AST® High Profile PolyGeyser® (HPPG)

Description & Technical Details

BEAD FILTER SOLUTIONS astfilters.com

Ronald F. Malone Ph.D., P.E.

&

Rhine Perrin, P.E.

AST™
BEAD FILTER SOLUTIONS

2120 North 3rd Street | Baton Rouge, LA 70802
Phone: 504.837.5575
Toll Free: 800.939.3659
Fax: 504.837.5585
www. ASTFILTERS.com

Research and Development Department of AST®

This is not an operation manual. This document is to be used as a description and technical guide. If you have questions on how to operate an HPPG Filter, you can call AST at 1.800.939.3659 or find more instructions on our website at ASTFilters.com.

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Figure 1. A 100 Cubic Foot Fiberglass HPPG filtering runoff from a lumber

High Profile PolyGeyser$^{®}$ (HPPG) Technical Description

The High Profile PolyGeysers$^{®}$ are expandable granular filters that are now primarily used to remove suspended solids for various municipal, industrial, and agriculture wastewater applications. They use a floating plastic media that facilitates the internal recycling of backwash waters which greatly reduces the backwash volume generated when the units are expanded to clean the media. The units are pneumatically washed simplifying the filter's design and operation. They function like sand or gravel filters but are resistant to biofouling which permits their application in organically rich wastewater applications. They can be used for primary, secondary, or tertiary suspended solids removal.

Figure 2. Low density spherical beads

The fiberglass HPPG filter line is generally operated as pressurized units driven by centrifugal pumps (Figure 1). Fiberglass models range in media capacity from 5 to 100 cubic feet supporting flow ranges from 5-1500 gpm. The standard units are designed to operate at lower pressures (<20 psi), however custom units can be designed to support hull pressures above 40 psi for specialized applications. The fiberglass units are typically packed with spherical media (Figure 2) when used for solids removal. Enhanced Nitrification Media (EN) is used whenever the units are deployed as “Bioclarifiers” simultaneously acting as a physical and biological filter. EN media is also used whenever low-head or airlift operation is desired.

The stainless steel HPPG units are larger units ranging in size from 60 to 600 cubic feet, supporting flows in the 900-9,000 gpm range. These units are fabricated out of 304 or 316 stainless steel and current design options include rectangular or cylindrical vessel shapes. The stainless steel HPPG units can be configured with an open top for low-pressure (<5psi) or gravity-fed operations. Rectangular units such as the one shown in Figure 3 are typically used for these low-pressure systems. When higher pressures are demanded, a closed, pressurized unit is necessary and these units may be fabricated with a cylindrical hull to withstand the higher operating pressure.

High Profile PolyGeysers® are particularly robust solids capture devices capable of operating anywhere in a treatment train, and few other filters are as versatile. They can be used to function as a “roughing” filter to bring the suspended solids from 3,000-4,000 mg/L down to a few hundred mg/L, as is often seen in food processing. They can replace a primary or secondary clarifier in a traditional municipal treatment sequence, and they are equally well suited to polish effluents of fine solids in a tertiary position.

All PolyGeyser® models contain a "charge chamber" that underlies the floating bead bed (Figure 4). This compartment is used to accumulate air over several hours. The air input rate into the charge chamber is set to control the time required to fill the chamber. When filled, an internal "trigger" suddenly and completely releases the air content of the charge chamber and the bubbles pass through the bed abrading the bead surfaces and releasing captured solids. The sudden release of air causes the beads to initially "drop" as the air evacuates the charge chamber and causes the dirty water to replace the void in the charge chamber. The floating bead bed is almost immediately reformed as the unit refills by the incoming wastewater inflow, resuming the filtration cycle. Over the next (typically several) hours the charge chamber acts as a clarifier dropping the solids down to the sludge storage area. The air trickling into the charge chamber for the next backwash slowly displaces the now clarified backwash waters up through the bead bed where it is filtered as it co-mixes with the wastewater influent flow. The sludge accumulates

Figure 3. Illustration of a 200 cubic foot under construction. This model has a coned bottom to assist in the removal of sand and grit.

throughout these backwashes forming a concentrated sludge that can be periodically discharged by opening a valve at the bottom of the filter. The ability to internally recycle backwash waters reduces waste flow generation by as high of a factor of one hundred over similarly sized gravel or sand filters.

The elimination of water loss associated with backwashing is a key element of this new technology. In most applications, dozens of backwash sequences can be automatically executed before sludge removal is required. There is no water loss associated with the backwash process itself and the water loss associated with sludge drainage is minimal. The pneumatic strategy breaks the linkage between backwash frequency and water loss while allowing the solids capture capacity of the unit to be fully utilized. Frequent backwash sequences have proven advantageous by maintaining hydraulic conductivity while avoiding biofouling.

Fine solids removal improves with solids accumulation and/or biofilm development in the bead bed, so HPPGs used to remove suspended solids have backwash intervals set to avoid loss of particles' hydraulic conductivity and the associated back pressure buildup. Typical backwash intervals can range from once per hour to once per day.

