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Omni Mont-Royal

Phytotechnologies: New Sustainable Solutions for Environmental Challenges
FIELD TOUR
September 29, 2017

The first stage of our tour (stops 1 and 2) takes us to the Lanaudière region of Québec, specifically to the municipality of Saint-Roch-de-l'Achigan (5,000 inhab.), located about 50 km north of Montreal. Several research projects have been carried out by researchers from the Plant Biology Research Institute (IRBV) of the University of Montreal in this region. The majority of these projects have been conducted in partnership with the firm Agro Énergie (http://agroenergie.ca), one of the largest willow producers in North America.

In 2015, researchers from the IRBV and the Polytechnique School of the University of Montreal undertook the PHYTOVAL project. The aim of the project is to study various approaches to using willows for wastewater treatment.

The project is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), and involves the collaboration of 17 industrial partners. It is managed by the Plant Biology Research Institute (IRBV), Polytechnique Montreal and IMT Atlantique.

Researchers are working closely with the municipality of Saint-Roch-de-l'Achigan and its water resource recovery facility (WRRF) to study various approaches to identifying different green solutions that use willows to treat the wastewater from small municipalities with a population of less than 5,000 inhabitants in northern regions.

Today we will visit two sites where these approaches are currently being investigated.

STOP 1. CONSTRUCTED WETLANDS PLANTED WITH WILLOW FOR TREATMENT OF MUNICIPAL WASTEWATER

Context

This study aims to determine whether constructed wetlands (CW) made of willows are adapted to the socioeconomic reality of small scale communities in northern regions. This system is based on an innovative phytotreatment that meets discharge criteria to ensure the reliability of water systems in a sustainable way.
Experimental design

The experimental design was set up in July 2016 beside the wastewater treatment plant of Saint-Roch-de-l’Achigan (pop. 5,000). The climate of this region is semi-continental, with a mean monthly temperature reaching a minimum of -10.8°C in January and a maximum of 21.3°C in July. The experimental site is made up of a septic tank and 4 pilot-scale units of single stage CW (Figure 1). Each unit covers a surface area of 1.3 m² (4.5 m x 2.5 m), was constructed in layers totalling 1.2 m in depth using different types of media for filtration (Figure 2) and then planted with 45 willow cuttings (Salix miyabeana ‘SX67’). Two different organic loadings in percolated mode, representing 5 and 10 m²/PE (primary settled domestic wastewater effluent) were tested, CW1/CW3 and CW2/CW4, respectively. The saturated operation mode, including forced aeration, was applied to two pilot-scale units for four winter months (from January to April 2017).

Figure 1. Experimental design plan
The main results from July 2016 to July 2017 showed good efficiency in the four CWs (Table 1). There was no significant difference between the two types of organic loadings. A significant growth of willow shrubs was observed, with no mortality after the first winter, confirming that the willow species is well adapted for this kind of application in cold climates.

Table 1. Main results of removal efficiency from July 2016 to July 2017.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Percentage removal</th>
<th>Average effluent concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical oxygen demand (COD)</td>
<td>Average 91% (76 – 97%)</td>
<td>21 ± 7</td>
</tr>
<tr>
<td>Total suspended solids (TSS)</td>
<td>Average 89% (49 – 99%)</td>
<td>8 ± 6</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen (TKN)</td>
<td>Average 96% (78 – 100%)</td>
<td>0.5 ± 0.8</td>
</tr>
<tr>
<td>Total phosphorus (TP)</td>
<td>Average 73%</td>
<td>0.96 ± 0.65</td>
</tr>
</tbody>
</table>
Perspectives

Different types of organic loading will be tested during the second year of the project to evaluate the limits of this system in winter and approve the CW treatment system planted with willow prior to industrial application.

For more details about this project, see the First year performance of constructed wetlands planted with willow under cold-climate conditions (Grebenshchykova al., 2017) at the IPC2017 September 27 poster session.

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STOP 2. SHORT-ROTATION WILLOW COPPICE LAND APPLICATION SYSTEM FOR TREATMENT OF MUNICIPAL WASTEWATER

Context

Efficient wastewater treatment is still a challenge for many small Canadian communities, mainly due to a lack of expertise and funding. Therefore, there is a need to develop simple, low-cost wastewater treatment technologies. The use of a short rotation willow coppice (SRWC) land application system to treat wastewater constitutes a potential solution to this problem, since it can efficiently remove organic matter and nutrients (Figure 1). The objective of this research was to establish the design criteria for SRWC systems for municipal wastewater treatment under Canadian climatic conditions.

