Southshore Greenhouses Research project Executive Summary

Project description:
Beginning May 26 , 20011 a greenhouse leachate water treatment experiment consisting of horizontal and vertical flow constructed wetlands (VF CW) and denitrification rectors (DR) was installed at Southshore Greenhouses in Kingsville, ON. The experiment was located inside of an used portion of the greenhouse. The horizontal flow constructed wetland (HF CW) tested the contaminant removal efficacy of different types of plant growing media combined with an aggressive species of Asian Lettuce. The DR consists of cells containing wood material (shavings, chips). The VF CW tested the efficacy of 3 different types of root bed media acting as a “polisher” of effluent from the DR.

Experimental design:
Horizontal Flow Constructed Wetlands (HF CW): Two duplicate sets of HF CW's. Each individual set has one HF CW containing coco mulch (C), rock wool (R), coco mulch / rock wool combination (CR) and coco mulch / wood chip combination. Raw irrigation leachate water was simultaneously timed dosed to each individual HF CW. On average each HF CW received 110 L of water per day.

Denitrification Reactor (DR): Originally all of the water that drained from the HF CW was dosed to an individual DR that contained soft wood shavings. An analysis of the data revealed that this single DR reactor was hydraulically overloaded and little nitrate reduction was occurring. Therefore during the week of April 2, 2012 the original DR was taken out of service and 3 new DR's installed. These DR's contain a mixture of hard and soft wood chips as opposed to wood shavings. In addition the HF CW drain water was no longer dosing to the DR 'as produced' but the dosing was reconfigured to a timed dose. Each DR (1,2 & 3) was dosed at a different rate: DR 1 at 6 L / minute, DR 2 9 L / minute and DR 3 at 18 L / minute.

Vertical Flow Constructed Wetland (VF CW): Water drained from the DR reactor (before April 2012) and from DR1, DR2 & DR3 is dosed 'as produced' to 3 VF CW cells that operate in parallel. The purpose of the VF CW cells is to provide post treatment or polishing of the DR effluent. Three different media types were used: native sand collected from a local pit, commercially available crushed brick (commonly used in landscape applications) and the pit sand mixed with iron filing at a 20 (sand) : 1 (iron filings) ratio.

Water sample collection & analysis: efforts were made to collect water samples on average every two weeks. However gaps in the data exist due to inter cropping periods when no irrigation leachate water was available due to crop rotations in the greenhouse. Samples were collected at the influent to the HF CW, HF CE effluent, DR effluent and VF CW effluent. Water samples were sent to an accredited laboratory for analysis.

Results:

Horizontal Flow Constructed Wetlands: The data shown in columns 1,2 & 3 of table 1 show average values for industry recognized 'limiter' i.e. contaminants in the water that accumulate when water is 100% recycled. These contaminants inhibit plant growth and vegetable production when present at critical levels. The data in columns 4,5,6 & 7 show contaminants that would prevent discharge of the treated water to the environment as regulated by either the Ontario Building Code or the Ontario Ministry of Environment.

Table 1. Water sample results collected from the Horizontal Flow Constructed Wetlands.

Column	1	2	3	4	5	6	7
	Chloride	Sulphate	Sodium	Phosphorus	BOD	TSS	Nitrate
Irrigation leachate water (IN)	110.33	300.00	**86.83**	112.25	4.00	8.00	282.23
Coco (out)	217.38	473.75	134.15	101.06	4.00	4.67	343.63
Rock wool (out)	196.75	512.50	129.48	87.55	4.00	6.67	345.67
Coco / Rock wool (out)	170.38	473.75	109.73	111.01	4.00	4.83	336.33
Coco / wood chip (out)	189.75	486.25	130.51	87.92	4.00	3.00	319.13

The data show that for that all of the root bed media tested produce chlorides, sulphates and sodium. The coco / rock wool mix produced the least chlorides, the coco alone and the coco / rock wool mix produced the least sulphates and coco / rock wool produced the least sodium. None of the mixes produced or removed BOD, all reduced TSS, the coco / rock wool was most efficient. While all media mixes 'produced' nitrate the coco / wood chip mix removed the most nitrate.

Denitrification Reactor (DR): The data shown in columns 1,2 & 3 of table 2 show average values for industry recognized 'limiter' i.e. contaminants in the water that accumulate when water is 100% recycled. These contaminants inhibit plant growth and vegetable production when present at critical levels. The data in columns 4,5,6 & 7 show contaminants that would prevent discharge of the treated water to the environment as regulated by either the Ontario Building Code or the Ontario Ministry of Environment.

Table 2. Water sample results collected from the Denitrification Reactor (DR) before April 2012 and DR1, DR2 & DR3 after April 2012.

