each air hole will partially close the opening in these low flow reactors. To accommodate for this phenomenon, oversize holes by about 1.5 times the air flow needed per hole. For example, Table 5c shows that the airflow opening of 1/8 and 3/16 inch at a water depth of 20 inches will allow almost 1 CFM and a bit over 2 CFM, respectively. If 1 CFM per hole is the goal and there will be partial closure around the opening by biofilm, a hole size between 1/8 and 3/16-inch hole size (5/32") is theoretically correct, assuming partial closure. Coincidentally, 5/32" is almost the same as 4 mm hole size. System developers early on discovered that biomass growth and inorganic deposits partially restrict aeration capacity, so 4 mm (5/32 ") openings MINIMUM are required for SMART-Treat™ system design.

Example:

For a 45-inch water depth tank, use 5/32nd inch hole size at 6-15 inch air hole spacing to provide about 1 CFM maximum airflow per foot of air distribution header. Maximum distance between air distribution headers is 15 inches, with a range from 8 inches to 15 inches between headers. If 79 CFM of air is specified, determine the number of holes & length of header needed. In this case, since tank dimensions differ from tank manufacturer to tank manufacturer, it is best if the system designer finds the appropriate tanks and then dimensions the air headers to distribute uniform air equally over the entire area of the tank to be aerated. An example is provided of a design that would work with a particular tank dimension.
Tank Dimension: 150 " L x 60" W

79 CFM ÷ 1.0 CFM/ FT = 79 Ft Header Length

Header Dimension: Since this tank is almost three times long as it is wide, configure 1 rectangular header, ten feet long and four feet wide, with cross-members (shown in worksheet section) each 15 inches on center. This would equate to 9 laterals, each 4 feet long or about 36 lateral feet of distributor length.

Use 2-inch schedule 40 PVC pipe, with 5/32nd inch holes about 6 inches apart on the bottom of the header. On a header with two longer rectangular sides and 9 cross-members, there would be (8) 5/32nd inch holes per cross-member, for a total of 72 holes for the header. This would accomplish the minimum 1.0 CFM per foot air distribution requirement, with holes equally spaced around the length and width of each header. This header dimension should adequately cover the tank bottom, with room on the sides for concrete block hold-down weights.

Step D. Sizing of the Biological Solids Separation Clarifier. Use Table 6a or 6 b to determine the MINIMUM sizing of the clarification tank, dependent on whether the flow is not equalized at all, or is partially or fully equalized. The biological solids separation/clarification tank should have a sufficient sludge removal system, consisting of a central location for pump placement. The pump could be either the airlift variety (Contact EHS for Geyser Airlift pumps) or a mechanical pump. Solids removal from the settling zone should be on an intermittent flow (typical Geyser Pump action) or a timed basis. If on a timed basis, solids should be removed between 1 and 4 times per day. Solids should be pumped to a septic tank upstream of the biological aeration tank or other dedicated tank where solids are typically and routinely removed from the treatment system. (For extremely long extended aeration hybrid treatment plants, solids can be returned to the SMART-Treat™ MBBR tank, with a three-month interval for solids removal, or when solids levels are 18 inches or high in the clarifier, whichever is the longer timeframe).

V. CONSTRUCTION

Procedures used in construction of the SMART-Treat™ MBBR system are just as critical as the design of the component. Good design with poor construction results in component failure.

A. Critical issues are the ability to routinely remove accumulated biological solids from the clarifier bottom before they deteriorate to the point of adversely affecting the effluent quality. Therefore, a sloped tank that accumulates solids in a central location is preferred in larger systems (above 12,000 gpd) but not necessary. Flat bottom clarifiers may be successful for most any flow if designed properly. Tank manufacturers may be able to provide forms that can provide a slope from horizontal, so that tanks can be manufactured to that specification. Special sloped sections can be manufactured separately and inserted in the tanks, or for larger installations, concrete tanks can be poured in place with the proper dimensions for gravity settling/solids accumulation applications. BE SURE TO INSTALL ANTI-SYPHON VACUUM BREAKS DOWNSTREAM OF PUMPS THAT PUMP WASTE BIOSOLIDS/ WATER TO A LOWER LEVEL SUCH AS AWET WELL, SEPTIC, OR EQ/TIMED DOSE TANK. **(See App D for biosolids filter for <13 pe apps)**

B. Lay out the location and size of the pretreatment tank(s), SMART-Treat™ MBBR aerobic reactor tank and final settling tank.

C. BE SURE TO INSTALL CHECK VALVES DOWNSTREAM OF PUMPS THAT PUMP INFLUENT WATER TO THE SMART-TREAT AEROBIC REACTOR TANKAGE.

D. Determine where the biological solids return (pressure) pipe will be located relative to the clarifier. In denitrification designs this pipe will also act as the recirculation flow. Determine where the line will come off the clarifier and will connect to the septic tank or primary settling tank. For simple solids removal 1-2 times per day from the biological solids separation clarifier the line need only be 1 to 1 ¼ inch diameter. For denitrification applications where up to 200% of forward flow needs to be recirclated on a continuous basis, the size of the return line pipe is determined from the sizing requirements specified in this manual **and industry standard sizing methods for force or pressure mains.**

E. Excavate and install the necessary tanks at the proper elevations and locations. With the proper liquid flow and pumping equipment installed, the tanks can be placed at various elevations in the landscape. Tanks can be placed fully above the ground surface, on the ground surface, or partially or fully covered with soil. Maximum depth of soil cover is dependent on the tank manufacturer specification. In colder climates it is often easiest and most appropriate to bury tanks completely underground. However, for larger sized installations, to protect from excess heat loss, partially buried or totally exposed tanks above ground must be protected with enclosures adequate to maintain 40 degrees F, minimum temperature at all times to prevent freezing and lower wastewater temperature that will reduce biological metabolism and reduce treatment efficiency. Deep cylindrical tanks within a heated, enclosed building that is engineered for a high-moisture atmosphere is one suggestion for weather protection. Note that the deeper the tank, the greater the oxygen transfer efficiency for biological treatment.

   Standard engineering practices should be used during the construction phase. It is imperative that surface and ground water not be allowed to enter the tanks. When excavation is required for tank placement, a minimum clearance of 6" should be allowed around the perimeter of each tank. The top of the tanks must be above the seasonal high water table so groundwater does not flow into them.

When the excavation around the tanks is backfilled, it is done with backfill material that is placed in one-foot increments and compacted by use of water or tamping prior to additional backfill material being placed.

Install the valve boxes, distribution boxes, cleanouts, main air distribution piping, and recirculation piping in accordance with standard industry practices.

D. Install the air distribution system. Work with the tank top off of the tank until all piping is in place. From the main air distribution pipe from the blower, install tees or crosses (and air volume control valves, if specified) as needed to the point where piping enters tank. (Pre-arrange with tank manufacturer to provide airline holes where needed in top of tank. ALWAYS HAVE EXHAUST AIR PORTS OR VENTS ON THE SMART-TREAT AEROBIC REACTOR TANK). Install the air distribution header components, including the support blocks, perforated distribution laterals, and feed piping. Each header will have a vertical pipe element that will project through the side of the manhole. Air header distribution assemblies may be prefabricated and supplied by an off-site vendor, or can be fabricated on-site. The air distribution headers should be engineered to accommodate maximum tank bottom surface area coverage. Hole number and size for air distribution should be planned based on air required per aeration tank. See prior example for hole size & number, based on required air volume and tank area required for aeration. M<u>inimum hole diameter should be 5/32nds inch</u>. Typical air header distribution assemblies consist of 1"- 2" diameter schedule 40 PVC, with drill holes of 5/32 inch diameter at 12-15 "centers along the length of the header laterals–(all drill shavings and burrs to be removed prior to final assembly & gluing). Secure to lateral headers with tie-downs to the support blocks under the air distribution system. Install top of tank, leave access ports open.

[For systems of < 150 pe, the air distribution system may be fabricated on-site of typical PVC materials of the size plumbers usually use for these size wastewater treatment systems. (For larger flows and loads, the air piping systems should be engineered and potentially fabricated off-site or brought in as prefabricated, pre- assembled components).]

The aeration blower should be in an adequately vented enclosure, so that cool ambient air comes into the enclosure near the bottom, with vents near the top of the enclosure so that adequate convective currents allow air warmed by the blower motors cooling fan to escape, keeping the blower running relatively cool. Blower should be placed in the enclosure to take maximum advantage of vent ports. Blower intake air should be filtered, with the filter preferably outside the blower enclosure. Test the system for leaks and water tightness. Adjust as necessary.

E. Install the specified amount of biofilm carrier elements (media) in each reactor stage. Remember to adjust for media volume with correction factor if using carrier elements other than the K-1 model. Media requirements are usually based on achieving nitrified effluent, so Table 4b would typically be used to select media volume needed. Typical installation once tank is tested for leaks is to simply insert media into tank with air also coming into tank for mixing. Media is shipped in boxes or a bag, so pouring media into the tank from the shipping containers is the most economical. TEMPORARLY CLOSE OFF OR COVER THE OPEN TOP OF THE STRAINER SIEVES TO AVOID GETTING MEDIA ON THE INSIDE OF THE STRAINER. WHEN FINISHED INSTALLING THE MEDIA, REMOVE COVER FROM TOP OF STRAINER. [If multi-stage aerobic reactor, typical ratio of media addition is the same ratio as the reactor stage volume. Example: Volume of a 2-compartment tank is 600 gallons in compartment 1 and 400 gallons in compartment 2, and 10 cubic feet of media is supplied. To achieve the proper amount of media per stage (unless otherwise specified) add 6 cubic feet to compartment 1, and 4 cubic feet to compartment 2.]

