Suitability of Using "End of Pipe" Systems to Treat Farm Tile Drainage Water

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Introduction

Many farms in Ontario rely on subsurface "tile" drains to help remove excess water from farm fields. Despite all of the benefits from a "crop production", and even from an "environmental protection" point of view, tile drains can act as conduits for contaminants. This can allow rapid movement of these contaminants to surface water. Many practices have been promoted over the years to prevent this movement of nutrients and other materials. The approach has been that it is much more efficient to prevent a problem than to clean it up after the fact. However, there may be cases where an "end-of-pipe" treatment system makes good sense and serves as a backup level of protection. This review is an attempt to document the kinds of end-of-pipe treatment systems available on the market and to judge whether or not they may be suitable for improving the water quality from agricultural drainage systems.

Contaminants

Over the years, land owners have come to recognize that installing drains is one of the most beneficial capital improvements they can make to a farm. The greatest value is in their ability to lower the water table in the spring and fall and to remove excess water after rains occur during the growing season. Drains have been shown to increase crop yields, allow more flexibility in crops grown, improve efficiencies of land operations, and reduce soil erosion, among other benefits.

Occasionally, however, these drains have served as conduits, speeding up the movement of contaminants to surface water (i.e. ditches, streams, etc.). The major potential contaminants reaching surface water through this pathway include:

> **Pathogens** - This includes a number of strains of bacteria and other micro-organisms that can cause disease in humans and/or animals. The main sources of these are human and animal feces. The animals could include wildlife, but the bigger concern has been the flow of liquid manure through soil macropores at spreading time. There have been cases of domestic septic systems with illegal connections to field tile systems - contributing pathogens to surface water. Also, there have been cases of milkhouse washwater systems illegally connected to tile drains. In the past decade, there has been a greatly increased awareness of these problems and many landowners have taken steps to eliminate or reduce potential contamination.

Nitrogen - This nutrient is used extensively for crop production. Two forms of nitrogen are of concern in surface water. Ammonium-N is usually not detectable in tile water. It may be found immediately following application of nitrogen fertilizer to the land, especially in the anhydrous ammonia form. Also, it represents over half the N content of liquid manure so is often associated with manure entry to tile drains. The other common form of N is as nitrate. Concentrations vary in tile water. A three-year survey of 20 tile drain outlets in southwestern Ontario found an average nitrate-N concentration of 17.0 mg/L (Fleming et al 1998). One of the best ways to keep nitrate out of tile water is to practise good nutrient management - adjusting fertility applications based on the needs of the crops and the background levels in the soil.

Phosphorus - Often the limiting nutrient for algae growth in surface water, P is another nutrient widely used in crop production. It is a main cause of eutrophication of surface waters. Usually, it is associated with overland flow, because it is easily bound to soil particles. However, it has been measured in tile drains at elevated levels. In the study by Fleming et al (1998), the average tile water P concentration was 0.48 mg/L. The provincial target maximum value is 0.03 mg/L. Once again, proper nutrient management is the best way to keep P out of tile drains.

BOD (Biochemical Oxygen Demand) - This is a way of expressing the amount of organic matter in a liquid. As the organic matter is broken down by microorganisms, oxygen is used up. This competes with the oxygen needs of aquatic life. BOD in tile drains is usually associated with either livestock manure or milkhouse washwater or domestic septic systems. Typical treated sewage (i.e. discharged to surface water from a sewage treatment plant) has a BOD concentration of less than about 8 mg/L. Raw sewage, on the other hand is often in the range of 150 to 250 mg/L. Runoff from a solid manure pile may be in the range 400 to 10,000 mg/L. Liquid manure is usually in the range 10,000 to 30,000 mg/L. Therefore, even with dilution, liquid manure entering surface water has the potential to do a great deal of harm.

