HYBRID CONSTRUCTED WETLAND

FOR SMALL COMMUNITY WASTEWATER TREATMENT AND REUSE

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INTRODUCTION

A pilot hybrid constructed wetland system was established in 2007 at the Institut Agronomique et Vétérinaire Hassan II in Rabat, Morocco, in order to evaluate and optimize system design for small community wastewater treatment and reuse in Morocco. The technology treats a portion of the campus wastewater (12 m³/d) and occupies 4.5 m²/capita.

HYBRID WETLAND TECHNOLOGY

The hybrid wetland technology is depicted in Figure 1 and consists of three stages: a primary vertical flow (VF) wetland to remove solids, a secondary horizontal flow (HF) wetland to remove organic matter and nitrogen and a tertiary vertical flow (VF) sand filter to remove pathogens and to nitrify effluent. Wastewater is recycled from Stage 3 to Stage 2 to promote denitrification.

The first stage is a primary VF wetland following the CEMAGREF design (see Figure 2).[1] The filter consists of: a 15 cm drainage layer of 20–40 mm gravel, a 10 cm intermediate layer of 12–20 mm gravel and a 30 cm layer of 8–10 mm gravel. Three filters (5 x 5 m) are planted in native *Phragmites australis*. Each filter is dosed for 4 days followed by an eight-day rest period.

The primary filter receives raw wastewater and removes solids and organic matter through filtration and biological treatment. Organic matter accumulates in the filter and mineralizes over time. Root penetration and wind induced swaying of the *Phragmite* stems act to maintain drainage pathways and avoid clogging of the filter surface.

Figure 1. Hybrid Pilot Wetland Cross-Sectional View

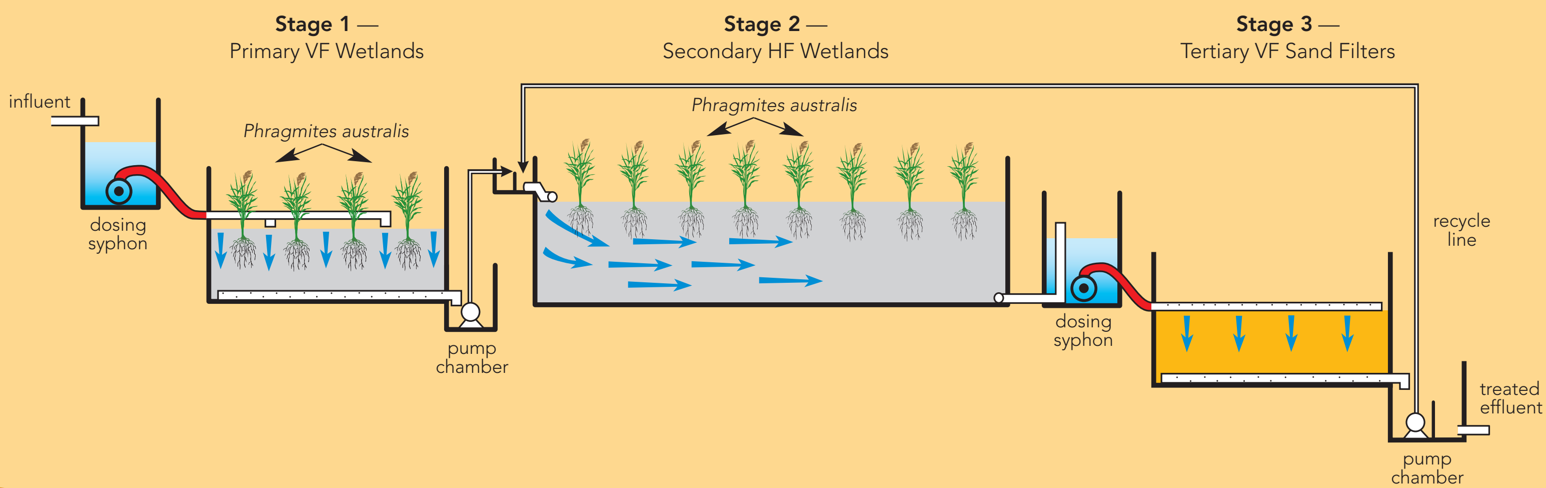

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Figure 2. Stage 1 — Primary VF Wetlands