Sludge accumulates in the bottom of the unit over multiple backflushes. Periodically, sludge is purged from the units by simply opening a ball valve at the bottom of the unit. The advanced stainless-steel models are designed to pneumatically lift and discharge sludges without electronic or manual intervention. Pneumatic sludge discharge is powered by the same air pump driving the backwashes and is accomplished without any moving parts which minimizes the potential for failure.

In typical wastewater, upwards of 50% of the organics are particulate. The removal of these particulates can immediately reduce the water’s BOD5 by 40-50%. The organic-rich tend to overload or biofoul many biofilter formats. Engineers traditionally tend to first remove particulate matter, then conduct biofiltration to attack soluble organics, and finally target ammonia by the process of nitrification. So, it is not surprising to see HPPGs used as clarifiers in front of a variety of biofilter formats. Also, in many applications, HPPGs are used to clean up biosolids behind the biofilter.

The HPPG is a direct challenger to various clarifiers and filtration devices. The selection of an HPPG is usually dictated by secondary considerations (Table 1). In comparison to settling basins, the HPPG has 1/40th of a footprint and superior suspended solids capture. A bead filter's performance is relatively insensitive to flow variation and self-cleaning. Its biggest advantage over microscreens is its intrinsic simplicity (no moving parts) which translates into reduced upkeep and in some applications its superior fine solids capture profile proves valuable. In practice, modern sand filters tend to use a finer media (typically 0.1-1.0 mm) and can show better fine solids removal but suffer from high backwash water production. Since the pneumatically washed HPPG line recycles its own backwash water, it dramatically reduces the backwash water discharge issues seen with sand filters. Sand filters are also woefully sensitive to organic loading which precludes their application in many wastewater applications where PolyGeysers® thrive.

The HPPG series provides a format that can process relatively strong wastewaters as roughing filters. Whereas a single-pass HPPG is limited by oxygen to a soluble Biochemical Oxygen Demand (SBOD5) reduction of the order of 5-10 mg/L, the industrial HPPG can be configured to achieve particulate plus soluble BOD (BOD5) reduction on the order of 500-1000 mg/L. They reduce high concentration levels to levels acceptable for discharge to community treatment systems without surcharges. It can also be used to polish the effluent from a lagoon or treatment system to acceptable levels for direct discharge to sensitive receiving systems. They typically do this by simultaneously removing suspended solids, biodegrading dissolved organics (the SBOD5), and nitrifying in a granular fixed film format using recirculation on an adjacent tank to increase the oxygen supply. The unit provides relatively precise control on mean cell residence time which becomes critical when the wastes targeted include more refractory organic wastes

Table 1. Typical HPPG Advantages over other common clarifiers and filtration devices

	Low water loss	Low upkeep	Finer solids capture	Size	Low Hydraulic Sensitivity	Biofouling Resistance	Low Head loss
Settling basin	X	X	X	X	X		
Micro-screen1)	X	X	X				
Sand Filter	X	X				X	X

1)40-60 micron screens

that can be generated from oil and gasoline, hormones, explosives residuals, and a variety of industrial waste streams.

