Modern living necessitates double-filtering residential sewage

By E. Craig Jowett

In the 1950s, Ontario riverfronts were often smelly addresses for residential living, as sewers directed raw sewage into rivers and lakes. As kids we swam in and rafted on the Speed and Bighead, for instance, alongside still recognizable pieces of sewage. (Natural immunity to H1N1 may have been an unanticipated benefit!)

The Ontario Ministry of the Environment (MOE) cleaned up the rivers almost overnight in the 1960s by installing sewer systems and treatment plants. These are professionally operated and consistently remove organics, solids, ammonium, total nitrogen, phosphorus, and pathogenic microbes, before dispersal of treated effluent into now healthy rivers.

Natural soils 'managing' sewage

But what about septic systems used for residential sewage? In the 1950s, they consisted of a septic tank and a tile bed in natural soils; these were larger for clay soil and smaller for loamy soil, with no maintenance contracts. There was modest use of water, chemical cleaners and disinfectants, etc., and septic systems were deemed acceptable if the sewage did not rise out of the ground to create a health risk.

Today, the same sized septic tank and a tile bed, with no maintenance contracts required, are still the norm, but water usage has increased as has the use of chemical cleaners and disinfectants. Deterioration in septic tank health is very noticeable with excessive use of household chemicals. Without healthy microbes, sewage treatment will not occur.

There is no sign of improvement for septic systems, and, perhaps, not even any recognition of poor habits. Natural soils and groundwater are still relied upon to degrade sewage and disperse and dilute the products of decay; surface break-out is the only trigger to take care of unsafe operation. Disposal, not treatment, is still the objective of soil-based septic systems.

In 2001, a study was made of treatment performance in a code-required 900-mm-deep soil vadose (unsaturated) zone. After five months of biological maturing, effluent concentration over the next five months averaged ~30 mg/L BOD and ~20 mg/L TSS, with 96-99% removal of fecal coliform. This effluent quality, entering groundwater at a depth of 900 mm, is poorer than that following the double filtration technologies described below.

NSF Standard 40 testing for secondary quality effluent (<25 mg/L BOD, <30 mg/L TSS) ends six months after startup. The 900-mm-thick profiles tested in 2001 would not pass an NSF-40 test for secondary treatment units even with the underdrain, controlled laboratory conditions, and after the five-month startup period. When a treatment unit cannot pass a test protocol, then it should not be called a treatment unit.

The Ontario MOE requires campgrounds, golf courses, truck stops, churches, etc., to treat their sewage before it enters the natural soil. Organics and solids are to be removed before subsurface disposal, and treatment objectives for phosphorus, nitrate-nitrogen, and pathogens are becoming more prevalent before subsurface disposal. The same can be carried out for residences.

Is septic biomat needed in the soil?

Potent effluent from septic tanks (Figure 1) promotes a biological mass or "biomat", a black gelatinous slime and organic layer clogging soil porosity in the upper 150 mm or so. Accumulated organic matter plugs soil pores, decreases permeability, maintains anaerobic or septic conditions, ponds the sewage in the trenches, and increases the risk of unhealthy surface break-out.

Even in a coarse-grained sand filter, ponding of ~200 mm occurs within a few months of startup, peaking during winter, and increasing to ~250 mm in the second year.

Septic vs. aerobic effluent

Commonly heard speculation is that potent wastewater and septic biomat in soils are prerequisites, and that treatment of the sewage before it enters the soil may even be a health risk. In regard to residential sewage systems, an Ontario

Figure 1. Septic tank effluent is potent wastewater that can legally be placed directly into natural soil without treatment and without maintenance contracts.

Figure 2. Clear sand is a standard medium used for filtration of sewage. Microbial biofilm coats the sand grains as wastewater moves down through the narrow interstices between grains. Only treated effluent enters the natural environment.

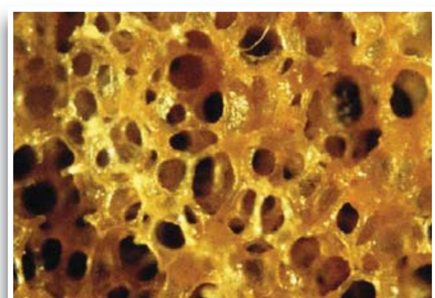

Figure 3. Beneficial microbes colonize interior surfaces of Waterloo Biofilter absorbent medium, and grow out into large open pores, allowing 10 times the loading rate of sand without plugging, with the same high-quality effluent.

