Constructed Wetlands are not a Viable Alternative or Addition to Waste Stabilization Ponds

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Abstract Constructed wetlands (CW) and waste stabilization pond (WSP) systems are compared for land area requirements, performance and costs to produce effluents of three different qualities for surface water discharge; and for treatment prior to agricultural and/or aquacultural reuse in tropical climates. In temperate climates WSP with aerated or unaerated rock filters had lower land area requirements and costs than CW for the same performance. In tropical climates prior to agricultural reuse WSP systems need only comprise an anaerobic, a facultative and a single maturation pond to comply with the new WHO Guidelines; for aquacultural reuse only an anaerobic and a facultative pond are required. CW cannot be reliably designed to produce effluents complying with the new guidelines.

Keywords: Constructed wetlands; costs; land area; performance; reuse; waste stabilization ponds

Introduction

The question to be answered is: Are constructed wetlands (CW) of any type a suitable replacement or addition to waste stabilization pond (WSP) systems? In this context WSP systems may or may not include rock filters (Middlebrooks, 1995), and these may or may not be aerated (Mara and Johnson, 2006a).

There is a very extensive literature on CW, as evidenced by the proceedings of the IWA CW Specialist Group's conferences. The overwhelming conclusions of this literature are that CW are a viable wastewater treatment process in almost all situations where land is available. Kadlec (2004) recommended that CW be used to 'polish' WSP effluents as they cannot meet secondary discharge standards , at least in the United States, despite Middlebrooks (1995) having shown that rock filters were superior on grounds of cost and simplicity to many other polishing processes, including CW. Mara (2004a) questioned the role of plants in CW, and Mara and Johnson (2006a) reported the superior performance of aerated rock filters over subsurface horizontal-flow CW in temperate climates in winter.

In this paper subsurface horizontal-flow (SSHF) constructed wetlands and WSP systems are compared in terms of land area requirements, performance and cost in temperate climates for surface water discharge and tropical climates for wastewater use in agriculture and/or aquaculture. Reuse is chosen for tropical climates because of increasing global water scarcity (Hinrichsen *et al.*, 1998; United Nations Population Division, 2000) and because wastewater is a highly reliable local water resource, especially during droughts (Asano, 2002).

Temperate climates

Performance and land area requirements

SSHF CW and WSP systems were designed to achieve the following three effluent qualities: (1) that specified in the EU Urban Waste Water Treatment Directive (UWWTD) (≤25 mg filtered BOD l^{-1} and ≤150 mg SS l^{-1} for WSP effluents, and ≤25 mg unfiltered BOD l^{-1} for CW effluents (mean values) (Council of the European Communities, 1991); and two common requirements of the Environment Agency (the environmental regulator in England and Wales): (2) ≤40 mg BOD l^{-1} and ≤60 mg SS l^{-1} (95-percentile values) ("40/60"), and (3) ≤10 mg BOD l^{-1}, ≤15 mg SS l^{-1} and ≤5 mg ammonia-N l^{-1} (95-percentile values) ("10/15/5"). The results, shown in Table 1, indicate that a secondary SSHF CW requires 60 percent more land than a secondary facultative pond to produce an UWWTD-quality effluent, and 38 percent more land than a secondary facultative pond and an unaerated rock filter to produce a 40/60 effluent. Were it to be used to produce a 10/15/5 effluent, it would require ~1000 percent more land than a secondary facultative pond and an aerated rock filter.

Costs

Based on comparative costs in France, Germany and England, SSHF CW are more expensive than WSP systems comprising primary/secondary facultative ponds and unaerated/aerated rock filters (Table 2).

Tropical climates

Wastewater use in agriculture

The new WHO Guidelines for wastewater use in agriculture (WHO, 2006a) require (a) ≤1 human intestinal nematode egg per litre of treated wastewater, and (b) pathogen removals of 3 $\log_{10}$ units for restricted irrigation and 6−7 $\log_{10}$ units for unrestricted irrigation (Mara *et al*., 2006; WHO, 2006). The required the 3-log unit pathogen reduction for restricted irrigation has to be achieved solely by wastewater treatment. However, the 6−7-log unit pathogen reduction for restricted irrigation refers to the reduction from their number in the untreated wastewater to the number ingested. It is equivalent to a rotavirus infection risk of $\sim 10^{-3}$ per person per year (pppy) and a tolerable additional disease burden of ~1 μDALY loss pppy (DALY: disability-adjusted life year).

Restricted irrigation. In tropical climates a WSP system comprising an anaerobic pond, a secondary facultative pond and a single maturation pond will achieve the required 3-log unit pathogen reduction and also ≤1 human intestinal nematode egg per litre (Oragui *et al*., 1987; Mara and Silva, 1986). The 3-log unit pathogen reduction is broadly equivalent to a 3-log unit reduction of *E. coli* and the WSP system is designed on this basis (see Mara, 2004b).