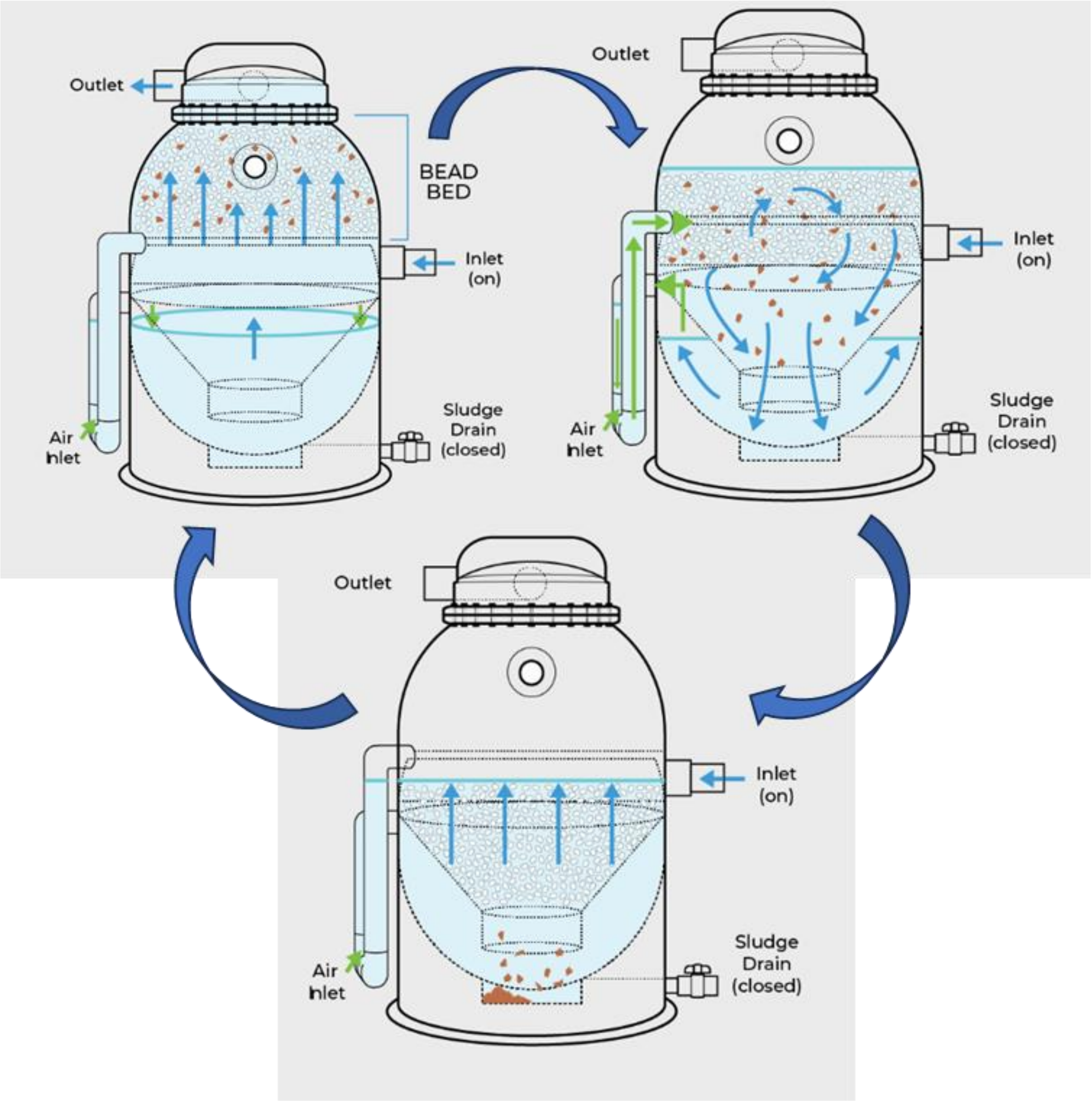

Figure 4. HPPG Backwash and Sludge Storage

HPPG Background

The family of PolyGeysers® is uniquely designed to accommodate low-head operation as they function concurrently as a suspended solids filter and a biofilter. This is facilitated by an internal charge chamber that implements a pneumatic backwash and then concentrates the sludge produced as it recycles the dirty backwash waters. The charge chamber is driven by a small secondary air pump that continually fills the charge chamber at a slow rate. When the chamber fills the trigger assembly suddenly releases the air (in about 6 seconds). This causes the floating bead filtration bed to drop away from the outlet screen and churns the beads so captured suspended solids and excess biofilm are released from the beads. The water pump is never turned off, so it quickly refills the internal filter chambers. The beads float back up to reform the bed while the dirty water is trapped in the charge chamber. The solids accumulate creating sludge which can be removed later.

This backwash strategy was specifically developed to optimize the harvesting of biofilm so the fixed film biofiltration processes could be optimized. The backwash process breaks the linkage between backwash frequency and water loss allowing high-frequency washing to be used to reduce the impact of particulate and soluble organics on a sensitive process such as fixed film nitrification. Inherently an excellent suspended solids filtration device, the granular static low-density media (SLDM) bed is also capable of biofiltration, allowing these units to act as bioclarifiers and simplifying the sequence used to treat water.

The term PolyGeyser® describes a process more than a physical configuration. The original PolyGeyser® (PG) was designed to support koi ponds and small-scale fish tank operations. The fiberglass Low Profile PolyGeysers® (LPPG) are designed low to the ground to facilitate airlift water circulation with a fish tank, typically under five feet tall. Our most popular HPPG line is designed to support larger scale operation and is available in bead bed sizes of 5-100 ft^3 fiberglass and currently up to 300 ft^3 in stainless steel. The Recirculating PolyGeyser® (RCPG) line, all stainless steel, are the heavy lifters ranging in size from 50-500 ft^3. They are equipped with an internal reservoir and a large airlift that assures oxygen delivery for concentration wastewater applications. There is also the 3-liter Nano 8000 designed to support racks of research fishes and amphibian tanks in biomedical laboratories. Finally, the aquaponic favorite, the plastic Endurance PolyGeyser® is equipped with a sludge digestion compartment and pneumatic sludge discharge. The units vary in shape, size, and material; but what they share is a bead bed, a charge chamber, and a trigger. Although shaped differently, our filters have almost identical functions.

Frequent backwashing has proven advantageous for optimizing the nitrification capacity of PolyGeyser® filters. Numerous gentle scrubbing cycles promote a higher rate of nitrification by maintaining a healthy thin biofilm on the surface of the bead media. Typical backwash cycles occur every 3-6 hours. The performance of these HPPG units is further enhanced by using "Enhanced Nitrification" (EN) media that protects the slow-growing bacteria during a backwash event (Figure 7). These beads also increase the bed's porosity, lowering head loss so energy-saving airlifts can be used to recirculate the water when applied to agricultural projects. The result is a compact and energy-efficient treatment approach.

Figure 5. Enhanced Nitrification Bead shaped to protect biofilms during backwashing.