VI. OPERATION, MAINTENANCE AND PERFORMANCE MONITORING

A. The component owner is responsible for the operation and maintenance of the system. The county, department or POWTS service contractor may make periodic inspections of the components, and effluent levels, etc.

The owner or owner's agent is required to submit appropriate records routinely to the county or other appropriate jurisdiction and/or the department.

B. Design approval and site inspections before, during, and after the construction are accomplished by the county or other appropriate jurisdictions in accordance to Ch. Comm 83 of the Wis. Adm. Code.

C. Other routine and preventative maintenance aspects are:

1. The treated water effluent filter is to be inspected and maintained at least every six months.
2. The grease interceptor tank (commercial/light industrial applications) should be pumped and maintained on a routine schedule according to need. The septic and biological solids clarifier tanks are to be inspected and maintained at least every two to three years, or more often as need dictates. If the scum and sludge occupies 1/3 of the tanks' volume, the tank shall be pumped and its contents properly disposed of.
3. An inspection of the SMART-Treat™ MBBR component performance is required at least every six months for the life of the treatment system by a properly trained and certified POWTS system maintainer. Inspection of the blower will also continue at six-month intervals each time the blower filter is changed. These routine inspections by the contracted system maintainer will also include checking the liquid and solids levels in the tanks, checking air distribution system for proper pressure and operation, checking drainfield observation pipes and examination of other system component such as pumps, for proper operation.
4. The pump frequency and run time are to be checked at least every six months.
5. A good water conservation plan within the house or establishment will help assure that the SMART-Treat™ MBBR system will not be overloaded.

D. User's Manual: A user's O & M manual is to accompany the SMART-Treat™ MBBR filter component. The manual is to contain the following as a minimum:

1. Diagrams of all system components and their location.

2. Specifications for electrical and mechanical components.
3. Names and phone numbers of local health authority, component manufacturer or management entity to be contacted in the event of a failure.
4. Information on the periodic maintenance of the SMART-Treat™ MBBR system, including electrical and mechanical components.

E. Performance monitoring must be performed on SMART-Treat™ MBBR system components installed under this manual.

1. The frequency of monitoring must be conducted by a properly trained and certified POWTS maintainer under contract with the system owner:
    a. At least once every six months after installation for the entire life of the treatment system, and
    b. At times of problem, complaint, or failure.

F. The minimum criteria addressed in performance monitoring of the SMART-Treat™ MBBR system components are:

1. Type of use.
2. Age of system.
3. Nuisance factors, such as odors or user complaints.
4. Mechanical malfunction within the component including problems with valves or other mechanical or plumbing components.
5. Material fatigues or failure, including durability or corrosion as related to construction or structural design.
6. Neglect or improper use, such as overloading the design rate, poor maintenance of landscaped cover, inappropriate cover over the SMART-Treat™ MBBR system component, or inappropriate activity over the SMART-Treat™ MBBR component.
7. Installation problems such as improper materials or location.
8. Pretreatment component maintenance, including pumping frequency, structural integrity, groundwater intrusion or improper sizing.
9. Blower and pump maintenance, including improper maintenance, infiltration, structural problems, or improper sizing.
10. Blower or pump malfunctions including dosing volume problems, pressurization problems, breakdown, burnout, or cycling problems.

G. Reports are to be submitted in accordance to Ch. Comm. 83, Wis. Adm. Code.

VII. REFERENCES

IAWQ (1997): Newsletter No. 7, IAWQ Specialist Group on DESIGN AND OPERATION OF SMALL WASTEWATER TREATMENT PLANTS. Nov., IAWQ. London, UK.

Neu, K. E. and Rusten (1997) On-site wastewater treatment with Kaldnes Moving Bed Biofilm Reactor. Environmental/Health Products & Service. P O Box 21, Richfield, WI. USA.

Neu, K. E. and Rusten, B.: (1999) Down to Size. Technical paper Published January 1999 in the technical journal publication: Water, Environment & Technology. Water Environment Federation, Alexandria, VA.

Neu, K. E. (2000) Operation & Maintenance Manual for On-site wastewater treatment using the Small Flow Moving Bed Biofilm Reactor.

Odegaard, H. and Helness, H. (1998) Floating filters for particle removal in wastewater treatment. Proceedings from WEC/EWPCA/IWEM Specialty Conference. INNOVATION 2000. Cambridge, UK. July 7-10.

Odegaard, H., Rusten, B., and Siljudalen, J. (1998) The development of the Moving Bed Biofilm process—From idea to commercial product. Proceedings from WEC/EWPCA/IWEM Specialty Conference. INNOVATION 2000. Cambridge, UK. July 7-10.

Rusten, B., Kolkinn, O., and Odegaard, H. (1994): Moving bed biofilm reactors and chemical precipitation for high-efficiency treatment of wastewater from small communities. Proceedings from WEFTEC '94. Chicago, IL. Oct. 17. Paper # AC 94 1305.

Rusten, B., Hem L., and Odegaard, H. (1995a): Nitrogen removal from dilute wastewater in cold climates using moving bed biofilm reactors. Water Environment Research, Vol 67, No. 1. pp. 65-74.

Rusten, B., Hem L., and Odegaard, H. (1995a): Nitrification of municipal wastewater in moving bed biofilm reactors. Water Environment Research, Vol 67, No. 1. pp. 75-86.

Rusten B. and Neu, K. E. (1998) Moving Bed Biofilm Reactors (MBBR) move into the Small Flows treatment Arena. Proceedings from WEFTEC '98. Orlando, FL. Oct. 3-7.

Neu, K.E. (2009) Small Flow High Strength Waste Gets "Super-Charged" Treatment with Good Results. A Case Study of the SMART Treat™ moving media aerobic reactor. Presented: NOWRA Tech Convention-MKE, WI, 4/09, & WEFTEC, Orlando Fl 10/2009

Neu, K.E., Marcolini, L., Rusten, B. (2012). Industrial Pretreatment When There is Trouble Downstream. A Case Study Using Complete Mix Fixed Film Biological Treatment. Presented at the Central States-WEA Annual Conference. St. Charles, IL. 5/12, Wisconsin Wastewater Operators Assoc. Annual Conference, Green Bay, WI, 10/12.

VIII. WORKSHEET

SMART-Treat™ MOVING BED BIOFILM REACTOR SYSTEM WORKSHEET

Installation specifications

Occupancy – Residential - ____.

- Public Facility - ___.

DWF – Residential – _____ # of bedrooms x 150 gal/day = ________ gal/day

Public Facility – Estimated daily wastewater flow x 1.5 = _______ gal/day

FOG value of influent - _____mg/L

BOD_5 value of influent - _____mg/L

TSS value of influent - _____mg/L

Nitrification system design: ___ Yes ___ No

One or Two-family Dwelling, Multiple Home, Cluster or Subdivision Development.

PE based on Table 3 = _____PE

Commercial Facility (Commercial facility with or without living units).

System is sized based on the calculated PE value determined by DWF or pounds of BOD/day, which ever is higher, of the wastewater discharged into the MBBR system.

PE (based on DWF) = 1.5 x Sum of each wastewater flow per source per day ÷ 75 gal/day/PE

= __________ gal/day ÷ 75 gal/day/PE

=___________PE

THIS FORMULA FOR DETERMINING PE FOR PUBLIC FACILITIES SHOWS ALL OF THE CONVERSIONS USED.

PE (based on pounds of BOD/day) = mg/L BOD x 2.204623^{-6} lb/mg x 3.785412 L/gal x DWF (gal/day) ÷ 0.154 pounds BOD_5/day/PE

= _________ mg/L x 2.204623^{-6} lb/mg x 3.785412 L/gal x _____ gal/day ÷ 0.154 pounds/day

= ______ PE

THIS IS ANOTHER FORMULA *FOR DETERMINING PE FOR PUBLIC FACILITIES. IT CALCULATES THE BOD_5 IN POUNDS PER DAY, THEN THE TOTAL POUNDS OF BOD_5 IS DIVIDED BY THE BOD_5 THAT ONEPERSON GENERATES PER DAY, TO GIVE A POPULATION EQUIVALENT BASED ON TOTAL BOD_5. IT IS BASED ON USING BOD_5 CONCENTRATION IN MILLIGRAMS PER LITER, THE DESIGN WASTEWATER FLOW (DWF) IN MILLIONS GALLONS*

PER DAY, A CONSTANT OF 8.34 POUNDS WEIGHT OF WATER PER GALLON, AND 0.154 pounds BOD_5/day/PE.

PE (based on mg/L for BOD_5 = ______ mg/L BOD_5 x DWF (in million gal/day) x 8.34 ÷ 0.154 pounds of BOD_5/day/PE

= _____ mg/L x ________ x 8.34 ÷ 0.154

= _________ PE

Minimum requirements: Septic Tank, Septic tank solids separation compartment & Grease Interceptor
Use standard practice sizing for site; use Table 2 of this manual to assure minimum sizing requirements are met.

Septic tank size______________________
Mfg.__________________________

Grease Interceptor Size________________(commercial/light Industrial)
Mfg__________________________

A. Aerobic reactor tank liquid capacity

Domestic Wastewater Applications:

Aerobic reactor tank liquid capacity is designed to have a minimum of 5.3 hours of hydraulic retention time at average design flow for domestic wastewater. Use Table 4a (BOD reduction only) or 4b (BOD reduction +nitrification) to determine aerobic reactor tank liquid capacity based on population equivalents.

