Ontario's New Performance Septic Tank – Why & How

E. CRAIG JOWETT, Waterloo Biofilter Systems Inc., PAUL YAREMKO, Armtec Ltd., and RICHARD LAY, Enermodal Engineering

Designing for treatment in septic tanks

Although 30% of sewage generated in North America passes through septic tanks, there has been little recent study to improve the treatment efficiency of these important vessels. As summarized by *Lay et al. (2005)*, *Jowett (2007, 2009)*, and *D'Amato et al. (2008)*, existing literature shows that longer, narrower septic tanks improve effluent quality due to quiet, laminar flow and minimum hydraulic 'dead space.'

Early designers such as *Metcalf (1901, in Winneberger, 1984)* valued long septic tanks to produce "sedimentation by slow flow through long tanks." However, as *Winneberger (1984)* states, "…the value of long tanks became forgotten" and "probably because of construction convenience, short, stubby tanks became common." Entrained sludge particles settle out along the flow path, with longer paths required for smaller particles and for deeper tanks (e.g., *Novotny et al., 1989*). A long tank minimizes short-circuiting, "allowing only old water to leave the tank" *(Max Weiss, pers. comm., 2004)*. British standards *(BS 6297, 1990)* require a maximum 1000 mm water depth, resulting in a much longer, shallower tank than in Ontario.

Reducing the 'dead space' characteristic of wider, deeper box tanks has a treatment advantage as well. *Dunbar (1907, reported in Winneberger, 1984)* hung meat in septic tanks and found that "decomposition is quicker in a tank of 12-hour capacity than one of 2-hour capacity, but very much quicker than in a septic tank in which the sewage is stagnant." *Bailey et al. (1957)* hold stagnant flow responsible for accumulation of acidic waste products of bacterial decomposition, which, in turn "slow down or stop their growth," and they designed their poultry degraders with water inlets and outlets to a tile bed instead of a stagnant holding tank. Designing a tank with efficient flow paths to remove waste products from decaying organic matter is more desirable, from a treatment perspective, than just increasing the tank size.

'Floating scum storage' is a common reason for airspace in a tank, but *Winneberger (1984)* states "it is a common misconception that … lighter solids … rise to surface and form a layer of scum." Rather, a "tough, floating mass" forms when fermentation bubbles bring up sludge to be trapped by moulds living on the air-water interface *(Metcalf and Eddy, 1930)*.

Tank partitions with small orifices worsen effluent quality by causing high velocity flow and turbulence in the orifice and short-circuiting to the nearby outlet (Figure 1), as seen in dye and solids tracing, and in the sewage testing of *Rock and Boyer (1995)*.

Cold climate is an important factor in biodegradation efficiency, as exemplified by the study of decomposition of dead poultry by *Bailey et al. (1957)*. At 38°C, decomposition was complete after 11 days, but, at 27°C, only slight action was observed, and, at 10°C, "the birds were still well preserved." As a result, they designed their heated septic tanks with 100 mm insulation in the walls and floor to keep the tanks warmer in winter.

From prescription to functionality, if not performance

Industry standards

Septic tank standards that apply across Canada (*CMHC, 1984; CSA, 2005*) are primarily prescriptive construction manuals for building competent tanks out of various materials. Prescriptions are based on the established methods of the time of writing, and, once they are published and adopted by manufacturers and regulators, with time they develop a respectable and authoritative aspect. One is naturally more hesitant to change the familiar written word, which favours the *status quo* for incumbent technology and may obstruct the new.

Prescriptions set out designs that do impact sewage treatment, such as

Enermodal Engineering

Enermodal Engineering is Canada's largest consulting firm exclusively dedicated to *LEED* buildings and communities, being responsible for 40% of certified buildings in Canada. Originating in Ontario, Enermodal has now expanded to four locations and over 100 employees in North America. Enermodal delivered the *LEED* 2009 Rating System and serve as *LEED* faculty members, with President Stephen Carpenter appointed Chair of the Technical Advisory Committee. This firsthand knowledge of *LEED* is an important contributor to Enermodal's record-breaking 200 *LEED* projects across North America. Projects include the first Platinum certification in Ontario at Toronto Region Conservation Authority, first Platinum industrial certification at Fifth Town Cheese, first Canadian Stage 2 *LEED*-ND certification at Currie Barracks, and the largest *LEED* project in Canada at RBC Centre.