Filter Media

Granular floating bead filters remove suspended solids by the same physical mechanisms as sand filters. Physical straining of particles occurs whenever the suspended particle is larger than the opening the water is passing through. This is the principal removal mechanism of microscreens. This can be a significant mechanism for the largest particles >1000 microns (such as biofloc) but is generally considered problematic in granular filtration since it can lead to premature clogging of the filtration bed's surface. For most granular filter applications, the principal removal mechanism is microscale settling: the density difference between the fluid (water typically) and the suspended particulates causes the particle to fall vertically downward out of the flow path, striking or settling on the top side of the bead. This mechanism is most effective on the larger particles (>50 microns). With midrange particles, interception is the dominant mechanism. Here the particle deviates from the flow path in a bend where the particle's density causes it to swing to the inside or outside of the flow path striking the bead surface, typically on the forefront or downward-facing side of the bead. The small particles (<10 microns) tend to be removed by the molecular level turbulence (diffusion) that simply strikes the bead surface (adsorption) or becomes trapped in a biofilm (absorption). The capture of these finest solids is enhanced by biofilm development.

Table 2. Major factors influencing the rate of suspended solids removal in a granular filter (after Yao, 1971)

Characteristic	**Typical units**	**Comments**
Media grain size	mm	Fixed by design
Flux rate	gpm/ft2; ft/s	Principal operational control variable
Bed depth	Feet, meters	Fixed by design
Granular bed porosity	percent	Fixed by media selection
Density of water	g/cm^3	Can be impacted by salinity and temperature
Density of particles	g/cm^3	
Diameter of particles	microns	

Yao et al. 1971 describes the factors (Table 2) that impact the ability of a granular filter to capture suspended solids. His equations were adapted specifically for floating bead filters and extended to turbidity (Louque, 2019). These equations can be used to project removal efficiency for suspended solids removal. Studies were conducted to examine the removal effectiveness of standard (2-3 mm) spherical beads (Ahmed,1996), and these results were expanded by a USDA SBIR Innovative research grant (Drennan, 2013) that examined the removal for 18 beads of different shapes and sizes.

Figure 6 illustrates test results for the 20–50-micron cohort in column studies that used a three-foot bed depth and a variety of beads across a range of flux rates. The results show that most beads tested effectively remove almost all the particles above 20 microns. Even the EN media (Bead Sample 6), removed over 90 percent of the particles at a flux rate of 15 gpm/ft^2. Removal improves with the development of a thin biofilm. In comparison, gravity settling tanks are effective for the removal of particles above 100 microns, and broadly applicable microscreens for wastewater applications typically display near 100 percent removal for particles above 40-60 microns. And, as Yao (1971) would predict, sand filters and floating bead filters show comparable removal across a wide variety of conditions.

The ability to remove fine solids is illustrated in Figure 7; this graph shows the ability of various beads to remove the particles falling in the 5-10 micron cohort. These particles are represented by mid-sized algal cells and small bacterial clusters. Here the cohort removal efficiencies drop from near 100% at flux rates of about 2 gpm/ft^2 to near 40% at a high flux rate of 15 gpm/ft^2. Again, biofilm improves the capture rate. In recirculating aquaculture applications, repeated