Minimum tank capacity based on Table 4 using PE = _________ gallons

Selected tank size = ________ gallons

Tank manufactured by: ____.

Commercial/Light Industrial Applications

THIS IS CALCULATED EARLIER IN THE WORKSHEET

Determine minimum volume of aerobic reactor tank based on PE.

Aerobic reactor tank size based on Table 4a or 4b using PE =___________gallons

– Tank manufactured by:

____

B. Feed Pump Tank Volume (referred to or functions as surge or equalization tank)

The formula for determining the minimum volume for the feed pump tank is as follows:

Select a pump tank compartment that has liquid volume equal to DWF x 0.12 days. Then check to see if tank is properly sized based on volume for emergency cut off level for pump, volume of a single dose, and volume for surge capacity.

Liquid volume of feed pump tank ≥ DWF x 0.12 days

≥______gpd x 0.12 days

≥______gallons

Tank manufactured by: ______________________________.

C. Average gallons per inch volume of the feed pump tank

Gallons per inch (GPI) = liquid capacity of tank (gallons) ÷ Liquid depth (inches)

= _______ gal ÷ ____ inches

= _______ GPI (gal/in)

D. Elevation of low level emergency pump cut off/alarm

Elevation of cut off/alarm level ≥ distance required by pump manufacturer

≥_____Inches (This information will be used to determine the pump off float setting)

E. Volume of a single dose

NON-RECIRCULATING SYSTEMS: To determine the volume of a single dose to the aerobic reactor, follow the calculations below.

Dose volume = average gallons per inch of dose tank x inches from pump on to pump off.

Volume of a single dose ≥ DWF ÷ #of doses/day

≥ _______ gal/day ÷______doses/day

_______gal/dose

OR

RECIRCULATING SYSTEMS:

Volume of a single dose ≥ DWF x 2/3 x recirculation rate ÷ # of doses/day

≥ _______gal/day x 2/3 x ______÷ _____ doses/day

≥__________gal/dose

Note: # of doses per day must be between 24 and 48.

Determine the elevation distance between the pump on and the pump off levels by using the following formula:

Elevation difference between pump on and pump off level ≥ dose volume ÷ GPI (This information will be used to determine the elevation difference between the pump on and pump off float settings)

Determine the surge capacity of the feed pump tank by using the following formula:

Surge capacity ≥ DWF x 0.12

≥_____gallons x 0.12

≥_____gallons

Determine if the chosen feed pump tank volume is of sufficient size using this formula:

Liquid volume of feed pump tank ≥ (gallons required for elevation level of emergency cut off/alarm level) + (volume of a single dose) + (volume of surge capacity)

≥ (____GPI x ____inches) + (___gal) + (___gal)

≥_____Gallons (If volume is less than that of the chosen tank, then you must change tank size or number of doses. Then recalculate to determine if the change will produce a properly sized feed pump tank).

F. Determine the amount of biofilm carrier elements (media) needed for a given organic load

Use Table 4a or 4b to determine the volume of media to add to the reactor or reactor stages.

For BOD and nitrification, use Table 4b:

___________Population Equivalents = _____________ Cubic feet of media

For BOD removal only, use Table 4a:

___________Population Equivalents = _____________ Cubic feet of media

EHS supplies Biofilm Carrier Element Media for* SMART-Treat™ *MBBR systems. Biowater Technologies BWT-X media is standard & has a volume adjustment factor of 0.76 multiplier, based on having 198 sq ft/cu ft vs. K-1 media at 151 sq ft/cu ft. Nitrogen applications: BWT-15 has 253 sq ft/cu ft, so volume adjustment factor is a 0.6 multiplier.

G. Air Volume Needed

Use column 3 of Table 5a (BOD reduction only) or 5b (BOD reduction + nitrification) to determine the air requirements for treatment of the particular waste load based on lbs BOD loading. *Worksheet reminder: For BOD+ nitrification the volume of air applied is based on 80 % reduction of ammonia-nitrogen and therefore an organic loading rate of 0.72 pounds* BOD_5 *applied to each 1000* ft^2 *of media surface area (3.5 grams* BOD_5 *applied to each square meter of surface area).*

____________Population Equivalents = _________ PEAK CONDITION, CFM Air

H. Design Air Distribution Headers in Aerobic Reactor Tank.

_______CFM ÷ _____CFM/Ft for selected air hole size

=_______Ft of Air Header Length

Since tank dimensions differ from tank manufacturer to tank manufacturer, it is best if the system designer finds the appropriate tanks and then dimensions the air headers to distribute uniform air equally over the entire area of the tank to be aerated. Review the discussion of the example provided in the design section of this manual.

Note: Use Maximum Air volume requirements

Use Airflow through an Orifice table, Table 5-C, to design an air distribution system.

DESIGN ASSISTANCE, AIR BLOWERS AND DISTRIBUTION SYSTEM PIPING IS AVAILABLE FROM EHS OR DESIGNATED DISTRIBUTORS. CONTACT EHS AT: Business Phone: 262-628-1300, E-MAIL: ken-ehs@juno.com

I. Select Biological Solids Separation Clarifier Size

Use Table 6a or 6b to determine the minimum dimensions of the clarifier. Wastewater flow per day is the primary design criteria. Use this dimension for minimum sizing. Equalized flow means that there is enough tankage or a separate tank and pump system to accumulate wastewater and feed it into the aerobic reactor more slowly over a greater time period, than for non-equalized conditions. Non-equalized flow is more often the case in the majority of subsurface discharge applications.

Find Minimum tank volume, depth and overflow rate:
______Design flow, gallons/ day

=______Minimum tank size, from Table 6a, 6b, or 6c

=_____Minimum water depth, feet, from Table 6a, or 6b

=____ Minimum water surface area, square feet, from Table 6a or 6b

Note: EHS can provide tanks for any flow volume. Appendix B shows drawings of some of the available biosolids settling tanks. Contact EHS for all of your biosolids settling tank needs, including design details and price quotes. Effluent filter alternatives are also available from EHS. Inquire about the details with the contact information located in this manual. EHS can also size drainfields and provide proposals for gravel-less trench systems for subsurface disposal.

J. Size effluent distribution and dispersion according to standard industry practice for highly pretreated effluent applications.

IX. EXAMPLE WORKSHEET

MOVING BED BIOFILM REACTOR SYSTEM WORKSHEET

A. Size Pre-treatment Tankage

One or Two-family Dwelling, Multiple Home, Cluster or Subdivision Development.

DWF = 150 gal/bedroom x # of bedrooms

= 150 gal/bedroom x ______# of bedrooms

Assume 1 bedroom per 2 people,

= # of bedrooms x 2

= _______Population Equivalents (PE)

Assume 75 gal / day / PE

=______Number of Population Equivalents x 75 gal/PE/day

= ____________ gal/day

Public Facility.

A golf & supper club is chosen as a real-world design example. Using Table 8 and the specific conditions at the facility (which varies- facility to facility), the flow and organic load were derived. Sizing of the system is done by calculating system flow from Table 8, then calculating organic load to be treated. A sample of the wastewater to be treated aerobically was collected. A conservative approach to design was to estimate that the organic load may actually be higher than the collected sample indicated (in terms of BOD_5), so a correction factor of 122.5 % was used to raise the organic load figure for design purposes.

Restaurant and four 1-bedroom cabins

Design Wastewater Flow (DWF): 4500 g.p.d.
Independent Certified Laboratory Results

Septic Tank Effluent	Sample Collected 10/27/00
Temperature: 50-65 degrees F (10-18 degrees C)	
BOD 600-1200 mg/L	577 mg/l (COD was 1023 mg/L)
706 mg/l or 26.5 pounds/day TBOD	**(Correction Factor of 122.5 % was used)**
pH: 6.0 - 9.0	
Total Fat, Oil & Grease (FOG) < 150mg/L	60 mg/L
Total Suspended Solids 300-500 mg/L	242 mg/L
Total Kjeldahl Nitrogen 40-60 mg/L	104.4 mg/L
Total Phosphorus 8-15 mg/L	16.45 mg/L

Anticipated Effluent Quality - Tank size fitted to accommodate needed increase of biological surface area for increased flow/load (from future cabins), or increased water quality at same flow, but not both conditions.

BOD <25 mg/l (design for 25.6 pounds/ day BOD removal, no ammonia removal)
TSS <30 mg/l

Hydraulic Load Sizing

DWF = 1.5 x Sum of each wastewater flow per source per day

= ____4500_ gal/day

= 4500 gal/day ÷ 75 gal/day/PE

= 60 PE

Organic Load Sizing

26.5 lbs/day BOD_5 ÷ 0.154 lbs BOD/PE/day

= 172 PE*****

*** Use PE factor derived from organic load calculation to size system**

Minimum requirements: Septic Tank & Grease Interceptor
Use standard practice sizing for site; use Table 2 of this manual to assure minimum sizing requirements are met.

Grease Interceptor Size: 2500 gallons (commercial/light Industrial)
Mfg: Neeck Concrete

Septic tank size_____1650 gallon
Mfg.__Neeck Concrete

E. Aerobic reactor tank liquid capacity

Domestic Wastewater Applications:

Aerobic reactor tank liquid capacity is designed to have a minimum of 5.3 hours of hydraulic retention time at average design flow for domestic wastewater. Use Tables 3 & 4 to determine aerobic reactor tank liquid capacity based on population equivalents.