For over 25 years, Enermodal has pioneered the use of some of the most innovative and practical technologies for use in green infrastructure, even in remote Arctic areas. These include rainwater cisterns and re-use, onsite wastewater biofiltration, radiant cooling, renewable energy, and variable flow refrigerant systems. Enermodal's success is rooted in a hands-on approach and technical understanding of building systems and energy use, and a need to promote innovative technologies based on performance and testing for their projects.

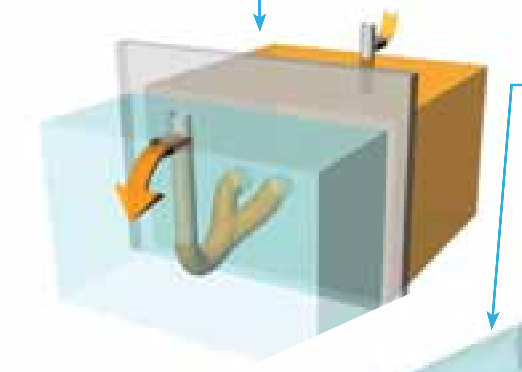


FIGURE 1
Standard Ontario 'box-type' 4500 L septic tank with 150 mm partition orifices close to the outlet. Turbulent plumes (in orange) short-circuit untreated sewage to outlet pipe (Lay et al., 2005).

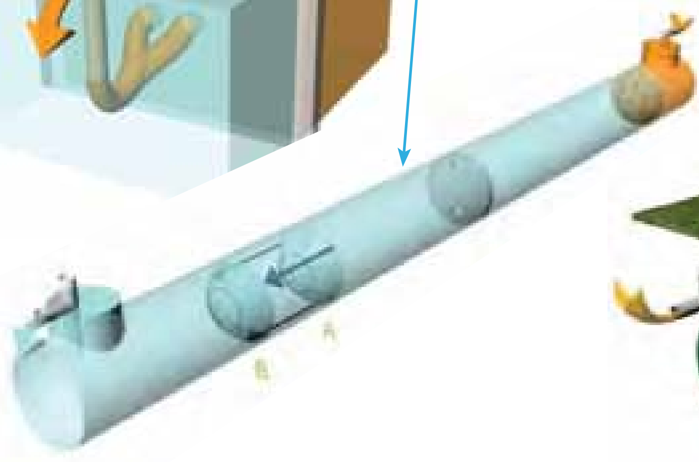


FIGURE 2
Closed-conduit tank limits turbulence (in orange) to the inlet area, and only 'old,' treated sewage exits the tank, depicted as laminar-flow parabolic discs A to B (Lay et al., 2005).

FIGURE 3
'Flooded' or closed-conduit flow tank of 5700 L capacity tested side-by-side with conventional single- and double-compartment tank at Buzzards Bay test facility.

Waterloo Biofilter

For his Doctorate degree at University of Toronto and as a NATO Science Fellow at Michigan and Cornell, Craig Jowett specialized in physical properties of rocks and fluid flow within sedimentary basins, to determine timing of flow and formation of hydrocarbon and metal deposits. As a Research Professor in Earth Sciences at University of Waterloo, he worked with colleagues in the world-famous Waterloo Centre for Groundwater Research, one of Ontario's Centres of Excellence, who were studying contaminant plumes beneath septic tile beds.

Although the septic tank was independent of the environment, the tile bed, where the 'rubber hits the road', was in fact nothing more than the natural environment itself, with pipes. Using natural soils for sewage treatment seemed like using rivers for treatment of factory wastes, or the ocean for treatment of garbage; you can justify it only for a while. The best farmland was being used for houses "because the soil can treat the sewage", and then once the sewage did enter the natural soil, no-one knew could know what was happening.

In the early 1990s, Jowett hired a young recent graduate in microbiology, Michaye McMaster, whom he met at an awards dinner (she was the award winner), and together they developed a simple, free-draining trickle filter suitable for peoples' back yards – for treatment before disposal. Beneficial microbes set up housekeeping on solid surfaces to treat sewage, but this attachment also clogs the small interstices of soil or sand, creating a potential health hazard. Jowett & McMaster chose a plastic medium with large open pores in place of sand grains, and a 3-D network of thin columns in place of interstices between sand grains. Reversing the physical properties resulted in the same high-quality effluent as sand in 10% of the volume. The world's first 'tile bed in a box' with manufactured synthetic medium in a transportable configuration was made in Ontario.

