

TREATING HIGHER-STRENGTH COMMERCIAL SEWAGE FOR DISPOSAL OR RE-USE

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ABSTRACT

Commercial high-strength sewage may have high organics and nitrogen, variable diurnal and seasonal flows, use of disinfectants and grease-strippers, and fast-food type employees. A 'pre-engineered' treatment process developed to counter these challenges results in a more consistent effluent quality. Consistency is important for nitrogen removal, for difficult disposal sites, and for irrigation or toilet re-use.

The standard process includes an exterior grease trap, septic tanks with effluent filters, surge flow storage in the pump tank, timed dosing to [Waterloo Biofilter](#) trickle filters, and 50-67% re-circulation to the septic tank inlet. For on-site subsurface disposal, a shallow, thin Area Bed made of medium-fine sand is preferred for optimum fecal removal. For irrigation re-use, UV disinfection is added for irrigation re-use, and multi-media filtration plus ozone + chlorine are added for toilet re-use.

The additional key component is a separate, closed-loop BIOFILTER with 100% return to the surge-pump tank. This independent BIOFILTER is hydraulically loaded at very high rates to remove organics and nitrogen, and to oxygenate the pump tank. Median effluent values in the first few months at five commercial sites are <10 mg/L cBOD and TSS, even though influent sewage is variable and high-strength.

With maturity, the nitrate-N to TN ratio approaches 1.0, and nitrogen removal increases to 40-80% by septic tank re-circulation alone, being higher with higher organic strength. Ammonium cleaner use can raise influent to >500 mg/L TKN.

For resort facilities such as golf courses and campgrounds, with a low flow followed abruptly by a high flow, the system requires quick ramp-up with little to no deterioration in effluent quality. The ClubLink golf courses are characterized by a step-function increase of 5-7 times within a week or two, and the BIOFILTERS have been designed to successfully pass this hurdle.

A new highway truck stop includes the 100% loop in two self-contained Waterloo SC-40 BIOFILTERS (ISO containerized), with the chlorinated effluent being re-used for toilet flushing in the facility, an estimated 60-70% of the water use. Groundwater shortages, nitrogen contamination of groundwater, and real estate savings are all factors in choosing re-use.

KEYWORDS. wastewater treatment, aerobic treatment, high-strength sewage, re-claimed water, nitrogen removal, pre-engineered design, waste utilization, subsurface disposal

INTRODUCTION

Challenges associated with treating commercial sewage from restaurants, golf courses, truck stops, and supermarkets include; (1) high organic and nitrogen strength, (2) highly variable diurnal and seasonal flows, (3) use of disinfectants and grease-strippers, and (4) 'fast-food' type employees (e.g., Crites and Tchobanoglous, 1998). As menus and employees change, and with

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more chemical use “for health and sanitation purposes” the wastewater becomes more and more difficult to predict, and this is a problem for the designer, regulator, and operator. Basically you never know what you are going to get, or when.

This paper describes a treatment process that is ‘pre-engineered’ to counterbalance these surprises and variability of sewage flows. The process can be designed initially or added as a retrofit. The dampened flow and organic peaks allow more consistent effluent quality, and thus more effective nitrification and nitrogen removal, easier disposal, and more comfort when the treated sewage is to be re-used for irrigation or toilets. Rapid ‘step-function’ increases in organic mass loadings at the juncture between low and high seasons can be handled biologically with little to no deterioration in effluent quality if the prolonged high season flow is the design criterion. Post-treatment processes are described for re-use for irrigation or for toilet flushing, and a successful ‘Shallow Area Bed’ is described that operates well in difficult soil areas, and in moderate to severe winters.

PRE-ENGINEERED CLOSED-LOOP PROCESS

Standard Treatment Process

The standard Waterloo Biofilter treatment process for residential sites is described in Millham et al. (2000) and consists basically of a septic tank and a demand pump chamber which doses the Waterloo on demand, with 50% recirculation to the septic tank a preferred option. However, for a high-strength commercial site (Fig. 1), it consists of; (1) an exterior kitchen grease trap, typically as two small double-compartment septic tanks in series, (2) septic tanks in series with capacity for 2-3 times peak daily flow (Q) or 4 times average flow, and including effluent filters on the outlet, (3) surge flow storage after the septic tanks in the pump tank, typically equal to $0.5*Q$ or the average flow, (4) timed duplex dosing of modular Waterloo Biofilter trickle filters, and (5) 50-67% re-circulation to the septic tank inlet, preferably by gravity from above-ground Biofilters (Fig. 2).