= ____ PE

= _________ gallons (size proportionately, using Table 4a)

Selected tank size = ________ gallons

– Tank manufactured by:

____

Commercial/Light Industrial Applications

Calculate pounds BOD_5 at DWF

706 mg/l BOD_5 x Flow (0.0045 million gal/day) x 8.34

=26.5 # BOD_5/day

26.5 # BOD_5 /day ÷ 0.154 #BOD_5 /PE/d

= 172 PE

Determine minimum volume of aerobic reactor tank based on pe.

Minimum Aerobic reactor tank size = 2880 gallons

Selected tank size = 2x1650 =3300 gallons

– Tank manufactured by:

Neeck Concrete

F. Feed Pump Tank Volume (referred to or functions as surge or equalization tank)

The formula for determining the minimum volume for the feed pump tank is as follows:

Select a pump tank compartment that has liquid volume equal to DWF X 0.12. Then check to see if tank is properly sized based on volume for emergency cut off level for pump, volume of a single dose, and volume for surge capacity.

Minimum liquid volume of feed pump tank ≥DWF x 0.12

≥ 4500 gpd x 0.12 days

≥ 540 gallons

G. Average gallons per inch volume of the feed pump tank

Gallons per inch (GPI) = liquid capacity of tank (gallons) ÷ Liquid depth (inches)

= 540 gal ÷ 48 inches

= 11 GPI (gal/in)

H. Elevation of low level emergency pump cut off/alarm

Elevation of cut off/alarm level ≥ distance required by pump manufacturer

≥ 0.5 inches (This information will be used to determine the pump off float setting)

I. Volume of a single dose

NON-RECIRCULATING SYSTEMS: To determine the volume of a single dose to the aerobic reactor, follow the calculations below.

Dose volume = average gallons per inch of dose tank x inches from pump on to pump off.

Volume of a single dose ≥ DWF ÷ #of doses / day

≥ 4500 gal/day ÷ 24 doses/day

= 188 gal/dose

OR

RECIRCULATING SYSTEMS:

Volume of a single dose ≥ DWF x 2/3 x recirculation rate ÷ # of doses/day

≥ 4500 gal/day x 2/3 x 2 ÷ 24 doses/day

≥ 250 gal/dose

Note: # of doses per day must be between 24 and 48.

J. Average gallons per inch of the dose tank (or 2nd compartment of septic tank)

Gallons per inch = liquid capacity of tank (gallons) ÷ Liquid depth (inches)

= 650 gal ÷ 44 inches

= 15 gal/in.

K. Elevation of low level emergency pump cut off/alarm

Elevation of cut off = distance required by pump manufacturer (inches)

= 0.5 in.

L. Determine the amount of biofilm carrier elements (media) needed for a given organic load

Use Table 4a or 4b to determine the volume of media to add to the reactor or reactor stages.

For BOD and nitrification, use Table 4b:

________Population Equivalents = ______________ cubic feet of media

For BOD removal only, use Table 4a:

172 Population Equivalents = 3.44 cubic meters x 35.34 cubic feet/cubic meter = 121.6 cubic feet of media (3.44 cubic meters) minimum

Supply 4 cubic meters of media, for safe, conservative margin to achieve desired treatment level when cabins are added, and to achieve some degree of nitrification

M. Determine Air Requirements and Design Air Distribution Headers in Reactor Tank.

DESIGN ASSISTANCE, AIR BLOWERS AND DISTRIBUTION SYSTEM PIPING IS AVAILABLE FROM EHS OR DESIGNATED DISTRIBUTORS. CONTACT EHS AT: Business Phone: 262-628-1300, E-MAIL: ken-ehs@juno.com

Determine air (CFM) required from Table 5a, based on tank availability, calculated for 172 pe, with peaking factor of 3.2 x average flow for this commercial application, 4-foot water depth and BOD removal only.

Use 40 pe condition for design line—based on 4 foot water depth--- and calculate air flow proportionately, since typical air requirements from the population equivalent row that would equate to 172 pe (through interpolation) depicts 6 foot water depth and potentially a 2.5 x average wastewater flow peaking factor.

Interpolation factor:

172 pe÷ 40 pe = 4.3 factor

Peak CFM @ 40 pe = 18.4 x 4.3 proportion factor = 79.1 CFM

Design Air Distribution System.

DESIGN ASSISTANCE, AIR BLOWERS AND DISTRIBUTION SYSTEM PIPING IS AVAILABLE FROM EHS OR DESIGNATED DISTRIBUTORS. CONTACT EHS AT: Business Phone: 262-628-1300, E-MAIL: ken-ehs@juno.com

Use Airflow through an Orifice table, Table 5-C, as an informative guide and design an air distribution system based on 5/32nd inch (4 mm) hole diameter, and about 1 CFM per hole.

Example:

_______CFM ÷ _____CFM/Ft for selected air hole size

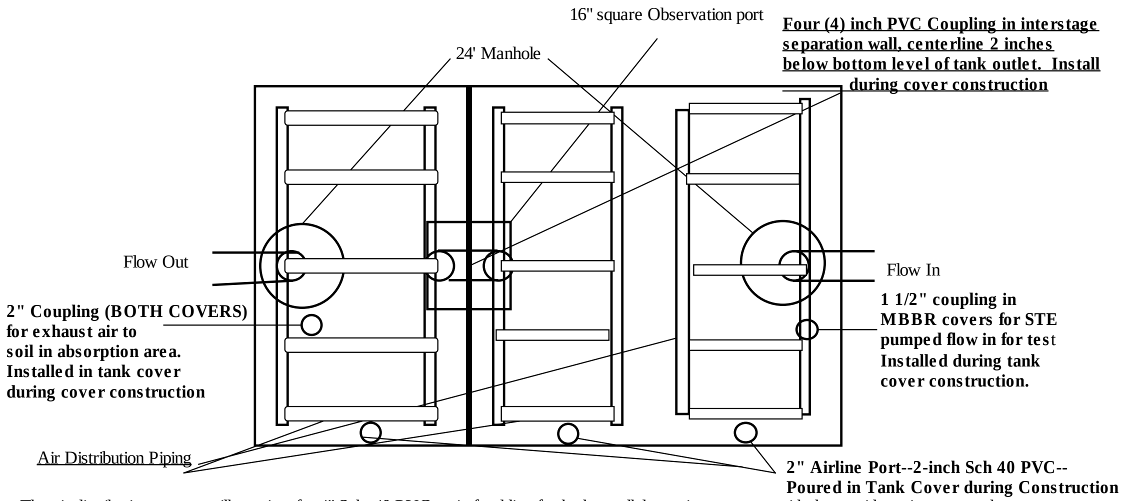
=_______Ft header Lateral Length

Since tank dimensions differ from tank manufacturer to tank manufacturer, it is best if the system designer finds the appropriate tanks and dimensions the air headers to distribute uniform air equally over the entire area of the tank to be aerated.

An example drawing of a SMART-Treat™ MBBR aeration tank is shown here, with a typical air distribution header also shown (top view).

Figure 4. Typical SMART-Treat™ Air Distribution Header Piping

Air Distribution Piping



The air distribution system will consist of a 4" Sch. 40 PVC main feed line for both parallel aeration reactors, with three grid sections per tank. Each grid section is two-inch Sch 40 PVC. Each lateral in Stage 1 is 30" long, & Stage 2 each is 40" long. Each grid section has 3/16" holes in the pipe bottom at 15 inch intervals on the bottom of pipe, spread equally around the grid. Therefore, each grid section has fifteen (15) holes. Each areation reactor then would have 45 air distiution points spread over 3 aeation grids. Alternatively, manufactured air diffusers could be used with similar distribution patterns. Each two-inch air distribution grid will have its own valve for air flow control, accessable from the surface , but located under weather-protective cover where 4" distributors come off of the 4 " main line from the blower. All air distibution piping will be below ground level except for where the pipe comes out of the blower enclosure, and where accessible below grade from the surface for valve adjustment. Grid air holes may become smaller over time with residue accumulations. It is important to monitor air flow and conduct maintenance as required. Equalized air flow over the grid at all times is the goal.

Tank Dimension: 150 " L x 60" W

79 CFM ÷ 1.0 CFM/ FT

= 79 Ft Header Length

Header Dimension: Since this tank is almost three times long as it is wide, use three headers, each with 27 feet (324 inches) of air distributor piping. Alternatively, assemble one header with similar overall lateral header length. If lateral length is longer, space air holes further apart.

The description above details dimensions of air distribution system. The header width should adequately cover one-third of the tank. Provide two identical headers, for a total of three headers to cover most of the entire tank bottom.
==

For higher air flow rates required for nitrification, use the following dimensions and figures:

- Use both aeration tanks, to accommodate needed time for biological nitrification reactions to occur.
- Assume design flow and organic load to both aerobic treatment tanks.

If 120 cfm of air is specified to achieve nitrification at design flow of 4500gpd, determine the number of holes and length of header needed for each aerobic tank. For a 48-inch water depth tank, use 3/16th inch hole size at 12-15 inch air hole spacing to provide about 1.0 CFM maximum airflow per foot of air distribution header.

120 CFM ÷ 1.0 CFM/Ft for selected air hole size

= 120 Ft distribution header length

Therefore, 120 CFM would be distributed to both aeration tanks, equally. Manufacture air distribution system the same for each tank. A second blower will be needed to achieve nitrification of 80% or greater. Before installation construction, assure that distribution piping from blower(s) to each distribution header is adequate to handle the increased air flow for the particular blower selection.

N. Select Biological Solids Separation Clarifier Size

Use Table 6a (Non-Equalized Flow) to determine the minimum dimensions of the clarifier. For sizing of the Biological Solids Separation Clarifier, design w*astewater flow per day is the primary design criteria, not Population Equivalents*. Use the flow criteria for minimum tank sizing.