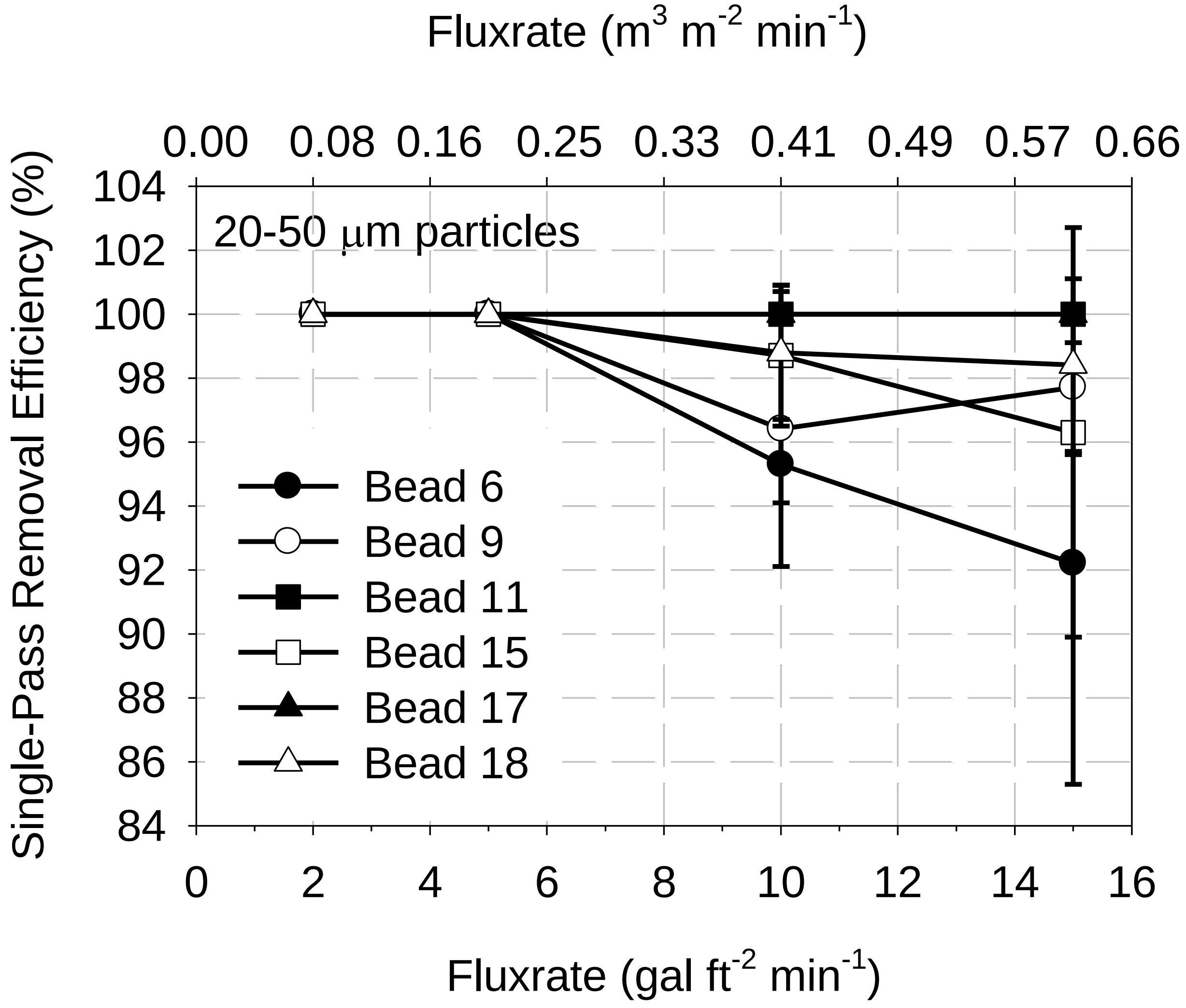

Figure 6. Standard spherical beads (#9) and EN media (#6) display high removals for particles in the 20 to 50-micron cohort (Drennan, 2013).

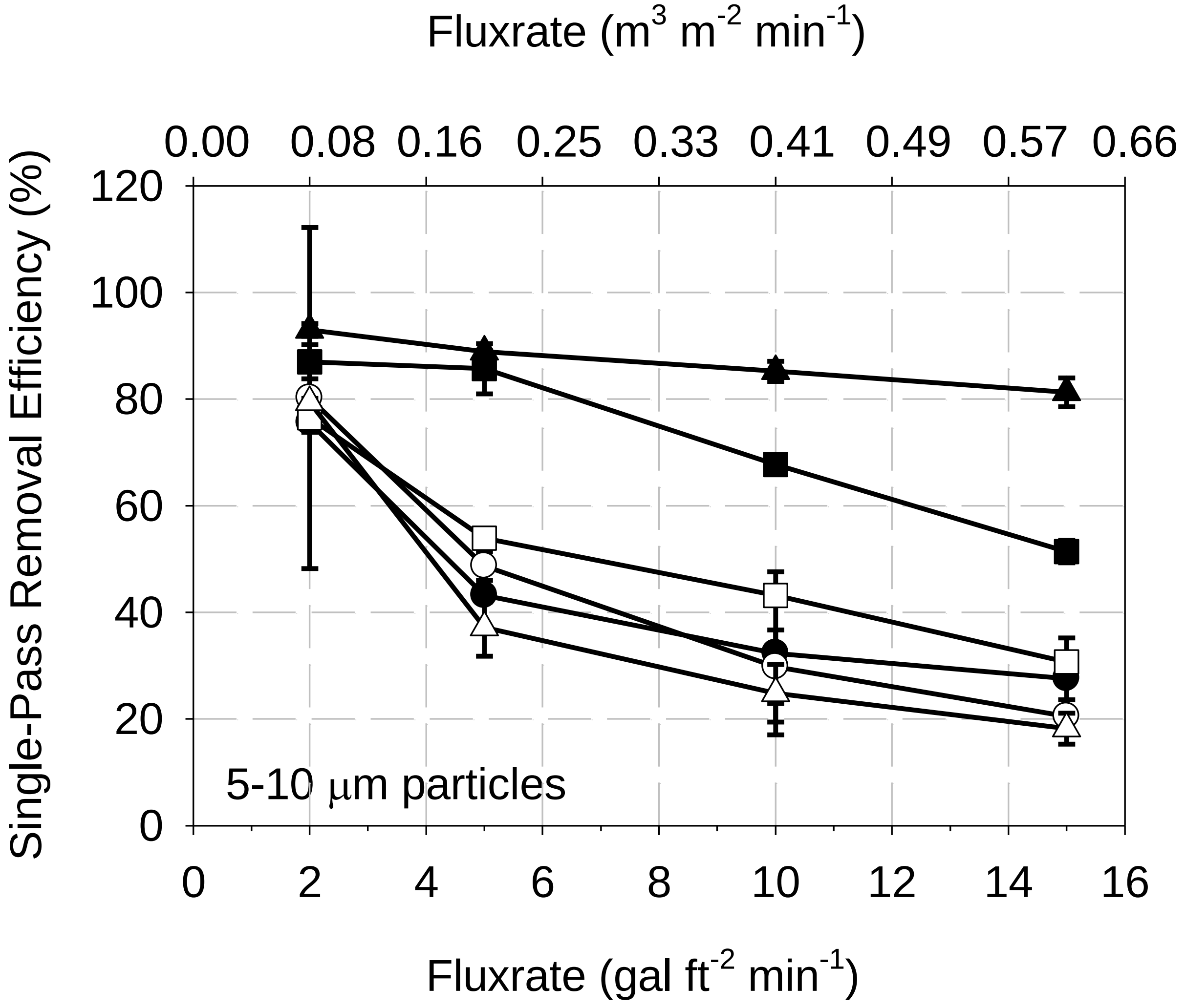

Figure 7. Mean removal efficiencies for six floating plastic media as a function of flux rate for particles ranging from 5 µm to 10 µm. Error bars indicate the standard deviation of the measurement.

treatment will ultimately eliminate these fine particles and create clear water conditions. In single-pass treatment effective removal of these fine particulates requires the use of chemical coagulants which aggregate smaller particles into large particles that can be effectively captured.