Traditional Solutions

There is little question that preventing entry of contaminants to a drainage system is much more efficient than treating the water after contamination. This is the basis of nutrient management planning, the Environmental Farm Plan and the Best Management Practices (BMP's) that many crop and livestock producers have been following for the past several years. Examples of strategies that have been used:

a) when applying livestock manure (liquid or solid) to the land - proper selection of timing of application (e.g. season of year, no rainfall in weather forecast, no tile water flowing), proper selection of application rates, consideration of soil moisture conditions, etc.

b**) when applying liquid manure to the land** - pre-tillage of soil to break up macropore pathways
c) when applying liquid manure to land - monitor tile outlets to make sure there is no manure flow in the tiles - may be followed by plugging the tile and pumping the liquid back on to the land if a problem is found
d) when applying liquid manure to land - plug the tile outlet and force any drainage water to back up in the drain for a period of time (e.g. a week) to minimize any eventual impact on surface water - can work in certain specific cases (Fleming et al 1995)
e) when any contaminant reaches the tile drain - rely on dilution in the receiving surface water to reduce concentrations to an acceptable level (this strategy is not one that is typically relied upon by farm operators, but sometimes comes to the rescue)

Even after following all of the recommended management practices, it is still possible that contamination of tile water may occasionally occur. It would be re-assuring to know that a back-up system might be used in specific high risk cases to provide an extra line of defence.

End of Pipe Systems
End-of-pipe treatment systems are sometimes used in urban stormwater management and in industrial settings. They are based on providing some form of treatment just before the water is discharged into the receiving waters. Following are examples of research studies involving these systems.

In 2002, a review was carried out on the management practices used for controlling water quality in California (Lee and Jones-Lee 2002). This review dealt mostly with issues regarding runoff of irrigation water. According to this review, the main urban Best Management Practices (BMP's) in use at the time were:

- drain inlet inserts
- extended detention basins
- biofilters
- media filters
- infiltration

Table 1, from this review, details the effectiveness of each system in removing contaminants from water. The review found that many BMP's could remove nitrogen, phosphorus and pesticides under certain climatic and low flow conditions. However, few could remove nitrogen and phosphorus or other contaminants under high flow conditions (Lee and Jones-Lee 2002). The authors discussed the science of developing BMP's. They stated that vegetative ponds and other conventional agricultural BMP's are often not effective at removing many of the pollutants in agricultural runoff during elevated flow conditions. The problem is related to the short hydraulic residence time of the water passing through the unit. Therefore, agricultural runoff treatment systems have to be able to handle high flows.

Table 1 - Percentage Reduction in Storm Water Load by BMP

Runoff Control	Solids	Nutrients	Pesticides	Metals	Bacteria
Drain Inlet Insert	10	5	5	5	5
Ext. Detention Basin	75	25	25	50	40
Vegetated Swales	70	30	30	50	0
Filter Strips	85	40	40	63	0
Media Filters	85	40	40	70	55

(Lee and Jones-Lee 2002)

The study went on the summarize advanced treatment controls for urban stormwater runoff:

- ion-exchange
- reverse osmosis
- disinfection
- ultra-filtration

Unfortunately, none of these had been tested on a prototype scale for stormwater. These systems could potentially be used to treat contaminated runoff from agricultural operations (Lee and Jones-Lee 2002).

In southwestern Ontario, Ng et al. (2001) carried out a study that compared controlled drainage and sub-irrigation (CDS) to "free" tile drainage (FD). A farm was divided into two 1.9 ha plots and planted with corn. One plot had a free tile drainage system and the other plot had a CDS system. The average field slope was 0.5%. Each plot had 10 subsurface tile drains, spaced at 6.1 m between tiles. The average drain depth was 0.6 m below the soil surface. The CDS system was manufactured by Innotag Inc. a company from Montreal named The researchers found that with the CDS treatment, the crops used N and water more efficiently. This resulted in increased productivity and improved water quality. The nitrate concentration was reduced by 41% and the nitrate loss in tile drainage water was reduced by 36% with the CDS system compared to FD (Ng et al. 2001). Therefore, the controlled drainage and sub-irrigation system increased crop productivity and improved water quality.

