Estimating the resistance of a porous media that numerically represents a floating treatment wetland

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Abstract Floating treatment wetlands (FTWs) are an important nature-based solution to treat water, wastewater and stormwater. FTWs can be numerically represented as a porous media, in which the resistance is usually estimated by fitting the simulation to measured data. This study presents a new approach to estimate the viscous and inertial resistance factors of the porous media. The FTW is treated as a packed bed, for which the Ergun equation is applied, but in the vertical direction (flow parallel to the roots) the root diameter is estimated as a hydraulic diameter, which creates a non-isotropic resistance. This resulted in better agreement with the experiments than the fitting strategy, for a simulation case.

Keywords: wetlands, CFD, porous media, validation.

Methods

FTW root zone:

- CFD (flume, single FTW, 3 FTWs in series, $\Delta x = 2L_{FTW}$)
- Porous media (Darcy's Law)
- Packed bed (Ergun equation estimates $1/\alpha$ and C_2):

$$\frac{1}{\alpha} = \frac{150}{D_p^2}\frac{(1-\epsilon)^2}{\epsilon^3}$$

$$C_2 = \frac{3.5}{D_p}\frac{(1-\epsilon)}{\epsilon^3}$$

- Horizontal direction: D_p can be assumed as the root cylinder (d).
- Vertical direction: D_p can be estimated as the hydraulic diameter (d_h) (Oldham & Sturman, 2001):

$$d_h = d\left(\frac{4(s/d)^2}{\pi} - 1\right)$$

Results

Single FTW (Fig. 1):

- Best-fitted resistance: $1/\alpha = 10^{-6}$ m^{-2}
- Calculated resistance:
  - Horizontal direction: $1/\alpha = 70507.2$ m^{-2} and $C_2 = 73.2$ m^{-1}
  - Vertical direction: $1/\alpha = 365.2$ m^{-2} and $C_2 = 6.1$ m^{-1}

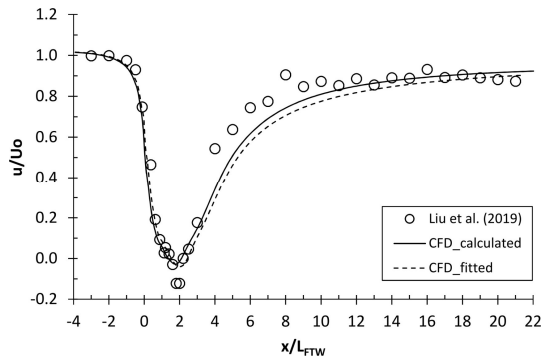

Fig. 1. Longitudinal profile of u/U_0 in the centerline and mid-depth of the FTW. The FTW is located at x/L_{FTW} = 0 and 1.

FTWs in series (Fig. 2):

- Calculated resistance: consistent agreement with the measurements for all FTWs
- Fitted resistance: underestimated the flow reaching the third and fourth FTWs

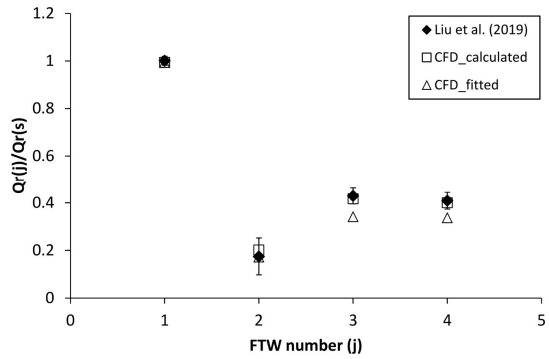

Fig. 2. Flow entering the jth FTW ($Q_{r(j)}$) normalized by the flow rate entering the first FTW ($Q_{r(s)}$).

Conclusions

The Ergun equation combined with the hydraulic diameter approach in the vertical flow direction showed to be a reliable method to estimate porous media resistance in the FTW.

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