In summary, the removal capabilities of a floating bead filter can be reasonably predicted provided the characteristics of the bed and the suspended solids are known. The units have been proven in the field and have consistently shown to capture nearly 100% of suspended particles above 30 microns and to capture a substantial amount of the finer particles on a single-pass. Organic loading improves fine solids capture and floating bead filters mesh well with chemical coagulants if complete fine solids removal is dictated.

HPPG For Denitrification

The HPPG units are packed with EN media for denitrification applications. The flow through the unit dramatically reduces the oxygen supply to the unit. As the water enters the HPPG, a small amount of carbon-rich compound (typically methanol or ethanol) is metered into the inflowing water which stimulates a rapid growth of aerobic heterotrophic bacteria near the bottom of the bead bed. Oxygen is rapidly depleted and bacteria capable of using nitrate as an electron acceptor take over attacking the carbon source. The backwash frequency for the unit is usually set to once or twice per day preventing biofouling of the bed.

Although denitrification is essentially spontaneous whenever the carbon depletes the oxygen supply, denitrification units are typically tuned by measuring either the nitrate levels or redox levels exiting the filter. If too little carbon is added to the system, then nitrates removal is poor. If too much carbon is added all the nitrate can be removed causing a free fall in the system redox levels potentially leading to the production of noxious sulfides. To avoid this, AST's HPPGs configured for denitrification are often equipped with a process control loop that controls the rate of carbon input to the redox level observed in the filter effluent. A redox potential near -200 mv is typically optimum and the control unit adjusts the carbon dosage to match the incoming nitrate levels.

Figure 8. An HPPG can be configured with a recicualting aeration tank to become an effective bioclarifier, nitrifying and reducing soluble BOD while capturing solids.

Virtually any carbon-rich source can be used to stimulate denitrification. Methane and ethanol are generally recognized as the least expensive carbon source. However, these compounds are flammable, even explosive, under the wrong conditions and generally require stringent safety protocols for safe use. Carbon-rich compounds such as microC2000 (https://www.microc.com/products/microc-2000), albeit more expensive, are nonflammable and safe for use in smaller facilities.

HPPGs and Bioclarification

HPPG’s can be used for bioclarification, i.e. the concurrent operation as a solids capturer and as a biofilter removing soluble BOD5 and typically ammonia-N. As a single-pass filtration device, the HPPG's ability to control suspended solids is excellent, but the concurrent operation as a fixed film bioreactor is limited by oxygen transport issues. Typically, soluble BOD5 and TAN removal capabilities are limited to perhaps 20 and 2 mg/L, respectively, as the oxygen entering the unit is almost immediately exhausted by bacterial activity. This can be overcome by rapidly recirculating water with an adjacent aeration tank (Figure 8**).** This is sometimes done as a retrofit on existing treatment trains to polish effluents confronted by increasingly restrictive discharge standards.

Figure 9. This HPPG 10 was positioned next to a lagoon where its ability to filter fine suspended solids is being tested on algal cells.

When supplied with oxygen, HPPG units represent a robust and very manageable fixed film bioclarification unit for the control of readily biodegradable organics and ammonia. The unit can be used with complementary treatment processes to target refractory organics such as hormones, pesticides, petrochemicals, and other industrial wastes. The HPPG can be used as a roughing filter to treat BOD_5 concentrations measured in the hundreds, or as a polisher to achieve the most stringent standards.

The EN bead is externally shaped to protect the biofilm during backwash events. With a porosity of about 50%, the bed facilitates the rapid transport of water and oxygen throughout the bead bed. Fast-growing heterotrophic bacteria rapidly fill the pore spaces and are sheared off during a backwash event. Deep pockets provide a habitat for slow-growing, long-lived bacteria. The "gently washed" (Golz et al., 1999) pneumatic backwash is tuned to disrupt but not destroy the biofilm. The specific surface area of the bead bed is approximately 1150 m^2/m^3 and consumes virtually all the available oxygen as the water passes through it only to be replaced with fresh oxygen-rich waters from the recirculating airlifts or pumps.

Sizing Process

Sizing an HPPG as a clarifier

The sizing of HPPG units for solids capture is normally based on flow rates. When filled with standard media (3-3.5 mm beads), the flux associated with this design line is set at 10 gpm/ft^3. This standard flux is associated with nearly complete removal of all particles above 30 microns. Under situations where turnover controls the effectiveness, the flux can be increased to 15 gpm/ft^3, a flux that will result in the lowering of the efficiency of removal (single-pass) for the smaller (<20 microns) particles. In these applications, the loss of single pass efficiency is compensated for by increasing the number of passes per day. If fine solids (<20 microns) are targeted, the design flux can be lowered to 5 gpm/ft^3, a flux that improves single-pass removal of the fine solids (5-20 microns).