Wong (2000) reported on a large petrochemical plant that investigated the possibility of wastewater recycling using end of pipe treatment. The plant was located in an area that usually suffered from drought. The operators wanted to evaluate the advantages of water conservation. The system took effluent from the organic wastewater treatment system and the cooling tower and treated the blended water with a membrane-based treatment system that included ultra-filtration and reverse osmosis. The reverse osmosis removed dissolved inorganic, organics, silica and residual colloidal materials. The treatment system was a success in conserving water resources.

Chung et al. (2000) conducted a study on the use of natural zeolite media as a way to remove nitrogen and organics from industrial wastewater. Zeolite is well-known for its capacity to preferentially remove ammonium ions from wastewater. An oxic/anoxic (O/A) process was modified in order to treat a high concentration of ammonium ion in the influent. The study concluded that with powdered zeolite in the modified O/A process, high nitrogen and organics removal efficiencies were obtained.

Bio-filters have been used to treat tile effluent. A field study carried out by Blowes et al (1994) used two bioreactors to remove nitrate-N from tile drainage water. Each bioreactor had a 200 L capacity and effectively lowered nitrate-N concentrations from initial concentrations of 3 to 6 mg/L to less than 0.02 mg/L. The system contained sand and organic carbon and its effectiveness relied on denitrification. The system handled flows of 10 to 60 L per day. Unfortunately, scaling up to a size needed to handle typical tile flows poses a problem with this system.

Members of the Blowes et al (1994) study team continued to work on the problem. Some of the work evolved into the study of Permeable Reactive Barriers (PRB's). These are trenches that act as biofilters, containing wood chips or other materials. Most of the research has looked at removing dissolved metals and nutrients from groundwater (e.g. near a contaminant source). Bioreactors have, however, been tested at tile drain outlets and have proven successful in removing nitrate from the water. A typical trench might be in the order of 1 m x 1 m x 10 m, filled with layers of organic materials. The work is near completion on this study (Merkley 2004).

Constructed wetlands (and natural wetlands) have been used for several years to treat wastewater/stormwater. Depending on circumstances, wetlands may remove over 70% of excess nutrients and they are "good" to "excellent" at removing bacteria (Taylor and Associates 1992). Unfortunately, size is an important issue. A 20 ha field would need a wetland of about 1 ha. This land area is seldom available at a tile drainage outlet.

Flow Rates

One of the drawbacks with a number of the systems on the market is that they are not designed to handle the high flow rates associated with agricultural runoff or agricultural drainage systems. To help put this into perspective, consider the design of tile drainage systems. One of the design criteria is the "drainage coefficient". This quantity represents the depth of water that a drainage system should remove from a field in a 24 hour period. The current number used for most Ontario on-farm systems is 12.5 mm (½ inch). Crop producers cannot afford to have water sitting on a growing crop after a heavy rain. This water must be removed as soon as possible. Based on 12.5 mm in 24 hours, a 10 ha field could have tile flows of about 870 L/min (1.25 million L/day) at the outlet pipe.

As mentioned earlier, the three-year survey of drain outlets in southwestern Ontario by Fleming et al (1998) found an average nitrate-N concentration of 17.0 mg/L. For the 20 drains in this study, the maximum flow rates averaged 49.9 L/min per ha. These maximum values ranged from 9.0 to 222 L/min per ha. The average size of drainage area for the 20 outlets was 15.9 ha, and the range was from 1.8 ha to 59.5 ha (Fleming 2004). Several of the systems listed below have treatment capacities less than 10 L/min. These would have

limited usefulness in typical farm situations, strictly from a capacity standpoint.

Systems Commercially Available

Following is a list of several systems that have been designed to treat stormwater or other water containing low levels of contamination. The list consists of a cross-section of systems advertised on the internet. All are commercially available - i.e. they are not still in the development stage.