Find Minimum tank volume, depth and overflow rate:

4500 Design flow, gallons/ day

= 1690 gallons minimum tank size, from Table 6a

= 5' Minimum water depth, feet, from Table 6a*

= 45 Minimum water surface area, square feet, from Table 6a

Select biological solids separation tank.

Tank size:
1000 gallons x 2 units
= 2000 gallons

Tank Mfg: AK Industries

Tank depth, Max
= 60 inches*

* Since 2 parallel aerobic treatment tanks are selected, two (2) clarifiers will follow these tanks each 1000-gallon capacity in a spherical tank, at operating water depth of at least 60 inches. This tank configuration provides over 45 square feet of surface area in one tank. Since the maximum depth is 5 feet, and the overflow rate is well within the Table 6a maximum of 350gal/ft^2/day only one clarifier would be necessary. However, to be conservative, and given the fact that there are two (2) parallel aerobic reactor tanks, it is acceptable to provide the two clarifier tanks in parallel.

Surface area:
45 ft^2 @ 72 inch circumference, each
= 90 ft^2

Over Flow Rate (OFR) @ peak flow:
= 4500 gpd Design flow x 3.2 peaking factor
= 14,400 gallons ÷ 90 ft^2 Clarifier surface area
=160 gpd/ ft^2 OFR

O. Size effluent distribution and dispersion according to standard industry practice for highly pretreated effluent applications.

X. PLAN SUMBITTAL AND INSTALLATION INSPECTION

A. Plan Submittal

In order to install a component correctly, it is important to develop plans that will be used to install the component correctly the first time. The following checklist may be used when preparing plans for review. The checklist is intended to be a general guide. Conformance to the list is not a guarantee of plan approval. Additional information may be needed or requested to address unusual or unique characteristics of a particular project. Contact the reviewing agent for specific plan submittal requirements, which the agency may require that are different than the list included in this manual.

General Submittal Information

- Submittal of additional information requested during plan review or and questions concerning a specific plan must be referenced to the Plan Identification indicator assigned to that plan by the reviewing agency.
- Plans or documents must be permanent copies or originals.

Forms and Fees

- Application form for submittal, provided by reviewing agency along with proper fees set by reviewing agent.
- Onsite verification report signed by the county or appropriate state official, if one is required.

Documentation

- Architects, engineers or designers must sign, seal and date each page of the submittal or provide an index page, which is signed, sealed and dated.
- Master Plumbers must sign, date and include their license number on each page of the submittal or provide an index page, which is signed, sealed and dated.
- Three completed sets of plans and specifications (clear, permanent and legible); submittals must be on paper measuring at least 8-1/2 by 11 inches.

Plot Plan

- Dimensioned plans or plans drawn to scale (scale indicated on plans) with parcel size or all property boundaries clearly marked.

- Slope directions and percent in component area.
- Benchmark and north arrow.
- Setbacks indicated as per appropriate code.
- Location information; legal description of parcel must be noted.
- Location of any nearby existing component or well.

Plan View

- Dimensions for SMART-Treat™ Moving Bed Biofilm Reactor system
- Location of observation, sampling and maintenance ports.
- Pipe layout, pipe material, diameter and length, number, location and function.

Cross Section of Component

- Lateral elevation, dimensions and depths of tanks, location and type of control panel for electrical controls and housing for controls.

Component Sizing

- For one and two-family dwellings, the number of bedrooms must be included.
- For public facilities, the sizing calculations must be included.

Tank and Pump Information

- All construction details for site-constructed tanks.
- Size and manufacturer information for prefabricated tanks.
- Notation of pump or siphon model, pump or blower performance curve, friction loss and calculation for total dynamic head.
- Cross section of tanks/ chambers to include storage volumes; connections for piping, vents, and electricity; pump “off” setting; dosing cycle and volume (if applicable); and location of vent and manhole.
- Cross section of two compartments tanks or tanks installed in a series must include information listed above.

Other

- For design flows greater than 1000 gpd, include the manufacturer, model, and location of a metering device, which accurately meters the amount of effluent entering the component.

B. Inspections.

Inspection shall be made in accordance with ch. 145.20, Wis. Stats and s. Comm 83.26, Wis. Adm. Code. The inspection form on the following pages may be used. The inspection of the component installation and/or plans is to verify that the component at least conforms to specifications listed in Tables 1-6 of this manual.

GENERAL INFORMATION		MBBR INFORMATION
Permit Holders Name:	County:	MBBR outside dimensions:
VRP Elevation:	Sanitary Permit Number:	Number of Stages:
VRP Description:	Plan ID Number:	Vol of Media/Surf Area:
Inspector Name & License #:	Parcel Tax Number:	Force main length:
Dates Inspected:		Force main diameter:

CONTRACTOR INFORMATION	
Plumber Name:	Phone #:
Electrician Name:	Phone #:
Excavator Name:	Phone #:

ELEVATION DATA				
STATION	**BS**	**HI**	**FS**	**ELEV**
VRP:				
STE:				
STPB:				
MBBRT:				
SetTk:				
SetTk PB: DB:				
Drainfield Elevation:				

SMART-Treat™ TANK INFORMATION	
Manufacturer: Tank Capacity:	Gallons/inch
Capacity of First Compartment:	
Capacity of Second Compartment:	

SEPTIC TANK VAULT	
Inside height:	Inches
*Alarm/timer override:	Inches
*Timer off:	Inches
*Red. Off/low level alarm:	Inches
Force main Diameter:	Inches
Force main Length:	Feet
* Measured from bottom of tank cover.	

BLOWER & PUMP INFORMATION		
	BLOWER (S)	**PUMP (S)**
Manufacturer: Model Number:		
Blower CFM:		
Friction Loss:		
Pump Head:		
As-Built TDH:		
System Demand:		

OPERATIONAL REVIEW		
STPB floats tested	Yes	No
SetTkPB floats tested	Yes	No
SetTk solids pump operate OK	Yes	No
As-built TDH below pump curve	Yes	No
Septic tank tested for water tightness	Yes	No
Owner issued operational manual	Yes	No
Blower Filter clean/maintained		
Programmable timer settings	On	Off

ADMINISTRATIVE REVIEW		
Revision to plans required	Yes	No
Construction directive issued	Yes	No
Construction order issued	Yes	No
Date of directive		
Directive deadline		
Enforcement order date		
Enforcement order deadline		
Date compliance issued		

MBBRT – SMART-Treat™ MBBR tank
SetTk – Settling Tank
DB – Distribution Box (treated effluent)
SetTkPB – Settling Tank Pump Base
STE – Septic Tank Effluent
STPB – Septic Tank Pump Basin
VRP- Vertical Reference Point

DEVIATIONS FROM APPROVED PLANS:

APPENDIX A

Preliminary BUDGET Pricing – (3 Examples) Domestic & Commercial Sizing

General Preliminary Budget Price Range Estimates for the SMART-Treat™ MBBR Portion of Small Flow Private Onsite Wastewater Treatment Systems

It is impossible to provide reasonably accurate cost estimates within this component manual for the entire job for any location due to labor rate differences, site requirements, etc, etc. However, a table can be developed which can be used as a rough estimate of a portion of the system cost, based upon size of treatment system, effluent requirements, (nitrification versus non-nitrification, equalized flow versus regular, non-equalized flow, etc.) While this type of estimate can be very broad it terms of preliminary budget pricing, it is by no means a firm system quote for any application. Caution is advised when using the following table, in that appropriate follow-up for detailed pricing estimates and quotes should be conducted on a job-by-job basis. Contact EHS with any sizing questions.

SMART-Treat™ MBBR Uninstalled Component ---Est.	**Population Equivalents**				
Equipment Retail Price Range, per Pop Equiv.	12	50	100	250	1000
(Units are $ per person or Population Equivalent, 2002)					
Low Estimate, BOD+Nitrification, Unequalized Flow	$ 390*	$ 356*	$ 220**	$ 175**	$ 102**
High Estimate, BOD+Nitrification, Unequalized Flow	$ 679*	$ 399*	$ 350**	$ 341**	$ 205**
Low Estimate, BOD Removal Only, Equalized Flow	$ 331*	$ 268*	$ 145**	$ 97**	$ 54**
High Estimate, BOD Removal Only, Equalized Flow	$ 578*	$ 300*	$ 228**	$ 187**	$ 103**

***Includes** Septic Tank in the first compartment as an integral part of the aeration reactor configuration.
However, for commercial applications, it does not include a grease trap tank in this estimate.
****Does NOT include** primary treatment (septic tank, grease trap) in any pricing estimate

<u>Domestic & Commercial/Light Industrial Sizing & Preliminary BUDGET Pricing. *Examples-ONLY*</u>
All examples EXCLUDE all risers, manhole covers, connection piping, al installation & electrical hook-up labor, all excavation, incl. all time & materials or subcontractors for soil absorption system (gravel less, stone & pipe, or mound). Soil Absorption Area <u>Downsizing Credit</u> can be taken for highly pretreated effluent.

