

An Evaluation of Constructed Wetland Design and Performance

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Clearly there is a necessity for alternative on-site systems to meet the needs of the public where conventional systems cannot. From an environmental standpoint it is also advisable to treat waste on site in order to return treated waters to their point of origin and maintain the natural hydrological balance. Traditionally there have been two basic design approaches to gravity-flow constructed wetland sizing. The first was developed by the Environmental Protection Agency [U.S. EPA, 1988] and is based largely on the methods of S.C. Reed [1988]. The second approach was developed by Tennessee Valley Authority (TVA) for small systems, (i. e. less than 20,000 gpd). TVA has also developed a new patented technology that relies on reciprocating reactors to enhance nitrogen transformations within the wetlands. The reciprocating technology (ReCip) has been used in four states to date and is being reviewed for testing at confined animal feeding operations (CAFO). This presentation gives an overview of the methods and presents operating data from several systems operating in North Alabama.

Gravity Flow Systems

A general summary of the sizing methodology for the two approaches is shown in Table 1. Most of the dimensions, such as length, width, and depth, are obtained geometrically. However, the most significant difference is in the surface area calculation. The TVA approach determines surface area by a hydraulic loading criterion, which is a constant value, expected to maintain subsurface flow conditions. The EPA model determines surface area by the organic loading of the system and calculates BOD₅ described by plug flow kinetics. The primary assumption for this model is that the wetland behaves similarly to other attached-growth treatment systems.

Reciprocating Constructed Wetland (ReCip)

This patented design consists of two or more adjacent subsurface flow cells that utilize the concept of reciprocation, that is alternately draining and filling on a defined and recurrent basis. This flow pattern achieves significant enhancement of both the biological and physical processes by exposing the bio-film directly to atmospheric oxygen [Sikora, et al., 1995]. Obviously this enhances nitrification process, additionally since all the wastewater in the cells is not drained in any cycle, anoxic conditions remain for denitrification. Another advantage is the smaller surface area required for the ReCip which offsets the power expenses.

Discussion of Results

Constructed wetlands in North Alabama were monitored for various water quality parameters for several years. A summary of the results is given in Table 2.

Average values of BOD5 in the effluent from the gravity flow systems was 13 mg/L, while the average ammonia concentration was 23 mg/L. The expected bacteria reductions are 2-log. Although both types of wetlands remove significant amounts of BOD, bacteria and turbidity [Leonard, 1998], data supports the observation that the ReCip has enhanced ammonia nitrogen removal. As is obvious in the last column, the ReCip out-performed the gravity flow wetlands in all parameters. Ongoing test results can be found at the bottom of this article.

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Table 1. Sizing Methodology for TVA and EPA Constructed Wetlands

Dimension (1)	TVA (2)	EPA (3)
Cross Section	Organic Loading Criterion* $A_o = L_{oc} L_{ow}$ or Darcy's Law (larger)	Darcy's Law $AH = Qh / (K_s S)$
Surface Area	Hydraulic Loading Criteria ** $A_s = L_{hc} Q_h$	Organic Loading $A_s = [Q(\ln C_o - \ln C_e)] / (KT d n)$
Width	Geometric $W = A_{cell} / D$	Geometric*** $W = A_{cell} / D$
Length	Geometric $L = A_s / W$	Geometric * $L = A_s / W$
Depth	0.3-0.5 m****	» 0.6 m

* $L_{oc} = 4.1 \text{ m}^2/\text{kg}$, ** $L_{hc} = 0.032 \text{ m}^2/\text{L}/\text{d}$, *** aspect ratio is also considered

Table 2. Summary of Removal Efficiencies of Constructed Wetland Types

Constituent	Type of CW		Difference ReCip-GF
	Gravity-flow	ReCip	
BOD5 (mg/L)	85%	90%	5%
NH4 (mg/L)	44%	98%	44%
Total Coliforms	91%	97%	6%
Turbidity (NTU)	57%	90%	33%

Conclusion

Constructed wetlands are a great low-tech alternative for on-site treatment with excellent organic, nutrient and bacteria removal rates. Additionally they are aesthetically pleasing, attractive to wildlife and maintain groundwater recharge.

The North Alabama data shows that the reciprocating wetland (ReCip) is the better alternative for reducing ammonia while only requiring a small surface area.

References

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