Figure 4. Multiple-barrier Waterloo "flat bed" and shallow area bed system protecting sensitive lakefront property — as simple and aesthetic as a filter bed, but with an underdrain to promote free-draining aerobic conditions and a maintenance contract for sustainability.

Clear "sand-filter-quality" effluent of absorbent filters can be verified and dispersed into the natural soil environment with minimal contamination and less health risk even on difficult sites.

regulatory body has said:

"The potential for contamination is increased when highly treated effluent is used and there is no clogging layer formed on the soil surface. The clogging layer, which is formed when septic tank effluent passes through the soil, significantly reduces the coliform bacteria count before it reaches the groundwater. Pre-treated effluent is less likely to form a clogging layer, in which case the effluent will reach the groundwater more quickly with less treatment in the soil."

"The detrimental effect of non-uniform distribution is further amplified when ..... highly treated effluent is applied."

Some scientists echo this. In a 2001 article in *Water Research*, S. Van Cuyk and others stated; "If clogging zone development is retarded or absent altogether, for example due to the application of highly pretreated effluent (e.g., sand filter effluent), purification of pathogens and other constituents of concern may be less than predicted and desired."

The logic of this argument would lead us to believe that rainwater infiltrating the soil is very risky because it is too clean to develop a septic biomat. Of course, this stance is as insupportable as saying, "Brantford should not treat its sewage — only the Grand River can do it safely."

Biological film does, of course, develop in a sand filter, as in all biological filters, and microbes have already done the job of the soil-based biomat, but independent of the natural environment.

Oxygen supply is needed

Ignored is the fact that high-quality effluent carries its own oxygen supply (4-8 mg/L D.O.) into the soil and, with <5% of the organic content of septic effluent, it is far less reliant on the vagaries of natural soils for treatment, especially on soil air influx to promote the aerobic treatment objective.

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Oxygen delivery down through soil pores to treat sewage, and its effect on biomat and sewage ponding, were discussed by J. Erickson and E.J. Tyler in the 2000 NOWRA *Conference Proceedings:* "Clogging mats [biomat] develop when organic matter loading is higher than the oxygen supply for aerobic bacteria. If the oxygen supply meets the demand of the soil organisms, then the organic clogging mat will not form. In the absence of a mat, the soil could accept wastewater at rates of two to three orders of magnitude higher than the current design loading rates."

Biomat and ponding are an effect of organic overloading of the soil interface at times when insufficient oxygen enters the soil-water interface to promote aerobic decomposition. Septic biomat appears not to be a desirable or necessary development. It may instead indicate overloading from insufficient trench length and poor soil air infiltration.

On filtration treatment units, such as sand, peat or absorbent foam, excessive sewage ponding on the filtration surface is viewed as hydraulic failure and requires recovery; the same standard applies to soil filters. Because it is an introduced accumulation of excess sewage by-products in the soil profile, septic biomat may in fact be termed a "soil contaminant".

Erickson & Tyler also stated, "...... the soil component of the wastewater infiltration system should be large, shallow, narrow, and have separated infiltration areas to maximize oxygen supply." In order to promote aerobic treatment in soils (which clogs the soil far less), it is better to have longer and narrower trenches, wider spacing between trenches, and higher-quality effluent with low organic loading.

In Ontario residences, sewage may be placed directly in trenches, 900 mm wide and 900 mm deep, and in tight soils, counter to oxygen delivery requisites. Even if treatment does occur, it is not verifiable, and soil-based systems can be termed only 'disposal', 'absorption' or 'dispersal', not 'treatment'.

Sand filtration: integrated disposal system

The MOE carried out world-class research in the 1970s on tank sludge accumulation rates, sand filtration (Figure 2), contaminant attenuation in groundwater plumes, etc. It formed the basis of Ontario's prescriptive subsurface regulations in 1982 and of OBC Part 8 in use today.

It has been demonstrated that sewage can be treated outside the natural environment to very high "sand-filter quality" (<10 mg/L BOD and <10 mg/L TSS) in the Canadian climate, with only clear effluent entering the earth for "polishing." Fecal coliform attenuation is excellent with a smaller sand grain size, but the coarse fractions can emit >200,000 cfu/100mL.

Biological filtration is the mainstay of small sewage treatment systems in Canada, because of low-energy input, ease of use, and ability to treat cold sewage. Biological film-forming microbes populate the surfaces of the filtration medium and consume contaminants that pass by. Septic and aerobic biofilm stays within the filtration unit and outside the natural environment.