Sponsors of this research were NSERC, MOE, and WCGR most notably, but also Conservation Authorities, homeowners, cottage associations, and concrete pre-casters. CMHC funded the 'Toronto Healthy House' where the sewage is treated with Waterloo Biofilters and sand filters and re-used immediately in the house. Dow Chemical and Ontario's Woodbridge Foam were very strong supporters of Waterloo's innovation in the environmental arena. The Waterloo Septic System conferences organized by the WCGR and MOE through the 1990s brought together researchers and manufacturers from around the world to Ontario to develop a new industry of on-site treatment before disposal. Waterloo Biofilter Systems was incorporated in 1995 to manufacture and market the patented system (www.waterloo-biofilter.com), and now has thousands of large and small systems across North America and elsewhere.

The MOE pioneered septic research from the late 1960s, and with MMAH, continued to be supportive of approvals for treatment before disposal, providing credit in the form of smaller disposal beds compared to septic tank effluent. Waterloo worked with MOE researchers on nitrogen and phosphorus technologies, and on passive disinfection methods. More recent innovation by Waterloo Biofilter include a laminar flow septic tank designed for treatment (see adjacent article in this issue of Influents), a more passive 'Flat Bed' configuration that can be dosed with a siphon, and an exciting nitrogen removal technology presented in the last issue of Influents.

Ontario has a great history of innovation in sewage treatment and Waterloo Biofilter is proud to be a personality in developing a modern industry.

TABLE 1
Study 1 septic tank effluent analyses following CSA B66 'Equivalency Test Protocol

Study 1 – 2850 L/d April 13 2005 – July 11 2006		BOD mg/L	COD mg/L	TSS mg/L
Number of QA/QC samples		51	22	76
DC West Sewage	**average**	**209**	**408**	**197**
	standard deviation	61.7	133.1	83.1
		cBOD mg/L	COD mg/L	TSS mg/L
Number of QA/QC samples		41	39	41
A3 WaterTube	**average**	**158**	**314**	**43**
	standard deviation	39.0	79.8	9.9
F3 Single Tank	**average**	**178**	**344**	**53**
	standard deviation	51.3	87.1	17.7
Student's t-test A3 & F3	% confidence	96.2	89.0	99.8

TABLE 2
Evolution along flow path on one-day in Study 1 (soluble COD sample is filtered)

February 8, 2006 2850 L/d	VFA mg/L	Soluble COD mg/L	Alkalinity mg/L	$NH_{3,4}$-N/TKN	PO_4-P/TP
A3 WaterTube tank					
A3-1 inlet	34	150	170	0.74	0.65
A3-2 end inlet segment	40	170	175	0.69	0.57
A3-3 start outlet segment	46	120	190	0.67	0.62
A3-4 outlet	51	120	195	0.76	0.75
F3 Standard tank					
F3-1 inlet	48	110	190	0.72	0.73
F3-2 outlet	80	110	190	0.72	0.71

TABLE 3
Study 2 comparison of tanks at 2500 and 2850 L/d

Study 2 – 2500 L/d 10 mo; 2850 L/d 2 mo November 17, 2006-November 19, 2007		BOD mg/L	COD mg/L	TSS mg/L
Number of QA/QC samples		58	-	94
DC West Sewage	**average**	**183**	**-**	**164**
	standard deviation	50.8	-	65.9
		cBOD mg/L	COD mg/L	TSS mg/L
Number of QA/QC samples		48	22	48
A3 WaterTube	**average**	**119**	**243**	**31**
	standard deviation	23.0	51.8	6.5
F3 Single Tank	**average**	**159**	**282**	**39**
	standard deviation	63.8	56.7	8.0
Student's t-test A3 & F3	% confidence	99.99	97.6	99.99

water depth, tank length, partitions, orifice sizing, and airspace, but without benefit of performance testing to determine what effect these requirements have on treatment. Intended functionality of these prescriptive designs may be lost or unknown, and it is difficult for a manufacturer to demonstrate equivalency when the function of established prescriptive technology is not apparent.

Actual benchmarks, by performance or by description of intended purpose, clarify requirements for equivalency, and ease objective evaluation of new technology. Clear benchmarks produce a 'level playing field' for new environmental technologies, minimize subjectivity, and free up the marketplace.

Septic tank equivalency benchmark

After several years of negotiation, an 'Equivalency Test Protocol' was included in the *CSA B66* standard in 2006, to allow innovative septic tank designs into the marketplace. After the test is successfully passed, a new tank is deemed to be 'equivalent in functionality' to the standard's prescription tanks, a phrasing developed by consensus to include a performance aspect yet maintain its overall prescriptive nature.