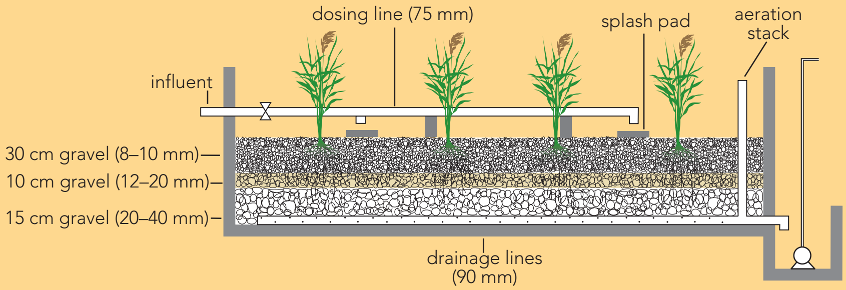

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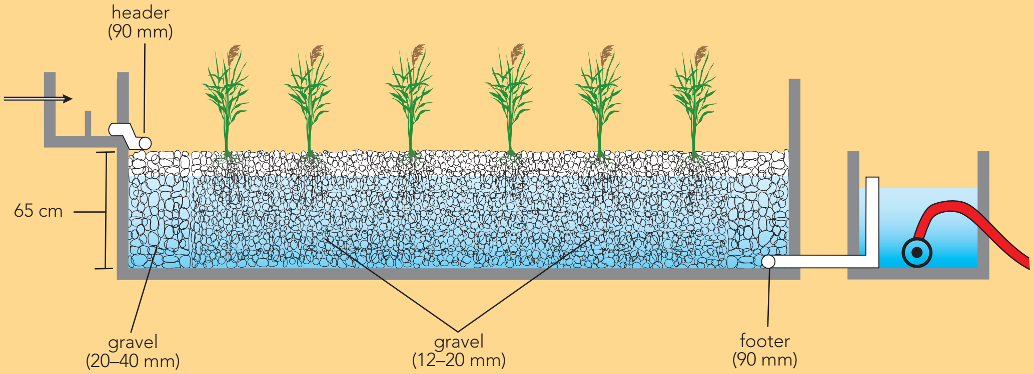
Figure 3. Stage 2 — Secondary HF Wetlands



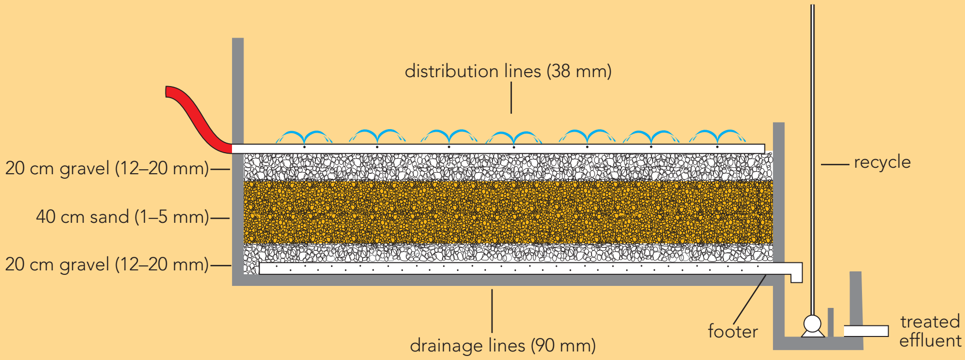
2007

2008

The second stage is a HF wetland also planted in native *Phragmites australis* (see Figure 3). The wetland sizing is based on first order kinetics for removal of organic matter.[2,3] The HF wetland consists of three parallel cells of 20 m × 2.45 m each with a depth of 65 cm of 12–20 mm gravel (middle cell unplanted). The HF wetland has a hydraulic retention time of 3.1 days.

The third stage is comprised of a series of three VF sand filters in parallel for nitrification and pathogen attenuation (see Figure 4). The design is based on a single pass sand filter designed for nitrification.[4,5] Each filter (4 x 4 m) consists of: a 20 cm drainage layer of 12–20 mm gravel, a 40 cm layer of 1–5 mm washed sand and a 20 cm layer of 12–20 mm gravel.