The MOE sand filter (OBC Filter Bed) began the trend of recognizing poor habits of soil disposal, and of minimizing soil and groundwater contamination.

Under present practices, the filter bed is installed without the underdrain (as it was originally tested), and, therefore, its performance cannot be predicted or verified. It is a single, integrated system, with sand and soil disposal combined. Clay soil below the sand filter is wetted and "smothered" by the sewage and sand cover, and its permeable topsoil structure is destroyed. A sand "mantle" is placed to the side for lateral dispersal into the shallow topsoil, but integrated into the filtration unit with no chance of verification.

It would be an improvement to underdrain the filter bed to verify treatment as tested, use the finer sand sizes and lower 50 L/m^2/d loading rate to improve pathogen removal, collect the effluent to verify treatment, polish the effluent in a separate finer sand bed to provide further removal of viruses and residual *E. coli*, and have maintenance contracts. These additions would bring filter beds up to the standard of the multiple-barrier, detached treatment-disposal systems discussed below.

Absorbent filtration: detached treatment disposal system

The industry has developed technologies that separate the aerobic filtration treatment and infiltration polishing functions from each other, primarily for verification and maintenance purposes. The biological treatment filter is kept unsaturated, with an underdrain for verification, followed by subsurface disposal in a thin bed of crushed stone and 250 mm of fine grained sand, high in the soil horizon to simulate the role of the "mantle" adjacent to a conventional raised sand filter.

In vertical flow conditions, the fine sand layer slows down the flow of treated effluent, disperses it over a wide area and removes all detectable residual fecal coliform, even at an extreme loading of 212 L/m^2/day. This fine sand polishing layer is suitable for installation on fractured bedrock, coarse soil, or near the water table.

In lateral flow conditions (clay soils), the fine sand removes fecal matter concentrations to swimming water quality levels within 5 m distance, and to non-detectable levels in 10 m, ensuring that surface stormwater ditches or rivers are protected by subsurface sand polishing after absorbent filtration treatment.

Absorbent filtration units, using engineered peat or synthetic open-cell foam, have been in continuous operation for about 17 years in Canada and the United States. The media are consistent in their physical properties for a more predictable performance, especially compared to soil. As in sand filters, sewage is treated outside the natural environment and septic biomat contamination is restricted to the filtration medium.

Unlike integrated sand filters, detached filters can be inspected for ponding malfunction, treatment can be verified in the underdrain, and the system can be recovered after ponding before the entire system needs replacing.

In the case of Waterloo Biofilter® open-cell foam medium (Figure 3), the physical properties are the reverse of sand, with large open pores instead of sand grains, and large water pathways instead of narrow interstices. Wastewater is absorbed into a sequence of foam pieces or slabs between capillary gaps in which the microbial colonies are protected from desiccation and freezing.

'Multiple-barrier' protection of soils and groundwater

Natural soil should not be used as a sewage dump, just as we have stopped using oceans for garbage. Ontario filter beds can be made verifiable by installing underdrains, which would keep the sand free-draining and aerobic. High-quality effluent from filter beds, peat or foam filters can then be placed in a "shallow area bed" for low-risk disposal.

The shallow area bed technology, used in Ontario since 1994, affords a two-stage filtration treatment train (Figure 4). The "roughing filter" of sand, peat or foam removes ~95% of the organics and >99% of *E. coli.* The second "polishing filter" is the fine sand layer in the shallow area bed, that removes the remaining *E. coli* for a total of 99.9993% removal before entering the natural environment. The soil and the groundwater are both protected, and health risks are minimized.

The double safeguard of filtration treatment followed by filtration disposal is similar to the preferred "multiple-barrier" approach to drinking water safety outlined in the Report of the Walkerton Inquiry: "The multi-barrier approach or defence in depth … has been an approach which has long been used by the water industry … to provide safe and secure supplies of drinking water … we don't rely only on one barrier in the system, we rely on a series of barriers."

The single biomat barrier in soil-based septic systems does not provide the safety of the multiple-barrier approach.

Conclusion

Following the trend of improving management of our larger wastewater flows and other waste types, the use of natural soils to dispose of untreated residential sewage is no longer tenable from a technological, health and safety, or environmental viewpoint. Filtration treatment of residential sewage, before disposal, is required for sustainability of our soil and groundwater resources.

E. Craig Jowett, Ph.D., P.Eng., is with Waterloo-Biofilter Systems Inc. E-mail: craig@waterloo-biofilter.com