Example 1: **Single family 4 bedroom home (150 gallons /bedroom = 600 gpd) with pressurized effluent, BOD removal only (Size for 10 population equivalents = conservative estimate)**
Equipment listed (from Sizing Tables) and approx. retail price for total items listed:

Item	Minimum Size
<u>Septic Tank / Aerobic Treatment Tank</u> Std 2-compartment tank, 2nd compartment modified for aeration tank	500 gallon / 200 gallon
SMART-Treat™ <u>Moving Bed Biofilm Reactor Equipment:</u> Aeration piping / media screen Blower Plastic Media-Biofilm Carrier Elements	8.5 CFM required, sized for 10 CFM, air header with ten 3/16 inch holes 8 cubic feet of media
<u>Integrated Electrical Control Panel:</u> Controls 1 Blower (for Aerobic reactor) & 2 Pumps (1-solids removal pump & 1-effluent pump)	W/ high water alarm, blower & pumps
<u>Settling Tank / Pump Tank</u>	400 gallon / 500 gallon
Total Prelim Budget Price (tanks $2100, SMART-Treat™ Equipment $2395)	**$ 4,495**

Example 2: **Apartment, multi-family dwelling cluster, or motel equivalent to wastewater of 60 people, 75 gallons/person/day = 4500 gpd, equalized flow) with pressurized effluent, BOD rem only.**
Equipment listed (from Sizing Tables) and approx. retail price for total items listed:

Item	Minimum Size
<u>Septic Tank / Aerobic Treatment Tank</u> Std 2-compartment tank, 2nd compartment modified for aeration tank	1250 gallon / 500 gallon
SMART-Treat™ <u>Moving Bed Biofilm Reactor Equipment:</u> Aeration piping / media screen Blower Plastic Media-Biofilm Carrier Elements	30 CFM blower, w/ rect. air header, w/ thirty 3/16 in. holes , 4" effluent strainer 43 cubic feet media
<u>Integrated Electrical Control Panel:</u> Controls 1 Blower (for Aerobic reactor) & 2 Pumps (1-solids removal pump & 1-effluent pump)	W/ high water alarm, blower & pumps
<u>Settling Tank / Pump Tank</u>	800gallon / 500 gallon
Total Preliminary Budget Price (tanks $6490, SMART-Treat™ equipment $ 10,775)	**$ 17,265**

Example 3: **Commercial Wastewater (Restaurant on lakeshore-American cuisine, plus five 2-bedroom cabins) equivalent to 250 Population Equivalents, (State of Wisconsin requires 50% add'l Scale-Up Factor = 375 PE) with pressurized effluent, BOD reduction + nitrification.**
Equipment listed (from Sizing Tables) and approx. retail price for total items listed:

Item	Minimum Size
Grease Interceptor Tank	6000 gallon
<u>Septic Tank / Aerobic Treatment Tank</u> Std 2-compartment tank, 2nd compartment modified for aeration tank	4000 gallon ST 6275 gal aeration reactor tank
SMART-Treat™ <u>Moving Bed Biofilm Reactor Equipment:</u> Aeration piping / media screen Blower Plastic Media-Biofilm Carrier Elements	102 CFM blower, w/ air headers built to evenly distribute air 531 cubic feet of media media strainer(s)
<u>Integrated Electrical Control Panel:</u> Controls 1 Blower (for Aerobic reactor) & 2 Pumps (1-solids removal pump & 1-effluent pump)	w/ high water alarm, blower & pumps
<u>Settling Tank / Pump Tank</u>	6500 / 1000 gallon
Total Preliminary Budget Price (tanks $18,250, SMequip $29,640)	**$47,890**

Fixed Film Microbe Surface Area: Biological Surface Area Comparison

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. 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 # BOD_5/d/ 1000 sq ft surface area=19,209 sq ft biological surface area is needed.

Table 1. Volumetric Stationary vs. Moving Media Comparison, High Strength Waste example.

	Media Density Sq ft/ cu ft	Media, Cu Ft needed (bulk density)	Equiv. media gallon volume	Equiv. gallon volume at 66% tank fill w/ media	Treatment volume w/ biosolids settling volume
Stationary Media	30.5	648.3	4850	7348 gal	11,000 gal
SMART-Treat, Biofilm Carrier Elements **I.e.: "Media"**	Kaldnes K-1 151	127.2	952	1442 gal	3,000 gal
	BioWater X 198	97	728	1102 gal	2250 gal
	BioWater 15 250	76.8	576	873 gal	2000 gal
Volume ratio difference: Stationary media to Moving Media treatment systems K-1 3.66 : 1; BWT-X 4.9 : 1; BWT-15 5.5 : 1					

Capital & Operating Costs versus Competitors. How do processes and costs compare?

- A 20-year Total Present Worth cost comparison for a 37,000 gallon domestic wastewater application for reduction of standard strength wastewater from a large community septic tank to 30/30 mg/l BOD and TSS was done in early 2009.
- Three (3) fixed film WW treatment alternatives were compared (SMART-Treat—using Kaldnes biofilm carrier elements, Orenco Advantex cloth media and BioMicrobics FAST (static plastic media). The results are listed below, SMART-Treat = smallest footprint.

Total Present Worth	EHS SMART-Treat™	Orenco-Advantex	FAST
Capital Cost	$ 195,200	$ 330,346	$ 314,500
O&M Cost	$ 213,413	$ 202,700	$ 404,900
Total Present Worth	**$ 408,613**	**$533,046**	**$ 613,100**

- Typical difference in capital and O&M costs of **the three main fixed film treatment systems that are available across the US for flows from 10,000 to 500,000 gpd**.

APPENDIX B

Some Examples of Available Products: Biosolids Settling Clarifiers, Equalization Tank, and Airlift Pump

Construction quality drawings may be received by placing a request with EHS. Also, please note that from time to time this information and these drawings may be upgraded and modified to include a broader range of selection. For example, currently only limited information is supplied regarding the 300-gallon and 750 gallon Wisconsin Settling Tanks. As more information and drawings become available for these and other products, it will be added to our file and become available to customers & potential customers.

The biosolids settling clarifiers shown here rely on gravity settling in a relatively small area in the center of the tank and solids removal pumped from a central location. There are no moving parts other than the solids removal pumps. The biosolids accumulate in the bottom center of the clarifier by gravity, either sliding down the angled exterior walls of the clarifier tank or a cone inserted into the center of the clarifier tank. For these cylindrical tanks (usually smaller than 10' diameter), a central pump in a pump vault draws solids from multiple locations within the settling tank.

For clarifiers and rectangular or square flat-bottomed biosolids settling chambers starting at about 10 feet in diameter, tanks can be imported to the job site in one piece, but most likely be built on-site. Usually, clarifiers of this type are flatter-bottomed, with mechanical solids cleaning from a relatively flat or slightly sloping tank. For new construction or retrofits of flat-bottom rectangular or square tanks, non-corrosive corner fillets could be inserted into the tank corners to reduce areas that might accumulate stagnant settled solids.

Mechanical removal systems are available from EHS for all clarifier sizes. Please contact EHS for requests regarding biosolids settling tank sizing and price quotations for all applications.

Wisconsin Settling Tanks Available

Tank sizes:

- **300 gallon**
- **750 gallon**
- **1000 gallon**

Bioprocess Cone Clarifier

Tank Sizes Available:

- 8' Diameter, 2000 gallon
- 10' Diameter, 3000 gallon

(The 10' unit may not be available due to shipping restrictions)

Equalization Tank System

Supplied by: EHS   Pump Options:
Geyser Airlift Pumps
Electro-Mechanical Pumps on timers
(Various pump and electrical control manufacturers)

Geyser Airlift Pump

Supplier: EHS
Pump sizes: 1" to 12"
Flow ranges from 3000 gal/day to 600,000 gal/day

APPENDIX C

SMART-Treat™ Moving Media Denitrification Design

Definition of Influent Flow Characteristics

As stated in the body of the component manual, and repeated in this appendix, typical domestic septic tank effluent has the characteristics listed in Table A. (While there is some variation in wastewater character from household to household, between communities and between commercial establishments (restaurants, for example) average range values are used here for design purposes to cover the majority of cases. For individual site design for facilities that might be out of these ranges, laboratory analysis may be in order to define influent characteristics to provide design data to enable an appropriate engineered treatment facility design to achieve treated effluent goals.

Table A.– Domestic Wastewater: Septic Tank Effluent – Defined (for the purpose of this component manual)

	Flow, Gallons/ person/day	**Total BOD_5**	**Total Suspended Solids**	**Total Nitrogen Ammonia, Organic N**	**Total Phosphorus**	**pH**
Typical Domestic SepticTank Effluent	75 gallon/day 282 liters/day	200-300 mg/l Ave=247 mg/l (~ .154 #/PE/d 70 gm/d/PE)	100-300mg/l Ave= 200mg/l	40-80mg/l Ave=60 mg/l	6-12 mg/l Ave= 9 mg/l	6.0 – 9.0 Ave = 7 standard units
Typical Restaurant SepticTank Effluent	Variable, See Table 8, of manual	700-1300 mg/l Av = 1000 mg/l	300-700mg/l Ave=500 mg/l	60-120 mg/l Ave 90 mg/l	6-16 mg/l Ave= 11 mg/l	5-10 Ave=7 Standard units

Special Note: For Domestic applications, SMART-Treat™ MBBR design for septic tank effluent is based on a conservative figure of 70 grams per day of BOD_5 versus 60 grams BOD_5 which is the typical BOD_5 generated by an average adult per day. For commercial applications, historical published data for independent studies, and historical laboratory analysis of existing SMART-Treat™ wastewater treatment plants has provided sufficient data to confidently design treatment facilities in these wastewater character ranges. Individual site characteristics may vary, and if suspected to vary outside of design ranges, individual site sampling and analysis may be warranted to more accurately define influent wastewater character.

Note: Detailed plans and specifications must be developed and submitted for review and approval by the governing unit having authority over the plan for the installation. Also a Sanitary Permit must be obtained from the department or governmental unit having jurisdiction. See Section X for more details.