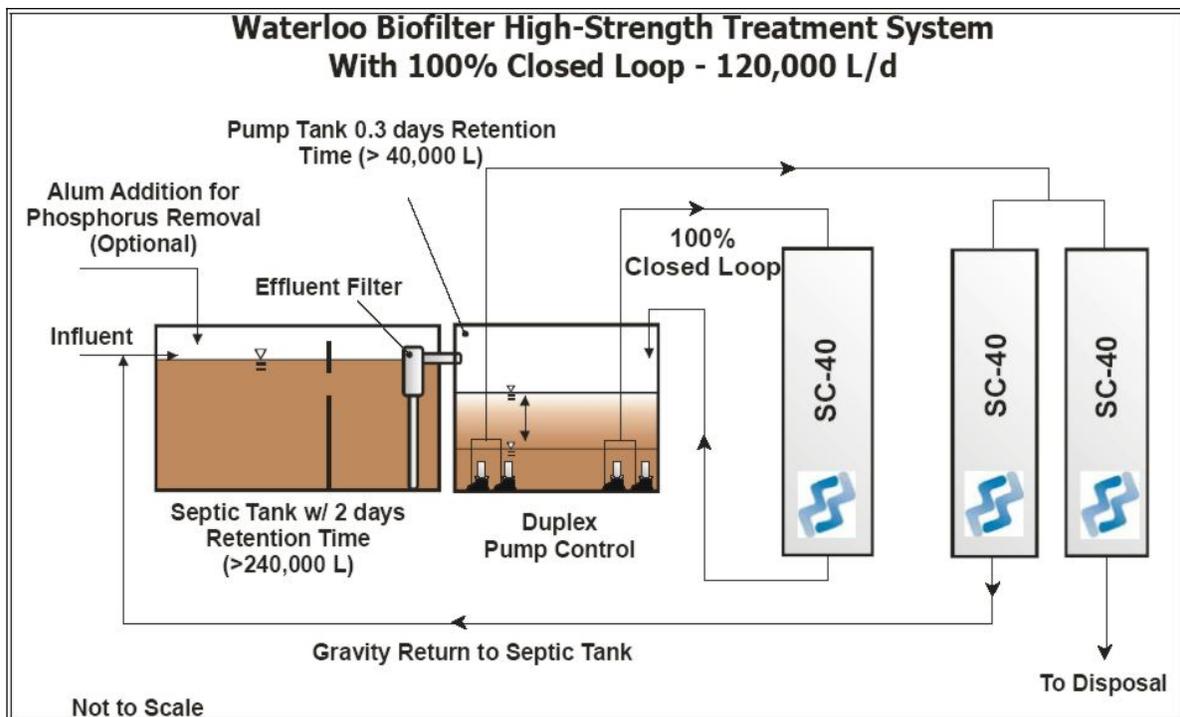


Figure 1. Commercial-scale treatment system using septic tank (after grease trap), surge pump tank, and multiple Biofilters in SC-40 configuration. Standard re-circulation is 50% back to septic tank inlet. The 100% closed-loop variant back to the pump chamber allows for high hydraulic loading, organics and nitrogen removal, and balance of flow variation (see text).



Figure 2. Waterloo Biofilter SC-20 shipping container at a truck stop, capable of treating 15-20 m³/day wastewater. Buried pump and septic tanks are in background.

The grease traps collect kitchen wastewater and discharge to the septic tanks, whereas the toilet and other wastewater discharges directly into the septic tank. Effluent filters on the grease traps are commercially sized Zabel filters, and have an access riser to surface for regular servicing. Septic tanks are set in series and are preferably double-compartment tanks, again with risers to surface to service the effluent filters.

The presence of a grease trap does not guarantee success if deep friers are emptied into the drains, or if excessive disinfectants are used in the facility. Used grease strippers for cleaning fume hoods cannot be disposed of in the grease trap or septic tank, or it will mobilize the grease into the treatment unit, and cause problems.

