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Filtering drainage water

Use of industrial byproducts shows potential in reducing nutrient and pesticide transport in subsurface drainage.

Tile drains and French drains are typically used to control subsurface drainage, especially on greens and fairways with shallow water tables or fine soil texture. Tile drains are defined as "drains constructed by laying drain tile with unsealed joints in the bottom of a trench which is then refilled," whereas French drains are a "type of drain consisting of an excavated trench, refilled with pervious materials such as coarse sand, gravel or crushed stones, through whose voids water percolates and flows toward an outlet" (ASAE Standard S526.2, 2001). Tile drainage and other subsurface drainage features are considered essential by turfgrass managers to maintain water tables at depths necessary for healthy plant growth; maintain sufficient water and air in soil void space to stimulate essential microbial activity; avoid rutting and soil compaction by maintenance equipment; and to allow site use soon after heavy rains.

Subsurface drainage increases the subsurface movement of excess water and facilitates infiltration. However, discharge from subsurface tile drains is known to carry elevated levels of dissolved pollutants such as phosphorus, nitrogen and pesticides. Agronomic practices alone such as application timing, placement and rate have not appreciably reduced the pollutant transport in tile drains.

Nutrient and pesticide transport through subsurface drainage systems may become a component of surface runoff if the drainage water discharges directly into surface water or onto the surface offsite or downslope. Subsurface drains conveying water directly into a stream or pond will bypass natural and managed filtering processes, including upland and riparian buffer zones. To protect these surface waters and comply with regulatory and/or permitting laws, treatment of the waters prior to their entry into a surface water body may be required. In-situ physical and structural approaches are being considered to address this concern.

In laboratory bench scale studies, natural minerals and industrial byproducts (e.g. zeolite, fly ash) have exhibited a range of success removing nitrogen, phosphorus and pesticides. For example, industrial byproducts high in aluminum, iron and calcium, such as fly ash, blast furnace slag and water treatment residual are ideal phosphorus-sorbing materials, while clinoptilolite, a naturally-occurring, inexpensive zeolite, has been shown to effectively remove ammonium-nitrogen from aqueous solutions. With respect to pesticides and other organic contaminants, adsorption to activated carbon is the preferred method for their removal from source waters. Inexpensive, activated carbons developed from coal, lignin (paper industry) and coconut byproducts have exhibited high contaminant-removal efficiencies.

Current research is designed to address the potential for utilizing a blend of these types of byproducts in an end-of-tile filter to significantly reduce the transport of nutrients and pesticides from golf course tile drainage outlets. The research will be conducted in two phases. The first phase is a controlled large-scale laboratory experiment designed to evaluate the filter's effectiveness while operating at flow rates comparable to those measured in the field. The second phase is a before-and-after field assessment of the filters under prevailing management practices on an existing golf course.

Table 1. Media Component Properties

Material	Chemical composition	Grain size (mm x mm)	Surface area (m^2/g)	Bulk Density (g/cm^3)
Activated carbon (Coconut Shell)	C	2.38 x 0.60	1100-1200	0.484
Activated alumina	Al_2O_3	1.41 x 0.61	380	0.673
Zeolite (Clinoptilolite)	$(Na_3K_4Ca)(Al_8Si_{40}O_{96})\cdot 2H_2O$	2.38 x 0.84	40	0.905

LABORATORY STUDY

For the laboratory study, a hydrograph generator was created to simulate tile flow discharge. Hydrographs with peak flow rates of 10, 20, and 30 gallons per minute were studied. The hydrographs were generated from a 2,000 gallon supply reservoir containing a solution of nitrate nitrogen (12 ppm), dissolved phosphorus (0.9 ppm), chlorothalonil (34 ppb) and metalaxyl (13 ppb). The initial concentrations were representative of or greater than concentrations generally measured in tile drainage discharge from managed turf. The water was pumped through the filter assembly using the hydrograph generator. Samples were collected prior to entering

Table 2. Mean (standard deviation) percent reduction in total load resulting from discharge water passing through the filter, summarized by hydrograph peak flow rate and pollutant (n represents number of replicates).