Product Name: **Advanced Water Filters**
Manufacturer/Distributer: Advanced Water Filters (www.advancedwaterfilters.com)
Approx. Cost: $385 US
Intended Use: residential wastewater
Performance: - uses reverse osmosis
                      - filters are easily changed

Product Name: **AmmEl System**
Manufacturer/Distributer: Enpar Technologies Inc. (www.enpar-tech.com)
Approx. Cost: operating: $1.63 per kg NH_3-N removed
Intended Use:
Performance: - converts ammonia to nitrogen gas
                      - uses ion-exchange column to remove ammonia from the waste stream
                      - leaves an ammonia-reduced effluent
                      - when the column becomes loaded with ammonia the waste stream is diverted to another column
                      - the ammonia is then collected and using an electrochemical process is turned into nitrogen gas

Product Name: **AQUAMEND**
Manufacturer/Distributer: Adventus Remediation Technologies (www.adventusremediation.com)

Approx. Cost:
Intended Use:
Performance: - conducted in fixed-film
                      - up-flow bioreactor units
                      - aerobic pre-treatment
                      - biocarriers support the growth and activity of denitrification bacteria
                      - nutrient packages are periodically added to the reactor to enhance denitrification activity
                      - can treat from 1,500 to 50,000 L/day (i.e. 1 to 35 L/min)

Product Name: **Chlorinator Systems, Sulfur and Iron Filters**
Manufacturer/Distributer: Your Water Needs (www.yourwaterneeds.com)
Approx. Cost:
Intended Use: residential wastewater
Performance:

Product Name: **Chlorine Dioxide**
Manufacturer/Distributer: Lenntech (www.lenntech.com)
Approx. Cost:
Intended Use: residential & industrial wastewater
Performance: - kills microorganisms by disrupting the transport of nutrients across the cell wall
- have to add acid to activate disinfectant
- only reacts with reduced sulfur compounds, secondary and tertiary amines, and some other reduced/highly reactive organics

Product Name: **Glendon BioFilters**
Manufacturer/Distributer: Glendon BioFilter Technologies (www.glendon.com)
Approx. Cost:
Intended Use: residential wastewater
Performance: - wastewater flows through sequential layers of mineral filter media within a containment vessel
- can treat from 340 to 5,700 L/day (i.e. 0.24 to 4 L/min)

Product Name: **NITREX**
Manufacturer/Distributer: Wastewater Science Inc.
Approx. Cost: $2,900 US (plus delivery)
Intended Use: residential wastewater
Performance: - reactive media is inclosed in a concrete tank
- effluent from septic tank is distributed by gravity flow to top of unit using PVC weeping tile
- for a 2,700 L unit average flow would be 300 L/day (i.e. 0.21 L/min)

Product Name: **Ozone, Oxygen, Water Filters, Controllers**
Manufacturer/Distributer: Environmental Water Solutions, Inc. (www.ozone-ews.com)
Approx. Cost:
Intended Use: industrial wastewater & urban stormwater treatment
Performance: - disinfection
- oxidation
- can treat from 83 to 4,200 L/min

Product Name: **PHOSPHEX**

Manufacturer/Distributer:	Lombardo Associates, Inc. (www.lombardoassociates.com)
Approx. Cost:	for residential use: $3,500 to $4,500 US
	for industry use: $0.5 - $1 /L/day
Intended Use:	residential wastewater & industrial wastewater
Performance:	- phosphorus contaminated water is gravitationally fed through the treatment module
	- wastewater must be pre-treated before entering the PHOSPHEX to reduce to organic loading on the media
	- can treat flows greater than 9500 L/day (i.e. 6.6 L/min)

Product Name: **The Snout**

Manufacturer/Distributer:	Best Management Products, Inc. (www.bestmp.com)
Approx. Cost:	less than $250
Intended Use:	- residential wastewater & urban stormwater treatment
Performance:	- precipitation of suspended solids
	- durable plastic
	- anti-siphon vent
	- controls discharge rate

Product Name: **Stormceptor**

Manufacturer/Distributer:	Rinker Materials (www.rinkermaterials.com)
Approx. Cost:	
Intended Use:	urban stormwater treatment
Performance:	- stormwater quality treatment
	- product line includes: in-line stormceptor, inlet stormceptor, series stormceptor, spills capture, submerged stormceptor