Once the appropriate flux (*f*) is selected it is divided into the given design flowrate, Q, to define the required size of the bead filter V_b:

$$V_b = \frac{Q}{f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

A judgment call is then made by matching the design sizing, V_b, with the nearest (or next largest) bead filter commercially available.

Occasionally, when the targeted solids are small (<20 microns) then a custom HPPG can be filled with a fine media (beads are 1 mm in diameter). These units are normally designed with a flux of 5 gpm/ft^3 and are highly effective at removing particles down to about 15 microns.

Sizing the HPPG as a bioclarifier for BOD5 removal

When an HPPG packed with EN media is paired with a recirculating aerated tank it effectively becomes an RCPG with adequate oxygen supply to provide effective BOD5 removal and nitrification. The reader is referred to Malone and Perrin (2023a;2023b) who describe the rationale for sizing RCPGs and provide a variety of sizing equations. Noting that the designed conversion must always be equal to the projected peak load, then embedding a 50% safety factor (sf=1.5) the principal equation used for low BOD$_5$ effluents (<50 mg/L) is:

$$Design\ Conversion = \frac{0.42 * {L_e}^{0.59}}{1.5} * V_b = Q_{max} * (L_i - L_e)$$

Or solving for V_b:

$$V_b = (1.5 * \frac{Q_{max} * (L_i - L_e)}{0.42 * {L_e}^{0.59}}$$

*0.42 kg/m3-day from PolyGeyser® bead filter BOD$_5$ conversion rate curve based on effluent concentration

Sizing HPPGs for nitrification

In the United States, the vast majority of ammonia effluent standards are set at values above 2 mg-N/. The design nitrification performance is currently around 1.8 kg-N/m^3-day for units operated with moderate BOD$_5$ levels (CBOD$_5$<20 mg/l). And noting the 1.5 safety factor, the predominant sizing equation used is:

$$V_b = (1.5 * \frac{Q_{max} * (A_i - A_e)}{1.8})$$

Internal recirculation rates between the aerated tank and the HPPG are set to ensure oxygen transport to the submerged bead bed. 10 gpm/ft^3 is generally adequate, but for heavy loadings it is prudent to sum the oxidation demands for organic oxidation (assume conservatively 0.75mg-O2 / mg-BOD5 removed) and nitrification (assume a net of 4.3 mg-O2/mg-Ammonia-N removed) under the assumption that the recirculation rate is 10 gpm/ft^3 beads (1.33 m^3/m^3-day). A bed effluent concentration of 2 mg-O2 will eliminate concerns about oxygen limitation.

Sizing an HPPG for denitrification.

The conversion capacity for a typical bead filter denitrification unit can be assumed to be more than 1 kg of nitrate-N conversion per cubic meter of media per day under typical industrial management. Rather than depend on detailed operation management to raise the conversion rate, systems are normally sized with an empirical conversion rate of 1 kg/m^3-day thus assuring that users of all skill levels can achieve their treatment objectives. Thus, the solving for the required bead volume:

$$V_b = \frac{Q(\Delta NO_3 - N)}{7482(1)}$$

Where:

$V_b = bed\ volume\ in\ ft^3$

Q = Flow in gpd

$\Delta \mathrm{NO_3 - N = Desired\ drop\ in\ nitrate - N\ concentration\ in} \frac{\mathrm{mg}}{\mathrm{L}}$

Typically, denitrification beds require about 30 minutes of hydraulic retention time. That information in combination with the knowledge that the EN media has a porosity near 50% allows the ability of the calculated bead bed volume to support the design flowrate to be checked using an empirically determined flux (typically about 0.125 gpm/ft3):

$$Q=0.125*V_b'$$

$$V_b' = \frac{Q}{0.125}$$

If $V_b' < V_b$ then V_b can be used for the sizing otherwise V_b' must be used to provide the desired hydraulic retention time in the bed.

The actual conversion capabilities of a denitrifying HPPG are controlled by the carbon feed rate. Generally speaking, a high carbon feed rate will induce a high nitrate conversion, but it may also result in high carbon concentrations in the effluent or low redox levels which may stimulate the production of noxious sulfides. Most denitrifying HPPGs are equipped with nitrate or redox probes which provide feedback to the carbon metering pumps. This allows the denitrification rate to be maximized without adverse secondary conditions. With process control support, conversion rates twice the design rate can be achieved.

HPPG Models and Capacities

Table 3 provides some sizing and performance estimates for the basic HPPG fiberglass line which ranges in size from 5 to 100 ft^3 and the stainless steel 300 ft^3 model. These basic units can be doubled or tripled to achieve treatments that require intermediate sizing. Estimated conversion rates are provided for BOD_5 and ammonia removal. Basic dimensions and critical elevations are provided along with weights for units in shipping and operation.