Peak Flow (L/s)	NO_3-N (nitrate nitrogen)	DRP (dissolved phosphorus)	Chlorothalonil	Metalaxyl
0.63 (n=3)	5.2 (0.43) a	53.5 (1.75) a	59.3 (1.89) a	31.0 (1.31) a
1.26 (n=3)	4.9 (0.56) a	53.9 (4.71) a	64.4 (7.45) a	30.1 (5.52) a
1.89 (n=3)	3.9 (0.11) b	47.3 (10.87) a	50.8 (12.05) a	25.5 (4.05) a
mean across all flows (n=9)	4.7 (0.68)	51.6 (7.17)	58.2 (9.91)	28.8 (4.58)

* mean (standard deviation) values within columns followed by different letters indicates statistically significant differences ($p<0.05$).

the filter and after flowing through the filter. The filters were created with a blend of activated carbon, activated alumina, and zeolite (Table 1, page 40). The blend was created by using equal parts by weight of each material.

Significant reductions in concentrations and loading across all three hydrographs were measured for dissolved phosphorus (51.6 percent), chlorothalonil (58.2 percent), and metalaxyl (28.8 percent). Nitrate nitrogen was reduced by 4.7 percent. Peak flow rate had a measurable effect on the amount of pollutant removed from solution (Table 2). In general, filter removal efficiency for all four contaminants tended to decrease as peak flow rate increased across all peak flow hydrographs. Removal efficiency also depended on the pollutant type. For example, approximately 50 percent reduction in the total loads of dissolved phosphorus and chlorothalonil was observed as a function of flow rates across all peak flow hydrographs (Table 2). Similarly, metalaxyl removal was nearly 30 percent of its total load. In contrast, filter removal efficiencies for NO_3 were significantly less (4 to 5 percent).

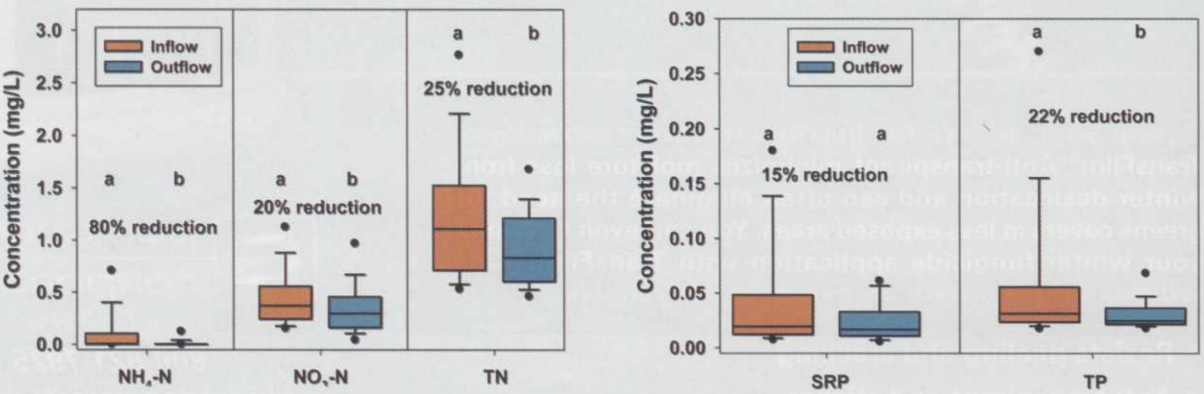
The reduction of dissolved phosphorus measured here is comparable to results achieved by incorporating aluminum oxide materials into the soil. However, the extent of dissolved phosphorus removal observed in this study was not as great as that observed in previously cited batch and column type studies. The reduced efficiency was attributed to shorter contact times with the filter media, a direct consequence of greater flow rates.

With respect to nitrate removal, the results were somewhat surprising; we expected a greater removal efficiency than was observed. Admittedly, clinoptilolite has been identified as an ideal agent for sorbing nitrogen as ammonium and not nitrate. However, activated carbon has been shown to be an effective nitrate sorbent. Nitrate removal may be most efficiently and economically achieved through microbial denitrification prior to or after water discharge through an end-of-tile filter. Cellulosic byproduct materials such as wood mulch, sawdust and leaf compost are well-suited, abundant and sources of carbon necessary for microbial denitrification.