Figure 4. Stage 3 — Tertiary VF Sand Filters



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SYSTEM PERFORMANCE

Performance of the hybrid wetland technology is presented in Table 1.

Table 1. Hybrid Wetland Performance

	COD (mg/L)	TSS (mg/L)	TN (mg/L)	*E.coli* (CFU/100mL)
Raw Wastewater	746 ± 137	328 ± 94	115 ± 11	5.6×10^6
Primary VF Wetland	199 ± 38	62 ± 32	68 ± 27	3.0×10^6
Secondary HF Wetland	56 ±13	25 ± 21	40 ±14	2.1×10^5
Tertiary VF Sand Filter	35 ± 15	20 ± 26	40 ± 14	1.5×10^4
Removal Rate	95%	94%	65%	2.6 logs

Organic Matter and Solids
The technology is very effective at removing organic matter and solids with most of the organic matter and solids removed after the HF wetland. For restricted wastewater reuse (i.e., irrigation of forage crops or cereals), TSS must be below 100 mg/L.[6] This level of treatment is achieved by the HF wetland stage. Therefore, if the objective is a secondary quality effluent it is not necessary to include a tertiary VF sand filter in the design.

Nitrogen
A total nitrogen reduction of 65% was achieved with a recycle rate of 100%. The VF sand filter was effective at nitrifying the ammonia from the HF wetland where the anoxic conditions were conducive for denitrification. It is important to reduce total nitrogen levels prior to irrigation as nitrogen is often in excess of crop requirements and could contaminate groundwater resources.

Irrigation and nitrogen requirements are given for several crops for the irrigated region of Tadla, Morocco (Table 2). Calculations were based on total nitrogen concentrations ranging from a typical value of 70 mg/L[7] to the 115 mg/L reported in Table 1. Nitrogen from treated wastewater meets crop N requirements in most cases when 65% is removed through recirculation. Therefore, recirculation to promote denitrification will often be necessary to avoid nitrate contamination of the groundwater.

Pathogens
The two pathogen indicators governing wastewater reuse are *E.coli* (bacteria) and helminth eggs. *E.coli* numbers are reduced by 2.6 logs throughout the system from 5.6×10^6 CFU/100mL in the raw wastewater to 1.5×10^4 CFU/100mL at the end of the VF sand filter. Although not enumerated in this study, helminth eggs are effectively removed through filtration and will likely be removed in the first filter, as they are closely associated with wastewater sludge.[11]

For unrestricted reuse (i.e., irrigation of produce eaten raw) pathogen standards are typically 10^3 CFU/100mL *E.coli* and <1 helminth egg/litre.[12] A further disinfection step would therefore be required as the VF sand filter reduces *E.coli* to only 1.5×10^4 CFU/100mL.

Table 2. Example of Crop Nitrogen Demand met by Wastewater Reuse (Tadla, Morocco)

Crop	Irrigation Water Requirement[8] (m^3/ha/yr)	Plant N Requirement (kg/ha/yr)	Wastewater N Supplied	
			With No Recirculation (40% removed) (kg/ha/yr)	With Recirculation (65% removed) (kg/ha/yr)
High N Required e.g., alfalfa, grain corn, citrus and olive plantations [9]	>8,000	200 – 300	336 – 550	200 – 320
Medium N Required e.g., wheat [10]	4,000	100 – 150	168 – 280	100 – 160
Low N Required e.g., barley	2,500	80 – 120	105 – 170	63 – 100

CONCLUSIONS

The hybrid constructed wetland technology is a promising wastewater treatment alternative for small communities in Morocco and for communities with comparable socio-economic and climatic conditions. The system has been shown to function well over four years of continuous operation. The passive wetland technology provides several advantages including: low capital and operating costs, low energy requirements and high levels of treatment. The system produces tertiary quality effluent suitable for direct discharge or for irrigation of forage crops, cereals and fruit trees while reducing pathogen risk and protecting groundwater from excess nitrogen leaching.

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