Re-thinking hydraulic flow in septic tanks

By Richard Lay, Max Weiss, Kris Pataky, Craig Jowett

The existing CSA Standard B66 on septic tank construction requires a continuous airspace above the water level specifically for "floating scum storage", and perhaps for "upwelling surge storage" to decrease velocities through the outlet pipe (Baumann 1978). But what does this airspace really do and is it even a good thing?

The first septic tank in the mid-1800s (Mouras tank) had its inlet in the roof and no continuous airspace. It ran into difficulties from accumulated fermentation gas pockets forcing suspended solids through the outlet. Venting of these gases allowed the tank to operate properly.

Other designs in the early 1900s used long tank configurations with no airspace, just venting, and these specifically excluded air to promote fermentation. From the mid-1900s onward, standard septic tank design comprised a box tank with openings in the end walls, a flat lid, and an airspace from inlet to outlet.

In his classic 1984 book, *The Septic Tank*, Winneberger questions the use of the airspace, concluding it "might not serve a useful function". He also suggests that the "configuration of septic tanks has long been dictated by simple construction convenience", and "most authorities would welcome improved septic-tank designs, but regulations pre-design tanks as they are", and "unfortunately, minimum standards become maximum practice."

Can we extend Winneberger's sightline further, look at the standard septic tank, and suggest ways to improve its intended function of (a) separating solids from sewage, and (b) optimizing fermentation and hydrolysis reactions?

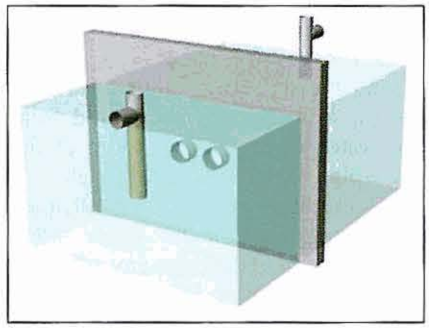


Figure 1a. Standard 4500 L Ontario CSA Tank B with 2:1 compartments and central openings in partition, before pump dosing.

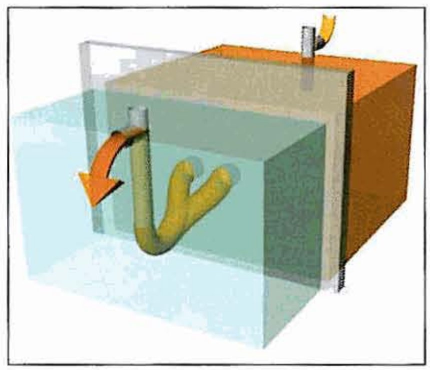


Figure 1b. Ontario Tank B during 5% and 10% volume dosing, showing upwelling into airspace, and the resulting visible "untreated sewage" plume formed directly between partition and outlet.

Forming Scum and Sludge

"Floating scum storage" sounds reasonable, but we would be better off with less scum and more sludge. Again Winneberger; "it is a common misconception that...lighter solids...rise to surface and form a layer of scum". Rather, scum is related to amount of gases evolved, because sludge particles are carried up by gas bubbles, only to sink again when released.

However, with an airspace present, vegetative moulds take hold and accelerate the trapping of rising sludge, matting them together into a "tough,

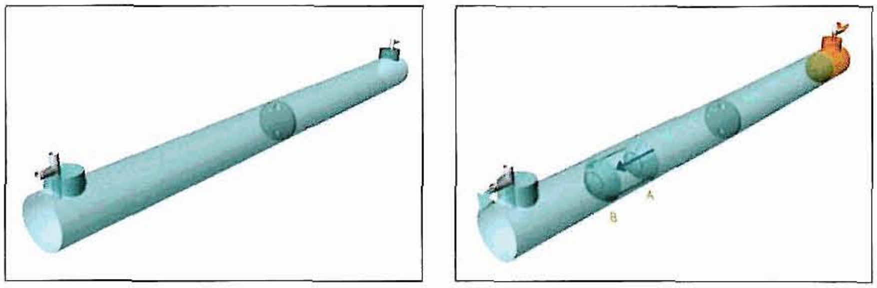


Figure 2a (left). Prototype 4500 L Tank D with no airspace between risers and 1:1 sections, before pump dosing.
Figure 2b (right). Prototype Tank D during 10% volume dosing (450 L), with "untreated sewage" contained near inlet, and only "old," treated sewage exiting tank. Parabolic discs depict relative flow velocities over cross-section of tank, and movement of water from disc A to disc B during 10% dosing.

floating mass". In comparison to sludge, this leathery scum is more difficult to pump out. Also it is denser than water, and can overturn and sink, causing re-suspension and out-flow of sludge. Removing the airspace from the tank will result in relatively more sludge and less crusty scum.

