Effect of design and dosing regime on pollutant removal in vertical flow constructed wetlands

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Master's thesis project in Ecology and the Environment 2010/11

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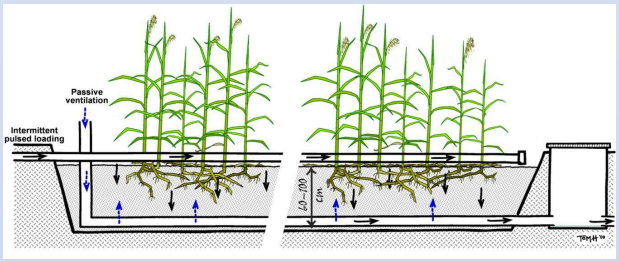
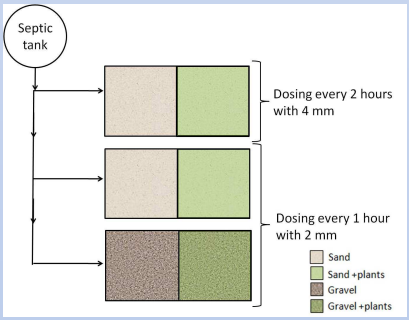
Background & aim

In vertical flow constructed wetlands (VF CWs), pollutants are removed in a filter bed of sand or gravel, mainly by a microbial biofilm growing on the filter medium. VF CWs are suitable for wastewater treatment because they are well oxygenated, which promotes microbial activity. This study investigated if the treatment efficiency of VF CWs depends on

1) **filter media size** (sand 1-3 mm vs. gravel 4-8 mm),
2) **dosing regime** (wastewater applied hourly with smaller doses vs. bi-hourly with larger doses), and
3) **presence of plants** (*Phragmites australis*).



Schematic picture of a VF CW. Wastewater enters through inlet distribution pipes and then percolates through the filter medium. The down flowing water creates a suction that draws oxygen into the media pores. Additional oxygen is supplied through ventilation pipes. (Courtesy of Tom Headley.)



Experimental setup; 6 pilot-scale VF CWs with different filter media, plant presence and dosing regimes. Domestic wastewater was pre-treated in a septic tank and distributed to each VF CW.

Two of the pilot-scale VF CWs; one planted and one unplanted.

Methods

- Wastewater grab samples collected from inlet, outlet and 3 different depths in 6 pilot-scale VF CWs. Samples were collected every 2-3 weeks during 5 months. The average hydraulic loading rate to each VF CW over the whole period was 94 L/(m^2*day).
- Laboratory analyses of organic matter, suspended solids, nitrogen and *E. coli.*
- Repeated-measures ANOVA to compare treatment performance among the VF CWs and over time.

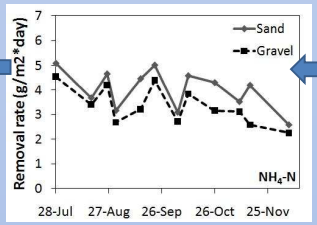
← Wastewater samples collected from inlet (0 cm depth), 3 internal sampling points (10, 20 and 40 cm depth) and outlet (80 cm depth) in a sand VF CW. Note the color difference from inlet to outlet.

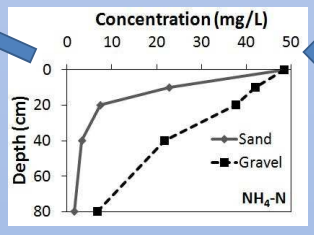
Interpretation & conclusions

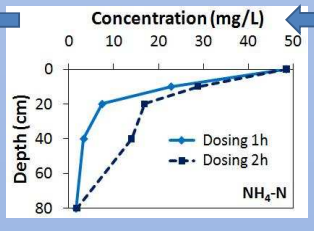
1) **Smaller media size was more beneficial for pollutant removal**, probably due to more efficient filtration (more removal in the upper part), and better oxygenation which promotes microbial activity. On the other hand, conditions for total nitrogen removal were better with larger media size, since less oxygen promotes microbial denitrification.

2) **Smaller and more frequent wastewater doses seemed to be the better dosing regime**, probably because a smaller dose mainly moves downward in smaller pores without taking shortcuts through larger pores. This gives more time for pollutant removal in the upper part; thus, the water would be cleaner at the outlet if the VF CW was shallower (which is often the case).

3) **Plant presence increased the removal of ammonium-N**, probably through plant uptake and root release of oxygen which stimulates microbial activity.







Results

1) VF CWs with sand removed pollutants significantly better than those with gravel. The only exception was total nitrogen, which was removed more efficiently in gravel beds. Oxygenation was always better in sand beds.
More removal took place in the upper part of sand beds (exponential removal) than in gravel beds (linear removal).

2) More removal took place in the upper part of the VF CWs when wastewater was dosed every hour with smaller doses. At a given depth inside the VF CW, the wastewater was cleaner with this dosing regime.

3) Ammonium-N removal was slightly but significantly higher with *Phragmites australis* present (96%) compared to without (94%).