Table 1 (reprinted from main body of manual) **INFLUENT FLOWS AND LOADS-Domestic Wastewater** **ANTICIPATED EFFLUENT QUALITY**	
SMART-Treat™ MBBR aerobic reactor Tank Based on population equivalent sizing of domestic septic tank effluent wastewater	
Design wastewater flow (DWF) from primary treatment tanks	Range: 375 gal/day to 100,000 gal/day (See component manual tables)
Monthly average value of Fat, Oil and Grease (FOG)	≤ 100 mg/L
Monthly average value of five day Biochemical Oxygen Demand (BOD_5)	≤ 247 mg/L
Monthly average value of Total Suspended Solids (TSS)	≤ 200 mg/L
Monthly average value of Total Nitrogen (TN)	≤ 60 mg/L
Design wastewater flow (DWF) from one and two-family dwellings	≤ 150 gal/day/bedroom, or 75 gpd/ person
Design wastewater flow (DWF) from public facilities (Use sizing chart to equate all design calculations back to population equivalents)	≥ 150% of estimated wastewater flow in accordance with Table 4 of this manual or s. Comm. 83.43 (6), Wis. Adm. Code
Forward flow	= Design wastewater flow (DWF)
Anticipated Effluent Quality, Domestic Wastewater Equivalent	BOD <30 mg/l, TSS < 30 mg/l, N Reduction, +80 % reduction of ammonia-nitrogen Total Nitrogen Reduction of 50-65 %, when designed to remove Nitrogen

Denitrification Design

The SMART-Treat™ MBBR treatment system is fully capable of partial denitrification, even when designed for BOD and ammonia removal. However, to achieve consistent nitrogen removal, a few simple modifications to the existing component manual design will assure nitrogen removal to desired levels. The extent of modifications, of course, depends on influent loading characteristics, and desired effluent quality.

There are several modifications that will be presented in this appendix that will assist the designer in achievement of nitrogen removal. The modifications will be listed in order of simplest to more complex, depending on site need.

SMART-Treat™ Design Discussion

Typically, the SMART-Treat™ moving media small flow design consists of a once-through or single pass flow mode. The two designs listed in the 2002 version of the manual were for BOD removal only or BOD and ammonia removal. For most applications (domestic & commercial), a small quiescent zone is listed in a separate table for residual bioslids settling and removal, pumped back to the septic tank 1-4 times per day on a timer-activated basis. The only solids removal for the system would be the typical interval of septic tank pumping. THE AEROBIC TREATMENT ZONE NEED NEVER BE PUMPED DOWN, AS IN COMPETATIVE MODELS.

Using these design tables, nitrogen removal could be achieved with slight modifications, such as:

Nitrogen removal for domestic applications:

--flows below 5000 gpd,

Continuous or intermittent biosolids settling zone recirculation to an upstream anoxic/anaerobic zone, the septic tank, or, with periodic burst aeration (to control solids deposition), to a surge flow/equalization tank. For example, the simplest denitrification method for a 5 bedroom home domestic wastewater flow (750 gpd) without flow equalization is to design for nitrification, install a 2-compartment SMART-Treat™ tank with minimum 300 gallon settling zone, provide appropriate biofilm carrier elements and air flow to the SMART-Treat™ aerobic reactor. Install a 1” Geyser airlift pump at the bottom of the settling zone. The use of a 1” Geyser Airlift pump with adjustable flow from 500 gpd to 3000 gpd could provide a wide range of recycle rates, dependent on influent flow volume. Allow enough air with an installed needle valve to the Geyser pump from the blower air supply (<1CFM) to recirculate about three (3) times the design flow (2250 gpd) to the septic tank. Doing so will get nitrate-rich water to the anoxic zone for nitrogen removal AND will direct any residual settled solids to the septic tank for ultimate disposal. Only one mechanical component—the blower—which is serviced semi-annually under a maintenance contract provided by EHS. Typical nitrogen removal with this scenario may be in the range of 50 to 70 % reduction provided carbon and nitrogen are in the listed typical ranges for domestic septic tank effluent.

Additional steps can be taken in the design and equipment selection process, and activated in the event additional nitrogen removal is needed, or to enhance nitrogen removal.

--the SMART-Treat™ blower could be equipped with a timer that would provide adequate non-oxygenated time in the SMART-Treat™ aerobic reactor for nitrate reduction in the reactor itself.
Water recirculation flow from the biosolids settler to the septic tank would be interrupted, but the effect on the treatment process would be enhanced due to lack of oxygen, and the geyser pump in the biosolids settler would resume pumping without priming upon the resumption of airflow to the pump.

--if intermittent biosolids recirculation is desired (versus continuous recirculation, a separate solenoid valve could be installed on the air flow from the aeration blower to the Geyser pump, with timered activation of the solenoid valve, which would direct air to the Geyser pump at selected intervals.

--this same intermittent recirculation flow could be achieved using a conventional electro-magnetic sump pump installed in the biosolids clarifier, activated by a timed ON/OFF control circuit.

For both of the above options, denitrification could be controlled and adjusted dependent on the volume of water pumped and the proportionate amount of time that the water is pumped back to the septic tank or EQ/surge tank.

Typically, 200-500% of forward water flow over a 24-hour period would be an appropriate recirculation rate. The electromechanical pump would cycle typically 1-3 times per hour, running for no more than 2-3 minutes per run cycle. The airlift pump may run for longer periods since its rate of pumping is lower than an electric sump pump. However, the Geyser airlift pump moves water at a small fraction of the energy cost, compared to conventional electrical submersible pumps

---Domestic wastewater flows above 5000 gpd, up to about 100,000 gpd

It is recommended that a separate denitrification zone be created, be it a separate tank or a compartment of the SMART-Treat aerobic reactor tank. This zone is typically sized about 50 % of the volume used for the BOD & ammonia-nitrogen conversion SMART-Treat™ aerobic reactor. Biofilm carrier element (media) fill level is 40-50 % of that volume. The media provides surface area for microbes favorable to nitrate conversion to useable oxygen and nitrogen gas. To agitate the media, a slow speed mixer may be placed into the tank. A preferred alternative to a mixer is to increase the DN reactor size by 5-10 % and use forceful coarse aeration for mixing only. A typical on/off sequence would be for example 3 to 5 sec of forceful aeration every 10 minutes. This air could be taken from the aerobic reactors using a reliable solenoid valve on a timer control. Using the aeration blower for DN stage mixing would eliminate a maintenance item-the slow speed mixer. This concept is probably the simplest, and will be most accepted, so typically periodic airbursts are used to both mix and move the water in the denitrification stage.

It is recommended that the treated nitrate-rich water from the aerobic reactor (rather than Clarifier contents) be recycled to the denitrification zone. Therefore, the appropriate-sized Geyser airlift pump could be set in a screened area of the SMART-Treat™ aerobic reactor, and recycle water directly from the aerobic reactor to the denitrification zone. Doing this will keep the biosolids settling zone sizing as it is in the existing component manual, rather than having to adjust settling zone volume to handle large recycle flows.

In that regard, it is recommended that flow surge equalization be designed, typically with at least 24-hour forward flow capacity. If the internal denitrification recycle is kept within the SMART-Treat™ anoxic/aerobic reactor tankage, then designs for denitrification for all flows can use existing BOD+ nitrification design tables. Note that for flows under 5000 gpd there is ample volume in the aerobic reactor and the clarifier to accommodate recycle flow to the septic tank of up to 300% of forward flow, but over 5000 gpd, flow equalization and separate denitrification tankage is required to achieve target nitrogen removal of 50-65 %.

To summarize, for nitrogen removal systems larger than 5000 gpd:

- A separate denitrification zone should be created, be it a separate tank or a compartment of the SMART-Treat™ aerobic reactor tank.
- recirculation of 100-300 % of forward flow should be accomplished internal to the SMART-Treat™ reactor, recycling from aerobic to anoxic zones
- An EQ/flow surge tank with periodic burst aeration for solids deposition control should be installed downstream from the septic tank and upstream from the SMART-Treat™ aerobic reactor. With larger water volumes, the design of the SMART-Treat ™tank and particularly the biosolids clarifier tank compartment could be kept at the same economical size as for BOD/ ammonia removal.
- To enhance denitrification further (say, beyond 65 % nitrogen removal) a means to recycle micro-organisms periodically from the biosolids clarifier to the EQ/surge tank would provide extra biomass to boost denitrification and drive down any excess oxygen before the denitrification stage.

Ideally, to properly size the denitrification stage in larger flow reactors, wastewater characteristics should be defined in each case. However, to simplify design, assumptions can be made that denitrification will occur to at least 50% nitrogen reduction when wastewater influent going into the anoxic/aerobic reactor is within the specified ranges, and the design modifications listed in this Appendix on denitrification are followed.

Carbon to nitrogen ratio is one of the key ingredients to successful achievement of nitrogen removal.

The appendix tables show domestic wastewater C:N to be about 4.2 : 1 and typical restaurant wastewater to be 11.1 : 1. These values are in the low and high range of where denitrification occurs. If the above guidelines are generally followed, nitrogen removal in the range of 50-65 % should occur. The C:N ratio should periodically be defined using approved laboratory analysis methods. Be aware that if desired results are not achieved, activation of enhancements mentioned may be in order, including adjustment to the C/N ratio to an acceptable range to achieve nitrogen removal goals.

For situations beyond the scope of the above operating parameters more advanced design work needs to be done. Adjustments to denitrification zone size are included here in a table format, where the size of the anoxic reactor is increased or decreased based on influent C/N ratios. The following table shows suggested increase in total amount of biofilm carriers in order to achieve denitrification and removal of total nitrogen, compared to a plant designed for BOD-removal + nitrification. For example, if the standard design table shows the amount of biofilm carriers for BOD-removal + nitrification to be 100 ft^3 for a domestic plant, this must be increased by 75 % (75 ft^3) to achieve 60-65 % removal of total N and necessary recirculation will be 200 % of influent flow.