Regarding chlorothalonil and metalaxyl, we assume adsorption to activated carbon to be the primary removal mechanism due to their chemical structure and hydrophobic nature. Variation in chemical structure may account for the differential removal efficiencies observed for each of these pollutants.

For example, chlorothalonil is significantly less water soluble (0.6 ppm) than metalaxyl (7100 ppm). Thus metalaxyl may be more hydrophobically attracted to the activated carbon in the filter cartridge than chlorothalonil. As with dissolved phosphorus, total removal of metalaxyl and chlorothalonil remained relatively constant

Figure 1. Box and whiskers plots of various nitrogen and phosphorus species entering (inflow) and exiting (outflow) filter cartridge system at Northland Country Club, Duluth, Minn., (n = 51) during 2009 sampling period. Boxes are bound by 25th and 75th percentiles, line in the box is median. Whiskers represent 10th and 90th percentiles while filled circles represent 5th and 95th percentiles. For each nutrient specie, different letters indicate statistically significant differences in median values (P < 0.05).



over the three studied hydrograph shapes. We attribute this trend to the high surface area of activated carbon. Again, using different types of activated carbons could increase their removal efficiency.

As previously described, the removal efficiency for all contaminants was consistently highest at the extremes of the rising and receding limbs of the hydrograph when the flow rates were least (and residence time high).

Thus, not surprisingly, this filter design may be most effective under baseflow conditions rather than storm flow events. These filters can be used under baseflow and storm flow conditions. However, the large volume of storm flow may rapidly expend the filter. Overall, further field-scale, long-term studies of these filters are required to determine the longevity of these filter materials; once adsorption sites are exhausted the filter will require replacement.

FIELD STUDY

The field phase of the research is taking place on two golf courses (Ridgewood Country Club, Waco, Texas, and Northland Country Club, Duluth, Minn.). The experiment in Waco is set up on a practice chipping green. The 8,000 square-foot green is 100 percent sand.

Water drains through a subsurface network of 4-inch perforated tile to an outlet containing a filter network. The filter has

IMPACT ON THE BUSINESS

Protecting water quality

A closed-loop bioremediation system was the answer to high contaminants found in a water way at The Rock Golf Club in Ontario. BY JASON WINTER

Planning for The Rock Golf Club and the resort began in 1998. It was marketed as Canada's first JW Marriott property and as one of the country's newest and exciting resort communities. Local residents, numerous environmental groups, and the Township of Muskoka Lakes raised many environmental concerns about the proposed use of land in a pristine region of Ontario.

The boom of new golf course construction in the Muskoka region during the 1990s, in conjunction with concerned citizens' questions about the new development, resulted in requests for several studies to be conducted to determine the health of the region's lands and lakes prior to this proposed development. In the end, the construction of The Rock was approved and a new standard was developed that would be the new environmental guideline that all new courses planned for construction in Canada would have to follow. Once the site plan agreement was in place and construction was underway, The Rock faced many challenges and continues to be under the watchful eye of adjacent landowners and the Township of Muskoka Lakes.

Water quality management continues to play a major role and is a major expense to the club as very aggressive monitoring of existing tributaries and management of stormwater ponds continues. During the first two years of operation, elevated levels of phosphorous were detected at Tributary B (one of five) that met "trigger" values and required investigation as to the source.

The site plan agreement had a condition in place stating that extensive water quality monitoring would have to continue for three years where no two consecutive "trigger" values were met or the monitoring cycle of three years would start over. With the high cost of monitoring water quality, the new golf course superintendent set out an action plan to identify and eliminate the source of contaminants. The primary goal of identifying these sources was to further show the commitment of the club to be a steward of the environment, gain support and acceptance of the club from adjacent property owners and ultimately reduce the cost of testing and the start of a new three-year monitoring cycle. Investigations into the source of the contaminants were found upstream of Tributary B in an area where equipment washing had been taking place since the opening of the golf course. Situated close to a natural water course and riparian area, this practice of washing grass clippings from machinery proved to have an adverse effect on water quality.