Capturing Scum and Sludge

The CSA B66 standard specifies a deeper tank (typically 1200 mm) and allows a short distance (1200 mm) between the inlet and outlet. Is this good design in a septic tank? Entrained sludge particles settle out (up and down) along the flow path, and are captured when they reach the floor or upper scum layer of the tank. The horizontal distance required for settling out increases with smaller particle size, and with greater depth. A longer, shallower tank therefore captures more sludge, and finer sludge, than a shorter, deeper, box tank.

Short Circuiting vs. Laminar Flow Patterns

Differential flow velocities, causing unwanted higher-velocity plumes, increase in tanks with shorter, wider, or deeper aspects (e.g., Figure 1), especially in those with 'point source' inlets and outlets like a septic tank. Higher-velocity plumes allow untreated sewage to short-circuit directly to the outlet. To optimize separation of solids and to maximize retention time without short-circuiting, the tank design should encourage a well-developed, laminar flow regime. The 'mixing zone', with eddy currents and pressure differentials characteristic of the inlet area, should be dampened as early as possible in the pathway of the sewage.

A tank design with longer, narrower, or shallower aspects (e.g., Figure 2) limits the mixing zone to the inlet area, and allows a well-developed, laminar flow regime to develop along the pathway well before the tank outlet. Only 'old' water that has completed the fermentation process, and that has settled out entrained sludge particles, will exit the tank. Untreated sewage, or 'new' water, will not circumvent the old water by way of higher-velocity plumes.

Comparative Hydraulic Flow Testing

Hydraulic tests were carried out on four different tanks:

Tank A: 1800 L Alberta CSA tank, no partition, single compartment,

Tank B: 4500 L Ontario CSA tank, partition with 2:1 compartments (Figure 1a),

Tank C: 4500 L prototype submerged tank, partition with 2:1 sections, and

Tank D: 4500 L prototype submerged tank, partition with 1:1 sections (Figure 2a).

The prototype design has the inlet and outlet up in the 450 mm risers and a long shallow, narrow submerged tank, with no airspace above the water level, between the risers. Light expanded clay aggregate (leca) was used as a surrogate for sludge particles (60% float; 40% sink), added to the inlet during pump dosing at a rate of 3.75 L/s (60 gpm). Volumes of ~5% and ~10% of the effective capacity of the tank (i.e., 90 and 180 L, 225 and

continued overleaf...

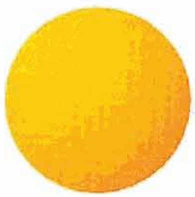
	AB CSA Single Tank A	ON CSA 2:1 Tank B	Prototype 2:1 Tank C	Prototype 1:1 Tank D
5%			—	—
10%			—	—

Table 1. Relative amounts of leca solids ("untreated sewage") passing directly through the tanks.

450 L for the 1800 and 4500 L tanks respectively) were added, and the effluent was screened for particles.

The small Alberta Tank A fared the worst with no partition wall and only 1200 mm between inlet and outlet. Even doses of 90 L and 180 L (5% & 10% of tank volume) allow escape of much 'untreated sewage'.

While the partition wall of Ontario Tank B kept much of the floating leca away from the outlet, a distinctly visible, higher-velocity plume developed across the short, 790-mm second compartment (Figure 1b). This plume emanated from the two partition openings and coalesced into a single plume directed to the outlet baffle, and substantial 'untreated sewage' escaped (Table 1).

For both tanks, the effect of doubling the pumped volume from 5% to 10%, was to produce more than twice the amount of 'untreated sewage' short-circuiting through the tank (Table 1).

Prototype Tanks C and D passed no solids through at all, even after flushing with additional water, presumably due to laminar 'plug' flow keeping 'new' water near the inlet, and allowing only 'old' water out. Longer term, stress tests were carried out on prototype Tank C, including continuous pumping, with only minute traces of solids passing through.

Instead of the single-tube tanks tested, the preferred configuration for septic tank design is shown in Figure 3,

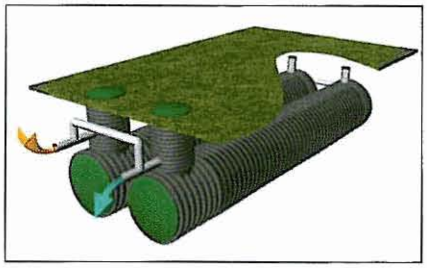


Figure 3.

with a 'double-back' design to ease installation in restricted space while maintaining the same hydraulic flow.

Conclusions

When the goal is to capture sludge particles and retain sewage in the septic tank long enough for thorough fermentation, a longer, shallower configuration with no airspace over most of the tank length appears to be preferable to the short, deep, box tank design now prescribed in CSA B66. Sewage volumes pumped to a standard septic tank should be limited to <5% of the tank volume to minimize untreated sewage being sent to the leaching bed.

Richard Lay, M.A.Sc., P.Eng., is with Enermodal Engineering, Kitchener, ON; Max Weiss is with Weiss Research, Polson, Montana; Kris Pataky, engineering student, and Craig Jowett, Ph.D., P.Eng., are with Waterloo Biofilter Systems, Rockwood, ON. Contact e-mail: rlay@enermodal.com.