Appendix C, Table 1

Suggested increase in the total amount of biofilm carriers in order to achieve denitrification and removal of total nitrogen.

Wastewater	Total N removal, %	Recirculation, * %	Increase in total amount of biofilm carriers (compared to design for BOD-removal + nitrification)
Typical domestic wastewater	~ 50	100	+ 50 %
	60 – 65	200	+ 75 %
	65 – 70	300	+ 100 %
	70 – 75	400	+ 125 %
Typical restaurant wastewater	~ 60	100	+ 30 %
	~ 75	200	+ 40 %
	~ 80	300	+ 50 %

* May be lower with intermittent aeration and simultaneous nitrification/denitrification in main reactor for domestic WW < 5000 gpd.

Appendix C, Table 2, Denitrificaion Summary Table

The designer must assume that the Carbon to Nitrogen ratio is above 4.1:1. If unsure, confirm that it is or is not if the **SMART-Treat™** system achieving < 50% TN removal

X = recommended for initial design. Other options may be applied if needed.

	Recirc from clar to ST at least 100% of forward flow, incr recirc up to 300 % if not achieving goal	**Design with Surge Flow Equalization tank, Recomm. Capacity = design forward flow volume**	**Cycle aeration blower ON and OFF to create low DO in reactor, to enhance DN**	**Design with separate anoxic zone upstream of Aerobic SMART-Treat™. Recirc from aerobic to anoxic 100-300 %**
Domestic WW Below 5000 gpd	**X**		**X** -start with 30 min ON, 30 min OFF, adjust to attain goal	
Domestic WW Above 5000 gpd		**X**		**X**
Commercial WW (1000 BOD) Below 5000 gpd	**X**	**X**		
Commercial WW (1000 BOD) Above 5000 gpd		**X**	**X**	**X**
Special Situations (may include):				
C?N ratio known to be inadequate		**X**	**X**	**X**
Greater than 65% TN removal required w/ marginal C/N ratio		**X**	**X**	**X**

Appendix D

EHS SMART-Treat MBBR Moving Media On-site aerobic treatment

Bio-Solids Separation with a SMART-Treat™ Bio-Solids Filter

In the main SMART-Treat MBBR Component Manual (ver 2, 2007, and version 3, 2012) there are sections on simple upgrading and rejuvenation / renovation of treatment systems with the SMART-Treat system and for new constriction design, that refer to substitution of the biosolids settling zone with a SMART-Treat Bio-Solids Filter.

This option is appropriate for domestic applications for up to 12 population equivalents, and would eliminate the need for a separate tank or compartment for biosolids settling zone. A maintenance contract is recommended by EHS and the State of Wisconsin for all advanced treatment systems, to ensure proper operation.

Biological Solids Separation.

Another option as a substitute for the biosolids settling zone (clarifier) in domestic applications up to 12 pe is biosolids reduction with a SMART-Treat™ Bio-Solids Filter. This filter could be placed at the outlet end of the SMART-Treat aerobic reactor, but more typically just down stream from the outlet end of the aerobic reactor in the surrounding earth. The filter components are composed of a Catch Basin or filter housing with removable module or bucket strainer filled with the same or similar media as the media moving inside of the aerobic reactor. It is about 12 inches in diameter. When placed at the outlet end of a SMART-Treat moving media reactor, the filter module is acceptable from the tank manhole. The Catch Basin ore external housing is part of the flow path, downstream from aerobic treatment tank, upstream of the drainfield or pump tank to soil dispersion, when the filter is located outside of the aerobic treatment tank.

This catch basin has a REMOVABLE basket. The use 1-2 cubic feet of the same media as in the aerobic treatment zone will act as a filter for biosolids. The fill level of filter media is the same for 3-6 bedrooms—simply fill the strainer basket or filter internal module to 1-2 inches from the top with K-1, BWT-X (or similar) media. The media acts to trap loose biosolids carried over from the aerobic treatment reactor. Cleaned on a regular six- to 18 month interval with a maintenance contract from a qualified provider, this device may serve as a substitute for the recommended settling zone for treatment systems up to 12 population equivalents.

The biosolids filter option would reduce cost of the entire treatment system. However, as with any filter system that is not self-cleaning, this filter would need to be cleaned on a regular basis, at least each 6 months. A service maintenance contract is required.

Cleaning consists of removal of the basket or module containing the plastic media, rinsing of the media (while in the basket strainer) by gentle agitation of the strainer and media in a 5-gallon bucket, to allow the accumulated solids to become loose from the plastic media. The use of a garden hose to accelerate the biomass loosening process is recommended. Once the biomass is loosened, removal of the basket strainer from the 5-gallon bucket will allow the loosened biomass to pass out of the basket strainer filter module through 1/8 inch holes, while the cleaned media remains in the basket strainer. Depending on the amount of material loosened, the rinsing process may need to be repeated. Disposal of the loosened biomass is a simple matter of placing it into the existing septic tank or trash tank.

Once the media is cleaned of biomass, the bucket strainer is simply re-inserted into the catch basin. The cleaning process is estimated to take less than 5-10 minutes. During this short cleaning process, there should not be a significant loss of unfiltered water to the drain field or pump tank.

The SMART-Treat media filter is a good substitute solids separation technique for domestic applications (new or existing) where space for construction is limited, such as small lots, lake lots, existing systems that need retrofitting with aerobic treatment, etc. Routine maintenance is a key ingredient to the successful operation of any treatment system. The SMART-Treat media filter is no exception.

SMART-Treat Media Filters may be purchased from EHS.

Appendix E

Biowater Technologies BWT-X & BWT-15 Carrier Element Specifications are included on the following pages

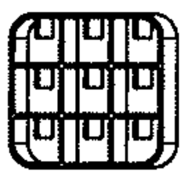
BioWater™ Biofilm carrier

Product Name: BWTX™

Prepared by:	TA	Approved by: TA	Trade mark registration
Rev.no:	001	Date: 04.03.2009	

Application: The BWT X™ biofilm carrier element is used in biological treatment processes for both water- and wastewater treatment plants.

Design: The BWT X™ elements consists of 9 cells and have the following dimensions;



Width/height	:	15mm
Length	:	8.5mm (tol.±0,5mm)
Perimeter outside	:	56 mm
Perimeter inside	:	197 mm
Tolerances according to	:	DIN 16941/3
Wall thicknesses	:	0, 3 (Tol.±0,1mm)

Material:

Polyethylene, high density (HDPE).

Colour: Natural

The raw material has a specific weight of 0, 96 (± 0, 02) kg/l, while the material after extruding has a specific weight of about 0, 95 (± 0, 02) kg/l.
Add-Max® 104 is added to the material to improve stabilization for the extruding process.

The biofilm carrier elements are produced from a material and with a procedure that ensures that the material will have a long aging time giving a proper operation for its service life, provided :

- stored and packed as from the producer
- applied in the reactors according to normal procedures

The shape of the Bio Media might be in some cases uneven, this has no negative effect and the total surface area guaranteed.

Main data:

The weight of the BWT X™ is	:	125 kg/m³ (in bulk, at production)
Efficient surface:	:	5,0 m^2/kg
Content of a big bag	:	Dependent on the preferred bag size
Protected surface area pr. M^3	:	628m^2

Quality assurance: The producer is instructed to take visual inspections/regular tests to control form, Dimensions and density (kg/m³ in bulk), in order to ensure conformity to the specification.

Offered by: Environmental / Health Products & Service Ph: 262-628-1300, ken-ehs@juno.com
PO Box 101, Phillips, WI 54555 PO Box 21, Richfield, WI 53076

BioWater™ Biofilm carrier
HS Code 3904.9000

Product Name: BWT15™

Prepared by:	TA	Approved by: TA	Trade mark registration
Rev.no:	001	Date: 15.09.2008	No 000982566-0002

Application:

The BWT15™ biofilm carrier element is used in biological treatment processes for both water- and wastewater treatment plants.

Design:

The BWT15™ elements consists of 25 cells and have the following dimensions;.

Width/hight	:	15mm(tol.±0,5mm)
Length	:	5mm (tol.±0,5mm)
Perimeter outside	:	56 mm
Perimeter innside	:	258,6 mm
Tolerances according to	:	DIN 16941/3
Wall thicknesses	:	0,3 (Tol.±0,1mm)

Material:

Polyethylene, high density (HDPE).
Colour: Natural

The raw material has a specific weight of 0,96 (± 0,02) kg/l, while the material after extruding has a specific weight of about 0,95 (± 0,02) kg/l.

Add-Max® 104 is added to the material to improve stabilization for the extruding process.

The biofilm carrier elements are produced from a material and with a procedure that ensures that the material will have a long aging time giving a proper operation for its service life, provided :

- stored and packed as from the producer
- applied in the reactors according to normal procedures

The shape of the biomedia might be in some cases uneven, this does not effect the total surface area guaranteed.

Main data:

The weight of the BWT15™ is	:	166 kg/m³ (in bulk, at production)
Efficient surface:	:	4,97 m^2/kg
Content of a big bag	:	Dependent on the preferred bag size
Protected surface area pr. Bag	:	828 $m^2 m^3$ (Randomly packed)

Quality assurance

The producer is instructed to take visual inspections/regular tests to control form, dimensions and density (kg/m³ in bulk), in order to ensure conformity to the specification.