CW cannot be used in this case as there are no generally accepted design equations for *E. coli* removal (IWA Specialist Group, 2000; Hagendorf *et al*., 2005) .

Unrestricted irrigation. The same WSP treatment system as for restricted irrigation is suitable for unrestricted irrigation if post-treatment health-protection control measures (Table 3) are in place to provide additional pathogen reductions totalling 3−4 log units. This is very easily achieved: for example, by the drip-irrigation of low-growing crops (e.g., lettuce, onions), which provides a 2-log unit reduction, and a 2 log-unit reduction due to die-off. Die-off always occurs, so it should always be taken into account (to ignore it requires more treatment and hence more money); it is a relatively simple matter to measure typical time intervals from the last irrigation before harvest to the appearance of the produce in local shops.

Wastewater use in aquaculture

The new WHO Guidelines for wastewater use in aquaculture (WHO, 2006b) are the same as those recommended by WHO (1989) − i.e., no viable trematode egg per litre of treated wastewater and ≤1000 E. coli per 100 ml of fishpond water. Treatment can therefore be achieved simply by an anaerobic and facultative pond, as shown by Mara *et al*. (1993). The fishpond effluent will have <<1000 *E. coli* per 100 ml and so can be safely used for either restricted or unrestricted irrigation, as noted above.

Conclusions

In temperate climates secondary subsurface horizontal-flow constructed wetlands require more land and cost much more than facultative waste stabilization ponds and rock filters.

In tropical climates where treated wastewater is to be used for crop irrigation WSP systems need only comprise an anaerobic, a facultative and a single maturation pond. Prior to fish culture WSP systems only need to comprise an anaerobic and a facultative pond.

Wastewater treatment engineers need to be aware of these disadvantages of constructed wetlands when compared to waste stabilization pond systems.

Constructed wetlands are thus not a viable alternative or addition to waste stabilization ponds.

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Table 1. Land area requirements of constructed wetland and waste stabilization pond systems in temperate climates to achieve three levels of required effluent quality

Wastewater treatment system	Land area requirements (m^2 $p.e.^{-1}$) for:		
	UWWTD	**40/60**	**10/15/5**
Secondary subsurface horizontal-flow CW	6.00	6.70	54[a]
Primary facultative pond	6.25	n.a.[b]	n.a.
Primary facultative pond and unaerated rock filter	–[c]	7.35	n.a.
Primary facultative pond and aerated rock filter	–	–	7.35
Secondary facultative pond	3.75	n.a.	n.a.
Secondary facultative pond and unaerated rock filter	–	4.85	n.a.
Secondary facultative pond and aerated rock filter	–	–	4.85

[a] In practice this is too large an area to even consider using.
[b] Treatment system not able to produce this quality effluent.
c Treatment system would not be used to produce this quality effluent.
Source: Mara (2006).

Table 2. Capital and O&M costs of CW and WSP systems in France, Germany and England

Treatment process	Capital costs	O&M costs
France [a]		
CW	190	5.50
WSP	120	4.50
Germany [b]		
CW	1,500	1.30
WSP	700	1.20
England [c]		
CW	1,100	n.a.[d]
WSP	400	n.a.

[a]Source: Alexandre et al. (1997). Costs in ecu (average 1997 exchange rates: 1 ecu = GBP 0.70 = USD 1.17).
[b]Source: Burka (1996). Costs in DEM (average 1996 exchange rates: DEM 1 = 0.53 ecu = GBP 0.43 = USD 0.66).
[c]Source: Mara (2006). Costs in GBP (average 2005 exchange rates: GBP 1 = EUR 1.46 = USD 1.84). CW cost includes primary treatment; WSP cost is for a primary facultative pond and a rock filter.
[d] Not available.
Note: exchange rates from www.oanda.com/convert/fxhistory..

Table 3. Pathogen reductions achieved by post-treatment health-protection control measures

Control measure	Pathogen reduction (log units)	Notes
Drip irrigationa	2−4	2-log unit reduction for low-growing crops and 4-log unit reduction for high-growing crops.
Pathogen die-off	0.5−2 per day	Die-off after last irrigation before harvest (value depends on climate, crop type, etc.).
Produce washing	1	Washing salad crops, vegetables and fruit with clean water.
Produce disinfection	2	Washing salad crops, vegetables and fruit with a weak disinfectant solution and rinsing with clean water.
Produce peeling	2	Fruits, root crops.

[a]See Polak et al. (1997) and Intermediate Technology Consultants (2003) for information on low-cost drip-irrigation systems.
Sources: Beuchat (1998), Peterson et al. (2003) and NRMMC & EPHC (2005).