With the source identified, the next step was to research ways to manage water used to wash equipment and find an appropriate and cost effective way to eliminate this contamination. Some of the systems researched included flocculation systems, a collection sump/solid separator system and the latest bioremediation closed-loop systems. With management company Marriott Golf committed to the environment and owner approval for funding, the choice was made to purchase the Mi-T-M closed-loop bioremediation system that would continually treat and recycle water throughout the season. Implementation of the closed-loop Mi-T-M system would ultimately reduce water consumption from an estimated 700 gallons per day to approximately 1,500 gallons per year.

The system was designed with both a solid separator and grass-clipping separator ahead of the five compartment filtration chambers. The chambers are designed to allow the introduced microbes to react and neutralize any contaminants in the water. This water is then pressurized through a pressure tank where the filtered water is again used to wash equipment.

The operation also needed a chemical storage area for pesticides and a safe mix/load area for the spray technician.

Funding was again approved for this state-of-the-art building to be constructed and further reduce the impact that a spill may have on the environment and water quality. The building serves for both storage and mixing/loading purposes. It was constructed with a 6-inch perimeter sill, an impermeable sump with a capacity of 325 gallons and a 1 percent slope that would direct any spillage to the sump area and not out of the building. Other features implemented in the design of this building are a premixer and stainless-steel sink, which allow for safer product handling. These features further reduced the potential for chemical to splash onto the applicator as the sprayer is being filled directly with water from the irrigation system. Water from the irrigation system was plumbed into the building and regulated down to 50 psi so that many different applications and procedures could happen simultaneously, ultimately speeding up the mixing process. Building a structure with these features has allowed the applicator to get on the golf course much quicker than before and be more precise with the mixing. Chemical applications are completed quicker, thus reducing the visibility of the sprayer to the guests.

The results of both of these efforts have resulted in vastly improved water quality and have proven the club's commitment to preserving the environment.

The Rock is looking forward to continuing to improve its water quality in the future. Much of the work done is cost prohibitive for a lot of properties, but there are several less expensive alternatives that can result in successes similar to ours. Our continued efforts will focus on educating people in the community, neighboring property owners and government groups at all levels to help them understand that The Rock is fully committed to continuing its environmental efforts. **GCI**

Jason Winter is the golf course superintendent at The Rock Golf Club in Minett, Ontario.

Source: The Environmental Institute for Golf's online environmental resource, EDGE (www.eifg.org/edge/).

recently been fitted with cartridges containing activated carbon, cement kiln dust and sand. Laboratory tests suggest that these materials should significantly reduce the amount of pollutants routed through the subsurface drainage.

At Northland Country Club preliminary data indicate that upwards of 20 percent to 60 percent of the pollutants measured at the stream outlet on the course are cycled through the tile drainage network. A filter identical to that tested in the large-scale laboratory study was installed in late 2008 on a tile drainage outlet that conveys water from a significant portion of the course.

The drainage water is a combination of subsurface drainage and surface flows that are collected in micro-depressions and routed to the tile.

Data are collected simultaneously using Isco 6712 automated samplers at the inflow and outflow of the filter following every 4,000 gallons of water that pass through the filter. This is a "real world" application of the filter and is representative of both baseflow and storm flow concentrations.

Preliminary findings from 2009 data at the field study in Minnesota indicate that the filter provides significant reductions in ammonium, nitrate, total nitrogen and total phosphorus (Figure 1, page 42).

No results are yet available for the pesticides. The removal of dissolved phosphorus from the tile flow was not as great as expected. This discrepancy in results for dissolved phosphorus is surprising, considering that in the laboratory the filters were able to substantially reduce dissolved phosphorus.

FUTURE RESEARCH

Future research will investigate different activated carbons and different byproduct mixes, inclusion of a denitrification barrier prior to/after the filter, long-term sorption capability, efficiency dependence on influent concentrations, optimizing contact time and scaling for larger applications. Identification and demonstration of a filter technology will offer superintendents a scientifically based option to better manage drainage waters in problem or environmentally sensitive areas. At this time it appears that drain tile filters have significant promise to reduce pollutant loads.

This information is important for golf course superintendents who need to protect their surface waters and comply with regulatory and/or permitting laws. **GCI**

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