Closed-Loop Variant

The key component for pre-engineering the sewage variability is a separate, closed-loop BIOFILTER module with 100% return to the surge-pump tank. This BIOFILTER is on its own timed pump system, and is hydraulically loaded at very high rate to remove organics, oxygenate the pump tank, and remove nitrogen. Because the effluent returns to the pump tank and to the septic tank, the high hydraulic loading and potential suspended solids are not an issue.

The combination of the 50% standard return to the septic tank and the 100% closed-loop process allows the variability in flow and strength to be moderated. Water is stored up in the surge tank and in the BIOFILTERS, and discharged on a more regular basis. Organics are removed by the 100% loop so that the standard system receives a more dilute wastewater, and can complete nitrification more readily. The incoming high-strength wastewater is diluted in the septic tank by the standard 50% return, reducing the potential for odour, and reducing the nitrate formed, thereby removing nitrogen.

Results from Commercial Sites

Results in the first few months in systems with closed-loops at five commercial sites are provided below (median values). The first month is typically the most difficult, and removal of both organics and nitrogen improves with time.

Site	# samples	cBOD	TSS	TKN*	TN*
Supermarket**	10	8.0	7.5	30 / 2	80 / 32
Supermarket	9	3.0	3.0	37 / 2	40 / 13
Factory**	5	9.0	9.0	22 / 82	125 / 183
Youth Camp**	3	4.7	2.6	19 / 4	27 / 23
Restaurant	visually	clear	effluent;	as yet, no	analyses

*before / after nitrification; **winter start-up

No flow data are available for these sites, but all have either industrial or commercial kitchen influent, and are variable in their use during the day. The ‘supermarkets’ include deli and meat departments, and bakeries. One has a high sulphur water source. The ‘youth camp’ has food preparation and cooking on site, with high shower use. The ‘factory’ typically has construction fluids in the septic tank, and its high nitrogen values are the result of ammonium cleaner use. All sites operate year-round, with the last two being more seasonal. As the biological system matures and nitrate-N to TN ratios approach 1.0, nitrogen removal increases to 40-80% by septic tank recirculation alone, and this improves when incoming sewage is higher strength.

The results are quite acceptable considering the variability in flow and composition seen coming out of the facilities.

‘SHALLOW AREA BED’ DISPOSAL

Design and Installation

The preferred method of disposal of treated effluent in all types of soils is the ‘Shallow Area Bed’ (Fig. 3). The beds are constructed with a 250-300 mm thick contact bed of clear medium-fine sand (<5% silt) set ~25 cm deep into the native soil. This sand size (percolation of $6 < T < 10$ min/cm or about $1.3e^{-3}$ to $1.3e^{-4}$ cm/sec) is fine enough to allow lateral movement and removal of pathogens, but coarse enough not to plug up with the clear biomat that forms even with highly treated effluent.



Figure 3. Example of ‘Shallow Area Bed’ for treated effluent in stone-pipe area in background, infiltrating into the sand and native soil mantle in the foreground.

For tight soils, the basal contact area is sized for a hydraulic loading rate of 15-20 L/m²/day based on the peak design flow Q. The bed is prepared by scarifying (only on a dry day on heavy clay soil), and by constructing a preferred direction of flow if desired. The mantle is the native topsoil lateral to the sand bed into which excess water infiltrates.

To distribute the effluent, a stone and pipe layer, again 25-30 cm thick, is laid on the sand bed, and sized for a loading rate of 50 L/m²/day for larger commercial sites, or a smaller 75 L/m²/day for residential sites.

On flat terrain with heavy clay soil, the Area Bed should be elongated 2:1 or 3:1 and the stone-pipe bed centred on the sand in the same orientation. On sloping terrain, the stone-pipe bed is elongated across the flow direction, and is set toward the uphill side of the sand bed. In sandy soil, a more equant bed is possible because of the greater vertical permeability.

Because they are elongated across flow direction, the lateral loading rate into the adjacent soil mantle is minimized and hydraulically more sustainable (e.g., Tyler, 2001), similar to the 'contour' trenches in Nova Scotia (NSDHF, 1988). Clay soil underlying an Area Bed retains its blocky, topsoil-like structure because it receives oxygenated wastewater in which earthworms can thrive, and is not smothered by a thick pile of sand or soil. Its lateral permeability is retained to remove treated effluent away from the disposal area, and to remove residual pathogens in a free-draining environment.

