Secondary treatment of concentrated landfill leachate by planted vertical aerated filters

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In Québec the most common method for the management of municipal solid waste is its disposal in engineered landfills. One major environmental problem with these landfills is the production of leachate by the percolation of water from precipitation events and humidity from the waste through the landfill. According to the environmental law in Québec, the leachate produced, which is contaminated with high concentrations of organic matter, ammonia and inorganic molecules, must be treated prior to its discharge. Treatment of landfill leachate is typically undertaken by intensive physical-chemical (e.g., flocculation) or biological (e.g., activated sludge) processes, with high construction and operation costs.

The objective of this study is to evaluate the feasibility of leachate treatment by vertical aerated filters (VAFs) planted with willow or *Sporobolus* species. Five experimental, pilot-scale (450 L) VAFs, one unplanted, two planted with willow (*Salix miyabeana*, 'SX67') and two with *Sporobolus michauxianus*, were operated in parallel in a greenhouse. They were operated under controlled "summer" growing conditions for a total of 26 weeks, divided into two seasons with a three month pause between the two. The VAFs were fed automatically with pretreated leachate in three batches per day (6 ± 2 L per day), collected from a 60 L upflow anaerobic sludge blanket system, and diluted with an effluent recirculation at a 1:1 ratio on average.

Over the duration of the experiment, VAFs were able to efficiently remove total suspended solids (TSS, 92% to 96%), ammonia (NH_4, 99% to 100%) and some organic matter (58% to 63%). VAFs retained about 85 to 90% of influent iron. The plants did not tolerate the leachate well and showed visible morphological changes by the end of the 26 weeks of operation. The willows showed a steady decrease in chlorophyll content during both seasons (300 to 150 mg/m^2 during the first season, 220 to 180 mg/m^2 during the second season). During the last month of operation, all four willows had no measurable leaves. The Sporobolus showed an increase in chlorophyll content during the first season (480 to 510 mg/m^2). During the second season, the chlorophyll content increased for the first three months (500 to 610 mg/m^2) then decreased for the remainder of the season (to 330 mg/m^2). By the end of the experiment, one Sporobolus plant had died.

VAF effluent TSS, NH_4, biochemical oxygen demand (BOD_5) and total phenolic compound concentrations, as well as pH values, met provincial discharge requirements. None of the VAFs met the discharge limits for zinc, however a coagulation-flocculation process and chemical precipitation are in operation at the landfill site to achieve additional zinc removal. While there are no discharge limits for iron, its accumulation in the VAFs may cause clogging, impacting the treatment efficiency in long-term operation and justifying the use of an anaerobic reactor upstream of the VAFs to favor iron sulfide precipitation.

The experiment is being continued for an additional season under "fall" and "winter" conditions, to provide insights into the effect of temperature on the VAFs removal of

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contaminants. Further studies are also being done to determine VAF effectiveness in treating contaminants of emerging concern as well as to determine if other plant species may be better adapted to concentrated leachate. At the end of the project, the design and operation criteria will be determined for a VAF that should be economical, environmentally friendly and sustainable for the treatment of leachate produced by a variety of landfills in Quebec, Canada and elsewhere.

Table 1: Environmental discharge limits for treated leachate compared with typical leachate composition and average effluent concentrations during the last month of operation[1].

Parameter	Units	Québec environmental discharge limits[2]	Typical leachate composition[3] (SD)	Average effluent of control VAF (SD)	Average effluent of *Sporobolus* VAFs (SD)	Average effluent of 'SX67' VAFs (SD)
TSS	mg/L	35	85 (1)	3.8 (2.1)	6.7 (4.9)	2.9 (1.1)
NH_4	mg N/L	10	1200 (20)	< 1.6	< 1.6	< 6.6 (7.0) [4]
BOD_5	mg/L	65	160 (20)	2.7 (0.5)	3.1 (0.4)	2.2 (0.6)
COD	mg/L	-	1950	600 (60)	670 (30)	570 (70)
Iron	mg/L	-	4.8 (0.1)	0.45 (0.17)	0.27 (0.02)	0.28 (0.18)
Zinc	mg/L	0.07	0.29 (0.01)	0.32 (0.11)	0.21 (0.01)	0.25 (0.13)
pH	-	Above 6.0, below 9.5	7.89 (0.00)	6.23 (0.71)	7.94 (0.61)	6.39 (0.99)
Total phenolic compounds[5]	mg/L	0.030	0.795 (0.015)	< 0.006 (0.004)	< 0.006 (0.003)	< 0.005 (0.004)

[1]: Last month of operation was August 2021
[2]: Average monthly value limit
[3]: Values from the week of August 3, 2021
[4]: Most values for the month of August measured below the detection limit of 1.6 mg N/L, except for two measurements at about 16.5 mg N/L
[5]: July 2021 data used because August 2021 results not yet received