![SRWC land application wastewater treatment system schematic](image)

Figure 1. SRWC land application wastewater treatment system schematic

Experimental design

The research was carried out at pilot scale beginning in July 2016 on a two-hectare willow (*Salix miyabeana* ‘SX67’) plantation located near the Saint-Roch-de-l’Achigan municipal water resource recovery facility (WRRF). The plantation was established in 2008 and has been coppiced three times since. Willow stems are now two years old.

Nine experimental plots measuring 108 m² were irrigated during the willow growing season (180 days) under one potable groundwater load (L0 = 14 mm/d in 2016, corresponding to 2.4 m/year) and two primary effluent loading rates (L1 = 10 and L2 = 16 mm/d in 2016, corresponding to 1.8 and 2.9 m/year) (Figure 2).
Figur

Figure 2. Experimental design at the willow plantation

The quality of the percolation water from these plots (COD, TKN, NOx, NH₄, TP, o-PO₄) was determined using 27 suction cup lysimeters (3 per plot) installed at a depth of 60 cm (Figure 3). Willow evapotranspiration was modelled using the FAO Penman-Monteith equation and crop coefficients associated with the *Salix* genus. Mass balances of the monitoring parameters were carried out using this evapotranspiration data.

Figure 3. Suction cup lysimeter schematic (© Soilmoisture Equipment Corp)(A) and suction cup lysimeter sampling in progress (B)
Results

The main results from the 2016 growing season showed: (i) a high removal efficiency of organic matter (OM) for both L1 and L2 (over 90% COD loading removal) (Table 1), which demonstrates the high OM mineralization capacity of an SRWC system and implies that OM loading was not a limiting design parameter; (ii) a high removal efficiency of phosphorus for L1 and L2 (98% TP loading removal), which is expected to decrease after a certain number of years of wastewater application due to soil P saturation; (iii) a significant difference between L1 and L2 TN removal efficiency (94 and 87%, respectively), suggesting that N loading was the limiting design parameter of the SRWC system studied and one that may apply for other municipal primary effluents.

Table 2. COD, total nitrogen (TN) and total phosphorus (TP) influent and effluent loadings and removal efficiency for the 2016 growing season

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>COD</th>
<th></th>
<th>TN</th>
<th></th>
<th>TP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>L0</td>
<td>L1</td>
<td>L2</td>
<td></td>
<td>L0</td>
<td>L1</td>
</tr>
<tr>
<td>Influent loading</td>
<td>(kg/ha)</td>
<td>0</td>
<td>2,650</td>
<td>4,150</td>
<td>0</td>
<td>370</td>
<td>580</td>
</tr>
<tr>
<td>Effluent loading</td>
<td>(kg/ha)</td>
<td>260</td>
<td>200</td>
<td>360</td>
<td>10</td>
<td>22</td>
<td>73</td>
</tr>
<tr>
<td>Removal efficiency</td>
<td>(%)</td>
<td>0</td>
<td>92%</td>
<td>91%</td>
<td>0</td>
<td>94%</td>
<td>87%</td>
</tr>
</tbody>
</table>

Market outlook

The preliminary results of a technical-economic analysis carried out in parallel to this research showed that the SRWC area required for the treatment of municipal wastewater is about 60 m²/population equivalent (PE). An additional area of 40 m²/PE would be necessary for winter storage of wastewater. SRWC land application systems show economic potential for use in wastewater treatment for municipal populations ranging from 300 to 800 PE, which would include 242 or 30% of those in the province of Québec.

Researchers involved:

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The next two stops, 3 and 4, will be in the eastern part of the City of Montréal, where several projects to decontaminate polluted soil are underway.

STOP 3. CONSTRUCTED WETLAND FOR THE TREATMENT OF UNDERGROUND CONTAMINATED WATER FROM A PETROCHEMICAL SITE

Context

In recent decades, the east end of Montréal Island has been one of the major hubs of Québec’s petrochemical industry. Many of the island’s contaminated sites (estimated to cover about 1,300 ha in total) are located in this area. The “Montréal-East petrochemical facilities trust”, in collaboration with the IRBV (Plant Biology Research Institute) and Chemistry ParaChem, worked together to install a constructed wetland for the treatment of collected groundwater mainly contaminated with organic compounds such as C10-C50 HP, HAP, BTEX and isopropylbenzene (cumene). The site (identified as K8) from which the groundwater will be collected has long hosted activities linked to the petrochemical industry.