Shallow-rooted vegetation such as cedars may be planted to remove water from the mantle area. Care must be made in grading to direct surface water runoff away from the bed, a common cause of disposal bed failure. Set-back distances to wells and property lines are dependent on local codes.

Fecal Removal in 'Area Bed'

To test the efficiency of fecal removal by the Area Bed sand, a pan lysimeter were placed below 250 mm (10") of medium-fine sand ('loamy sand' with estimated T = 4-5 min/cm (10-12 min/inch)) at the Buzzards Bay test facility in Massachusetts (Heufelder, 2003). The lysimeter was gravity-fed Waterloo Biofilter effluent at basal (no sidewall) hydraulic rates of 106 L/m²/day and at 212 L/m²/day for several months.

The medians of the fecal coliform analyses were 5 cfu/100mL when diluted to 10 mL (i.e., limit of <10 cfu/100mL), and 0.5 (<1) when diluted to 100 mL for a lower detection limit of <1 cfu/100mL. The highest value was 10 cfu/100mL (i.e., one fecal noted at the 10 mL dilution).

In earlier lysimeter tests at Buzzards Bay, 300 mm (12") of coarser sand with T < 0.5 min/cm (<2 min/inch) removed a total of >99.99% at 80 L/m²/day hydraulic load. In comparison, only 250 mm of the finer sand, loaded at 106 and 212 L/m²/day, removed >99.999% fecals (Heufelder, 2003).

Waterloo Biofilter treatment plus 250 mm of the finer sand at 106 and 212 L/m²/d basal loading was considered by Heufelder (2003) to be equivalent in fecal removal to septic tank effluent plus 1500 mm (60") of the coarser sand at only 80 L/m²/d basal hydraulic loading.

'STEP-FUNCTION' FLOW PATTERNS

In resort facilities such as golf courses and campgrounds, there is a definite pattern of low flow followed by high flow without a ramping up period. The system needs to have a quick response time, with no deterioration in effluent quality. With biological activity, the 'lag' growth phase is followed by the 'exponential' phase, then the 'stationary' and 'death' stage.

Low season flows can be considered as the lag phase and the exponential growth must keep pace with the increase in organic mass loadings. Under optimal conditions, the exponential phase can result in a median doubling time of only 60 minutes (Atlas, 1988). If microbes in the Biofilter reproduce quickly enough to degrade the organics, a high quality effluent is maintained. An example of how to predict performance when hydraulic flows jump from 50 m³/d to 400 m³/day is described in Jowett et al. (2003).

The example used is a large golf course resort with detailed remote monitoring and wastewater analysis information over the period of 1999 to 2002. Influent samples were taken every month, effluent samples every week, and flow data taken every day. Using influent samples, the relationship between organic mass load from the facility was related to hydraulic flow rate for both low season and high season.

The slight exponential relationship indicates that when the facility is very busy, the wastewater is higher strength. However, there was no relationship between influent mass and effluent concentration in either the low or high season periods, indicating that the Biofilter was sized appropriately to handle low and high mass loadings.

Using this exponential influent mass to hydraulic flow relationship, the mass loadings for every day during the low and high seasons were predicted (Fig. 4). The resulting plots show a distinctive 'step function' jump from low to high season, depending somewhat on the weather conditions for the start of the golf season. The treatment system was designed for the prolonged high season flow with sufficient absorption and microbial attachment sites in the Biofilter medium. The microbial population was able to keep pace with the flow from the 'lag' low season to the 'stationary' high season by exploiting their 'exponential' growth abilities.