Table 3. Select Characteristics of Selected Characteristics of the HPPG Models1)

Characteristic	HPPG Model				
	10	**25**	**50**	**100**	**300**
Bead volume (ft^3)	10	25	50	100	300
Flow (gpd)	14,400	360,000	720,000	1,440,000	3.6
Flow (gpm)	100-150	250-375	500-750	1000-1200	3000-4500
Flow (m^3/day)	55-82	136-204	273-410	545-818	1640-2460
Denitrification flow (gpd)	1800	4500	9000	18,000	54,000
Denitrification flow (gpm)	1	3	6	13	37
Peak Hull Pressure	<20	<20	<20	<20	<15
Oxygen Delivery(1) (kg/day)	2.7	6.8	14	27	85
Bead SA (m^2)	326	815	1,630	3,260	9,770
Proximate Removals					
BOD5 @10 ppm(2) (kg/day)	0.46	1.2	2.3	4.6	11.6
BOD5@30 ppm (2) (kg/day)1)	0.88	2.2	8.8	8.8	22
BOD5@250 ppm(2) (kg/day)1)	1	9.4	18.4	37.7	94.3
Nitrification(2) Ammonia @ 0.5 ppm (kg/day)	0.25	0.64	1.27	2.55	6.37
Nitrification(2) Ammonia>2 ppm (kg/day)	0.5	1.3	2.5	5.1	12.7
Denitrification(2) (kg/day)	0.28	0.71	1.42	2.83	8.50
Diameter (inches)	40.25	59	85	84	160
Height (inches)	84	104	114	150	208
Hull Weight (lbs)	750	1,700	3,250	6,100	15,000
Bead Weight (lbs)	275	688	1,375	2,750	6,875
Operational wt.	2,700	6,300	13,400	24,500	100,000

1)At a mean flux of 10 gpm/ft^3. Can be operated at 15 gpm/ft^3

2)Average projected conversion at 25°C

Glossary & Index of Terms and Definitions

AST®	Aquaculture Systems Technologies, LLC
BOD	Biochemical Oxygen Demand
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand (Day 5)
C/N	Carbon to Nitrogen Ratio
EN	Enhanced Nitrification
pH	The potential of Hydrogen or the Power of Hydrogen
HPPG	High Profile PolyGeyser®
HPPG 10	High Profile PolyGeyser® with a Bead Volume of 10 ft^3
HPPG 25	High Profile PolyGeyser® with a Bead Volume of 25 ft^3
HPPG 50	High Profile PolyGeyser® with a Bead Volume of 50 ft^3
HPPG 100	High Profile PolyGeyser® with a Bead Volume of 100 ft^3
HPPG 250	High Profile PolyGeyser® with a Bead Volume of 250 ft^3
HPPG 500	High Profile PolyGeyser® with a Bead Volume of 500 ft^3
HPPG 750	High Profile PolyGeyser® with a Bead Volume of 750 ft^3
$SBOD_5$	Soluble Biochemical Oxygen Demand (Day 5)
TAN	Total Ammonia Nitrogen
TSS	Total Suspended Solids
TKN	Total Kjeldahl Nitrogen – Sum of Organic Nitrogen, Ammonia, & Ammonium
30/30 Standard	30 mg/L: 30 mg/L

Glossary & Index of Mathematical Terms and Definitions

amps	Ampere – The base unit of electrical current in SI units
A_e	Total ammonia nitrogen concentration in the filter effluent ((g-N)/m^3)
A_i	Ammonia concentration flowing into the filter at peak flow ((g-N)/m^3)
°C	Temperature unit: degrees in Celsius
cfm	Cubic feet per minute
f	Flux (gallons per minute per cubic foot)
ft	Feet
ft^3	Cubic foot
gpd	Gallons per day
gal/cycle	Gallon per cycle
gpm	Gallons per minute
gpm/ft^3	Gallons per minute per cubic feet
hp	Horsepower
K_a	Ammonia concentration when VTR is at 50% of VTR_{max}
kg/m^3	Kilograms per cubic meter
kg/m^3-day	Kilograms per cubic meter of day
kg-N/day	Kilograms of nitrogen per day
kg/day	Kilograms per day
L_e	Effluent BOD_5 quality targeted (mg/L)
L_i	BOD_5 concentration in the water (mg/L)
lbs.	Pounds (mass)
mg/L	Milligrams per liter
mm	Millimeters
m^2/m^3: m^{-1}	Square Meter per cubic meter
m^3/m^3-day	Cubic meter per cubic meter of day
mg-O_2	Milligrams of oxygen
mg-BOD_5	Milligrams of biochemical oxygen demand (Day 5)
mg-$CaCO_3$/L	Milligrams of calcium carbonate per liter
mgd	Millions of gallons per day
mg-N/L	Milligrams of nitrogen per liter
µm	Microns
ppm	Parts per million
ppm-N	Parts per million of nitrogen
psi	Pounds per square inch
Q_{max}	Maximum design flow (gpm)
R_b	Rate of BOD_5 Conversion (kg-BOD_5/ day)
R_n	Rate of nitrification (kg-N/day)
SF	Safety factor
V_b	Packed bead bed volume (m^3)
VTR_{max}	Maximum volumetric nitrification rate
wt.	Weight

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