Product Name: **Wastewater Treatment Systems**

Manufacturer/Distributer:	Alkota (www.alkota.com)
Approx. Cost:	
Intended Use:	industrial wastewater
Performance:	- evaporators leave only a sludge that must be disposed of
	- water recyclers remove unwanted residue leaving high quality water that can be reused
	- 3.78 L/min

Product Name: **Water Treatment Plant Process Equipment**

Manufacturer/Distributer:	US Filter (www.water.usfilter.com)
Approx. Cost:	
Intended Use:	residential wastewater & industrial wastewater
Performance:	- variety of different systems

Product Name: **Waterloo Biofilter**

Manufacturer/Distributer: Waterloo Biofilter Systems Inc. (www.waterloo-biofilter.com)
Approx. Cost:
Intended Use: residential wastewater & industrial wastewater
Performance: - a single-pass aerobic biofilter
                        - uses an absorbent synthetic filter medium
                        - natural microbial action in the filter medium is enhanced by
                        its high porosity
                        - large surface area

Product Name: **Whitewater Aerobic Wastewater Treatment Units**

Manufacturer/Distributer: Delta Environmental Products, Inc.
                        (www.deltaenvironmental.com)
Approx. Cost:
Intended Use: industrial wastewater
Performance: - uses natural bacteria that helps speed up the process of
                        breaking down the sewage
                        - raw domestic sewage is mixed by air distribution system
                        - clear, odourless water is discharged
                        - can treat from1520 to 5700 L/day (i.e. 1.1 to 4 L/min)

The above systems are designed to treat a variety of problems. Table 2 summarizes the intended uses of the various systems. Those designed to handle urban stormwater runoff are typically the systems designed to remove sediment (i.e. solids) and oils. No single system would be appropriate for removing the target contaminants sometimes found in tile drainage water: BOD, P, N and pathogens. It is possible that systems could be combined, depending on the particular risks at the farm involved - of course adding to the cost.

Table 2 - End of Pipe Treatment Systems - What they Remove

Product	Pathogens	N	P	Solids	Metals	Oil	Odour	BOD
Advanced Water Filters				✔	✔			
AmmEl System		✔						
AQUAMEND		✔						✔
Chlorinator Systems, Sulfur and Iron Filters					✔			
Chlorine Dioxide	✔							
Glendon BioFilters				✔				✔
NITREX		✔						
Ozone, Oxygen, Water Filters, Controllers	✔			✔			✔	
PHOSPHEX			✔					
The Snout						✔		
Stormceptor				✔		✔		
Wastewater Treatment Systems				✔		✔		
Water Treatment Plant Process Equipment			✔	✔	✔		✔	
Waterloo Biofilter		✔		✔				✔
Whitewater Aerobic Wastewater Treatment Units	✔							

source of details: website advertising/promotion

Summary

Sometimes, despite the best efforts of the farm operators, contaminants can enter tile drainage systems. The four contaminants representing the greatest risk of occurrence on farms are: BOD (organic matter), Phosphorus, Nitrogen (as either nitrate or ammonium) and pathogens. At least in certain cases, there would be advantages to having end-of-pipe treatment systems available to farm operators. These would act as an extra line of defence, preventing contamination of surface waters by tile drainage systems. Some treatment systems are available that address these particular contaminants, though no systems will remove all four. Also, several of the systems on the market have been designed to remove contaminants that are not typically a concern in farm tile drainage water (e.g. metals and oils). Finally, many of the available systems have been designed for flow rates much lower than peak drainage rates found on farms. Unfortunately there is no good way to deal with this, since there are typically no ways to store the drainage water to moderate flows.

It is possible that farmers with very specific concerns will benefit from available systems. For the most part however, it appears that there would be only a limited demand to treat tile drain water using existing systems. Farmers should continue to follow the Best Management Practices needed to ensure the highest quality of drainage water.

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