The aim of this project is to achieve acceptable water quality levels for the treated water prior to release into the municipal sewer system.

Experimental design

The experimental constructed wetland (CW) is being built on the 84,829 square meters K8 site located in the Montréal-East municipality. The CW will cover about 2,000 square meters. It will be composed first of a sedimentation basin, then three basins laid out in a meandering manner at three different levels, and a final bigger retention pond for water treatment by plants. Additionally, 25 leachate wells will be installed and equipped with pumps to extract the contaminated groundwater and draw it to the CW through a pipeline system. The volume of groundwater recovered per day will vary from 60,000 to 129,000 L. Several aquatic and semiaquatic plants will be tested in the water remediation process. Trees, shrubs and grasses will be used to landscape the site. Depending on the CW efficiency, water could be released directly into the municipal sewer system or directed to another basin for traditional chemical treatment (Figure 1).
Perspectives

A treatment plan for polluted soils excavated from the site will be developed based on the results of this experimental study. Eventually, the basin may thus be used to treat leaching water.

Researchers and personnel involved:

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STOP 4. PHYTOREMEDICATION OF A PERI-URBAN BROWNFIELD IN THE EAST END OF MONTREAL ISLAND

Context

To test restoration alternatives for some of the many unmanaged brownfield sites (approximately 1,800 ha) on its territory and transform urban environmental challenges into economic opportunities, the City of Montréal recently developed a ground-breaking partnership with the Plant Biology Research Institute (IRBV) to implement a large-scale phytoremediation pilot project (4 ha) to decontaminate moderately contaminated soils. The role of the IRBV is to investigate the relevance of various plant species for phytoremediation purposes, and biomass production for bioenergy and bioproducts on derelict lands. The City of Montréal’s long-term objectives in engaging in this project are to broaden local implementation of green technologies and foster the expansion of an innovative green chemistry sector in the metropolitan region. The IRBV welcomes this opportunity to consolidate its expertise in phytotechnology.

Location

The experimental sites are currently being established in the industrial east end sector of Montréal Island. The project was launched in 2016 on a 1 ha brownfield. In 2017, a second 1 ha brownfield was also converted into a phytoremediation treatment unit. The technical field visit will focus on this second site. Two other 1 ha sites will be set up in 2018 and 2019. Both existing phytoremediation sites are embedded within the industrial landscape and act as a buffer for residential areas (Figure 1).

Figure 1. Location and aerial view (right) of the phytoremediation sites. The pale circles are Suncor Refinery’s fuel tanks.
Experimental design

Instead of relying simply on a conventional scientific design, with the help of a landscape architect, we developed an approach that integrates aesthetic considerations and scientific rigor (Figure 2).

While the implementation of such a design might seem complicated at first glance, it offers two main advantages. First, it facilitates acceptance of the project by nearby residents and creates a meaningful experience for people visiting the site. Second, this clearly highlights the fact that rigorous science and aesthetical considerations are compatible for achieving multiple goals.

Willows, poplars and herbaceous species were planted on the site. The efficiency and impact of several factors are currently being investigated: genotype, mycorrhizal inoculation, cutting length and density, planting techniques and diversity effects. Future results will guide the implementation of subsequent large-scale phytoremediation municipal projects to maximize efficiency.
Future perspectives

One major outcome expected from the project is the decontamination of these municipal brownfields. As well, the City of Montréal aims to establish its leadership in green, plant-based approaches to soil decontamination. IRBV scientists will simultaneously explore a number of related research avenues. The biomass produced during this trial could potentially be used as a carbon source for City of Montréal’s composting facilities. The high amounts of cellulose produced by plants could also be used to generate bioethanol (an ecological alternative to fossil fuels) and other bioproducts and phytochemicals, in partnership with leading global manufacturers that are Québec-based (such as Greenfield Ethanol and Enerkem).

Figure 3. Conceptual diagram illustrating the potential end-uses for the biomass produced during phytoremediation projects.

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