The protocol requires a new tank design to be tested side-by-side with a prescriptive tank for 12 months or more, using cold sewage of <10°C for at least three months. The test must be carried out at an accredited facility using high peak flows of residential-style sewage dosed to the tanks. Effluents are sampled at least 30 times for cBOD, COD, and TSS, and the median values calculated for each parameter. For a new tank design to pass, not one of its three median values can be more than 10% greater than the same parameter of the prescription tank, and more importantly, the average of its three medians must be less than that of the prescription tank. Therefore, the protocol puts a great onus on the new tank design to show that it is better than the existing tanks in order to be included in the standard.

First past the post – the '*waterTube*' septic tank

Two closed-conduit, laminar-flow septic tanks were constructed for *Waterloo Biofilter* by *Armtec* in Woodstock, Ontario by welding *Armtec's* extruded '*Boss 2000*' high-density polyethylene pipes. Guelph-based *Armtec* is Canada's largest and oldest manufacturer and supplier of high-quality corrugated steel products, corrugated HDPE pipe, and, now, concrete structures for infrastructure markets. Rockwood-based *Waterloo Biofilter* is a pioneering innovator in decentralized sewage treatment, nutrient removal, disposal, and re-use. Kitchener-based *Enermodal Engineering* is a major player in designing *LEED* buildings, which often incorporate sustainable 'green' infrastructure.

The first tank was 4500 L capacity for the tracing studies of *Lay et al. (2005)* (Figure 2), and second was 5700 L fabricated in two lengths (Figure 3) to fit within the test site at the Massachusetts Alternative Septic System Test Center (*www.buzzardsbay.org/etimain.htm*), where the biochemical testing is carried out. The 5700 tank segments were connected with two 200-mm pipes to allow sludge and scum to migrate between tanks and not to act as a partition.

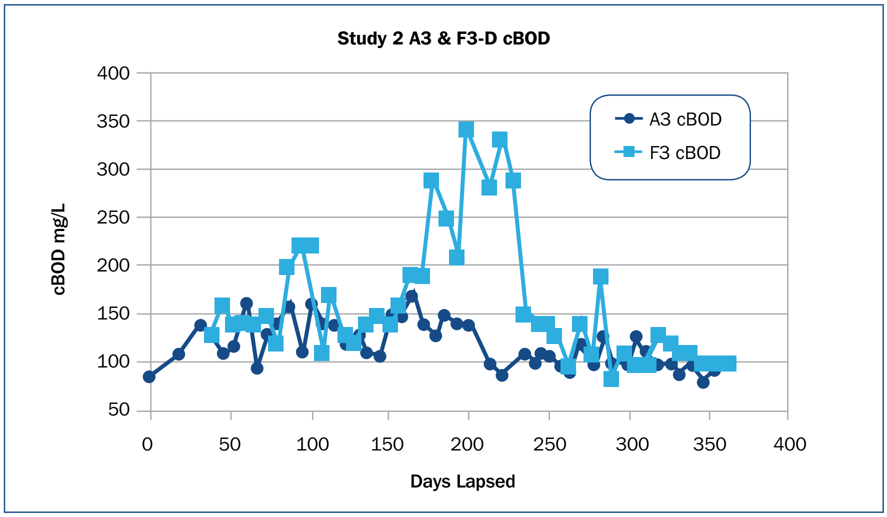
Long-term sewage test results

Since April 2005 a *WaterTube* tank has been in operation in side-by-side testing with a single-compartment 'Massachusetts' tank (Studies 1 and 2), fully presented in *Jowett (2007, 2009)* and summarized here. Study 3 is ongoing with an 'Ontario' tank + effluent screen.

Study 1: *B66* test protocol residential-type testing

Study 1 was carried out for 15 months and conformed to the *CSA B66* test protocol *(MASSTC, 2006)*. In the first three months of operation, the conventional tank accumulated 52% solids mainly as sludge, and the flooded A3 tank *(WaterTube)* had 15% solids with scum only in the inlet airspace. Table 1 shows Study 1 results of cBOD, COD, and TSS for influent sewage (DC West) and two tanks tested. The flooded A3 tank removed 24% cBOD and 78% TSS from the sewage, and the standard single compartment F3 tank removed 15% cBOD and 73% TSS.

FIGURE 4
cBOD analyses in Study 2 showing unexplained F3 anomaly at 170–230-day period.



WaterTube effluent averaged 158 mg/L cBOD and 43 mg/L TSS, and the F3 tank averaged 178 mg/L cBOD and 53 mg/L TSS. Unpaired student's *t*-tests indicate that the A3 and F3 effluent populations are statistically different at the 96%, 89%, and >99% levels of confidence, respectively. When the tank was pumped by a commercial pumper, the comments were "it looks like eight years of sludge buildup" in conventional tank F3, and flooded tank A3 "had a standard maintenance look" which is "three to four years' buildup" *(MASSTC, 2006)*.