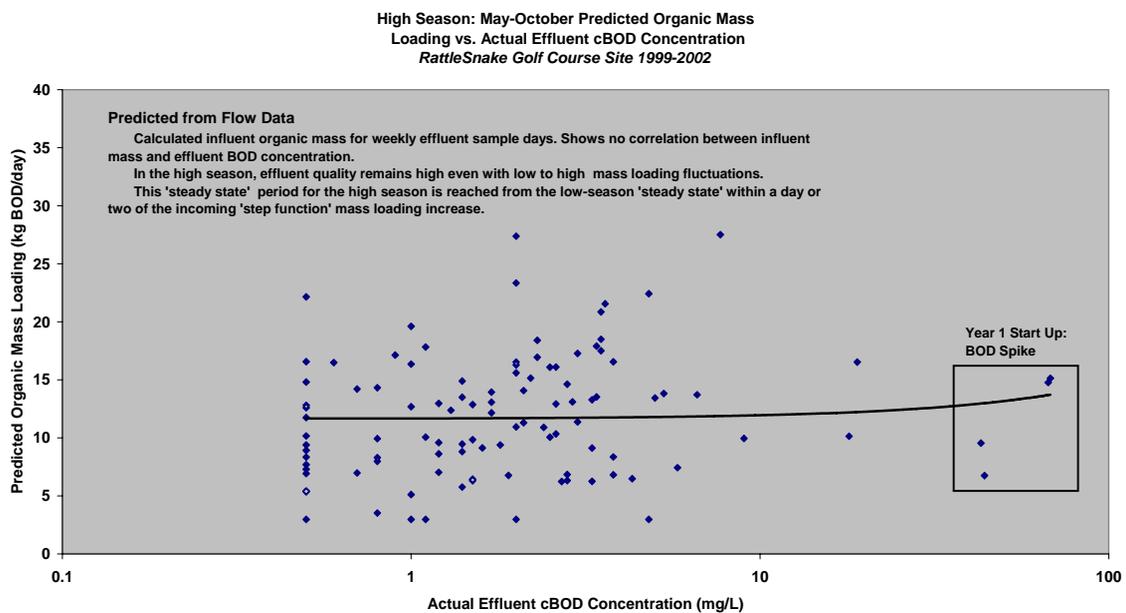


Figure 4. Predicted mass loadings are calculated using the relationship between actual organic mass load from the facility and the measured daily hydraulic flow for low and high seasons. Here the predicted high season mass loadings are graphed against actual weekly effluent analyses, and show that there is no relationship between mass load and effluent concentration.

RE-USE DESIGN

For irrigation re-use (Jowett et al., 2001), trough-type UV disinfection is employed. Often the effluent must meet surface water discharge quality, and alum (aluminum sulphate) is added to the septic tank to bind phosphorus in the scum or sludge. Because ammonium limits are imposed, and complete nitrification is difficult with high organic strength, dilution by the 100% loop does help comply with nitrification. In soft water areas, sodium bicarbonate is added as an alkalinity source for nitrification to proceed, typically dosed to maintain a pH of ~7.

For toilet re-use, multi-media filtration plus ozone is used to polish, disinfect and remove the brown colour that builds up during re-use as the recalcitrant lignins and tannins concentrate in the re-used water. To keep plumbing free from bioslime, ~0.2 ppm chlorine residual can be added.

A new highway truck stop in Ontario includes the 100% loop in one of two self-contained Waterloo SC-40 BIOFILTERS (ISO containerized). The effluent then passes through sand filters, is ozonated and chlorinated, and the disinfected effluent is re-used for toilet flushing inside the facility, for an estimated 60-70% saving of water supply. For this toilet re-use, the effluent criteria are cBOD and TSS <10 mg/L, and fecal coliforms <5 cfu/100mL. No phosphorus or nitrogen limitations are required, except to monitor the discharge to the disposal bed for nitrogen loading.

Groundwater shortages (now in Canada), nitrogen contamination of groundwater, and real estate savings are all factors in choosing re-use.

CONCLUSIONS

To take the vagaries out of commercial high-strength sewage sources, a pre-engineered closed-loop trickle filter component can be included in the design of the facility or readily added as a retrofit. The key component is a high-rate Waterloo absorbent trickle filter that re-circulates 100% back to the pump tank, acting as a roughing filter. This component removes much of the organics, thereby diluting the sewage, easing odour mitigation, and easing thorough nitrification. Diurnal flow variations are tempered by recirculation and storage in surge tanks and in the Biofilter itself.

For re-use for irrigation, disinfection by UV is readily accomplished in the clear effluent, and for re-use for toilet flushing, ozone can remove colour, and chlorine can be added to keep plumbing clear of bioslime.

On-site disposal is best done in a 'Shallow Area Bed' that allows oxygen infiltration and supports earthworms in the underlying soil. The finer sand recommended removes almost all the fecal coliforms left over from the Waterloo treatment, more than an order of magnitude more effective than the coarser sand.

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