Column	1	2	3	4	5	6	7
	Chloride	Sulphate	Sodium	Phosphorus	BOD	TSS	Nitrate
Denitrification reactor (IN)	203.14	514.29	127.70	101.16	21.80	41.00	332.86
Denitrification reactor (out) *Before* April 2012	215.00	581.67	**132.63**	43.37	N/A	N/A	330.01
installed 3 DR reactors April 2012							
Denitrification reactors (out) *After* April 2012							
Denitrification reactor 1 (out)	195.00	56.00	105.05	63.85	443.50	49.29	0.08
Denitrification reactor 2 (out)	190.00	123.50	112.00	34.52	273.33	27.86	0.06
Denitrification reactor 3 (out)	165.00	75.00	110.00	21.62	208.17	40.00	0.06

The data show that prior to April 2012 the DR reactor did little in terms of reduction of chlorides, sulphates, and nitrates (BOD and TSS data were not collected). The DR reactor did result in a significant decrease in phosphorous, from an average influent of 101 mg/L down to and average of 43 mg/L. After April 2012 the data show an increase in treatment efficiency of the DR reactors at all hydraulic loading rates.

Dr 3 removed the most chloride from an average influent of 203 mg/L down to an average of 165 mg / L. This

was followed by DR 2 at 190 mg /L and Dr 3 at 195 mg / L.

DR 1 removed the most sulphate, from an average influent of 514 mg/L down to an average of 56 mg / L. This was followed by DR 2 at 75 mg /L and Dr 3 at 124 mg / L.

DR 1 removed the most sodium, from an average influent of 128 mg/L down to an average of 105 mg / L. This was followed by DR 3 at 110 mg /L and Dr 2 at 112 mg / L.

DR 3 removed the most phosphorous, from an average influent of 101 mg/L down to an average of 22 mg / L. This was followed by DR 2 at 35 mg /L and Dr 1 at 64 mg / L.

All of the DR's produced BOD. DR 1 produced the most BOD, from an influent concentration of 444 mg / L up to 444 mg / L. This was followed by DR 2 at 273 mg / L and DR 3 at 208 mg / L.

DR 2 removed the most TSS, from an average influent of 41 mg/L down to an average of 28 mg / L. This was followed by DR 3 at 40 mg /L and Dr 1 at 49 mg / L.

All of the DR's removed nitrate equally, with effluent nitrate concentrations at or below lab detection limits.

Vertical Flow Constructed Wetland (VF CW):

The data shown in columns 1,2 & 3 of table 3 show average values for industry recognized 'limiter' i.e. contaminants in the water that accumulate when water is 100% recycled. These contaminants inhibit plant growth and vegetable production when present at critical levels. The data in columns 4,5,6 & 7 show contaminants that would prevent discharge of the treated water to the environment as regulated by either the Ontario Building Code or the Ontario Ministry of Environment.

Table 3. Water sample results collected from the Vertical Flow Constructed Wetland (VF CW) before April 2012 and after April 2012.

Column	1	2	3	4	5	6	7
	Chloride	Sulphate	Sodium	Phosphorus	BOD	TSS	Nitrate
Denitrification reactor (IN)	203.14	514.29	127.70	101.16	21.80	41.00	332.86
Wetland polishing cells (IN)	175.00	77.50	109.50	49.28	226.33	149.71	0.07
Before April 2012							
Wetland Sand cell (Out)	212.86	538.57	138.57	14.00	29.67	N/A	161.32
Wetland Crushed Brick cell(Out)	211.43	547.57	**122.71**	14.99	172.50	N/A	163.00
Wetland Iron filing / sand mixture cell (Out)	221.43	547.14	132.76	4.26	18.80	N/A	169.96
After April 2012 (installed 3 DR reactors)							
Wetland Sand cell (Out)	170.00	130.00	106.00	6.97	29.67	4.71	0.13
Wetland Crushed Brick cell (Out)	170.00	110.00	105.00	17.08	172.50	23.43	0.13
Wetland Iron filing / sand mixture cell (Out)	170.00	190.00	80.30	3.78	18.80	13.17	0.06

The data in table 3 show that a VF CW can significantly reduce phosphorous, BOD and TSS. The iron filing / sand cell removed the most phosphorous either before or after April of 2012, from an average of 49.28 mg/L down to 3.78 mg/L. No data are available to make a similar comparison for BOD and TSS, however all VF CW cells reduced BOD and TSS, with iron filing / sand cell removing the most BOD and the Sand cell removing the most TSS.

While the sand cells themselves did little to remove chlorides, sulphates, nitrates and sodium the data need to be viewed in the context as a treatment unit consisting of DR reactor followed by a VF CW treatment cell. If viewed as such then a valid comparison can be drawn between the DR influent versus HF CW effluent. In that regard each treatment unit (DR + VF CW) removed a significant amount of all contaminants.

Conclusions

1) All of the root bed media tested 'produced' chlorides, sulphates and sodium, indicating that without further treatment it is likely that 100 % 'close loop' irrigation system will accumulate these contaminants.

2) A DR reactor, with controlled flow and containing a mixture of soft and hard wood chips can dramatically reduce sulphates, with some reduction of chlorides and sodium while nitrates are completely removed.

3) Effluent from a DR unit requires post treatment as it contains elevated levels of BOD and TSS.

4) A treatment system consisting of a DR reactor followed by a vertical flow constructed wetland can provide good reduction of most contaminants of concern. The wetland cell containing the iron filing / sand mixture is required to provide sodium reduction.