Grab samples were taken along tank pathways to indicate evolution of anaerobic digestion and effluent maturity, using volatile fatty acids (VFA) and solubilization ratios of phosphate ion versus TP and ammonium versus TKN, as suggested by *Jeremy Kraemer (pers. comm., 2005)*, with Table 2 as an example (see *Jowett (2007, 2009)* for full details).

While not comprehensive, VFA generally increase from inlet to outlet, as do alkalinity and solubilization parameters. The performance parameters of cBOD, TSS, COD generally decrease as expected between inlet and outlet as the sewage is being treated.

Study 2: lower hydraulic loading rate

Study 2 was carried out for 12 months, with flows of 2500 L/d, increasing to 2850 L/d for the last two months. Tank A3 removed 35% cBOD and 81% TSS, and the F3 single compartment tank removed 13% cBOD and 76% TSS (Table 3).

The F3 anomaly in cBOD values for days 170–230 (Figure 4) is not explained by sewage values, and does not appear in COD or TSS values.

Conclusions

Removing the airspace to induce closed-conduit flow in a long, narrow, shallow septic tank results in substantially less scum and sludge formation and higher quality effluent compared to a conventional box-like tank with airspace. Introducing new technology into the environmental arena should be encouraged, to reduce pollution and improve health and safety. Standards organizations and regulators need to review existing prescribed designs, which may limit the treatment capabilities of the important septic tank, and to introduce performance standards and benchmarks suitable for Ontario's climate.

References

Bailey, W.A., Junnila, W.A., Aho, W.A. and Wheeler, W.C., 1957. A Heated Septic Tank for Disposal of Dead Poultry. Storrs Agricultural Experiment Station, University of Connecticut, *Progress Report* 21, 7 p.

BS 6297, 1990. Code of Practice for Design and Installation of Small Sewage Treatment Works and Cesspools. *British Standard Code of Practice BS 6297:1983* with *Amendment 6150:1990*, 40 p.

CMHC, 1984. *CMHC Septic Tank Standards*. Central Mortgage and Housing Corporation, 25 p.

CSA, 2005. *Standard B66: Design, material, and manufacturing requirements for prefabricated septic tanks and sewage holding tanks, 7th edition*. Canadian Standards Association, Mississauga, ON

D'Amato, V.A., Bahe, A., Bounds, T., Comstock, B., Konsler, T., Liehr, S.K., Long, S.C., Ratanaphruks, K., Rock, C.A., and Sherman, K., 2008. Factors affecting the performance of primary treatment in decentralized wastewater systems. *WERF 04-DEC-7 Research Digest*, Water Environment Research Foundation, Alexandria, VA, 38 p. with appendices

Dunbar, W., 1907. *Principles of Sewage Treatment*. Translated in 1908 by H.T. Calvert. Griffin, London.

Jowett, E.C., 2007. Comparing the performance of prescribed septic tanks to long, narrow, flooded designs. In, *WEFTEC Proceedings Technical Program 16*, San Diego, CA.

Jowett, E.C., 2009. Long-term comparative performance of two septic tank designs. In, *NOWRA Proceedings; Session 14: System Performance Evaluations and Modeling*, Milwaukee, WI.

Lay, R., Weiss, M., Pataky, K. and Jowett, C., 2005. Re-Thinking Hydraulic Flow in Septic Tanks. *Environmental Science & Engineering*, 18 (1), 50–52.

MASSTC, 2006. *On-site wastewater testing report 'WaterTube.'* Massachusetts Alternative Septic System Test Center, Falmouth, MA, 12 p.

Metcalf, L., 1901. *The Antecedents of the Septic Tank*. Trans. Am. Soc. Civ. Eng., XLVI (December, 1901).

Metcalf, L. and Eddy, H.P., 1930. *Sewerage and Sewage Disposal*. McGraw-Hill, New York, NY.

Novotny, V., Imhoff, K.R., Olthof, M. and Krenkel, P.A., 1989. *Karl Imhoff's Handbook of Urban Drainage and Wastewater Disposal*. Wiley, Hoboken, NJ, 416 p.

Rock, C.A. and Boyer, J.A., 1995. *Influence of Design on Septic Tank Effluent Quality. Proceedings*, 8th On-Site Wastewater Treatment Short Course and Equipment Exhibition, Seattle, WA, 45–62.

Winneberger, J.H.T., 1984. *The Septic Tank, Septic-Tank Systems, a Consultant's Toolkit. Volume II*. Butterworth, Boston, MA, 123 p.