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Modeling of flow and BOD fate in horizontal subsurface flow constructed wetlands

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HIGHLIGHTS

- ▶ Modeling of BOD removal in horizontal subsurface flow constructed wetlands.
- ▶ Use of MODFLOW-MT3DMS set of codes – validation with experimental data.
- ▶ Evaluation of first-order decay coefficient λ.
- ▶ Dependence of decay coefficient λ on temperature and HRT.
- ▶ Scenarios for various temperature, HRT, vegetation and porous media conditions.

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ABSTRACT

A numerical modeling effort of flow and Biochemical Oxygen Demand (BOD) fate in horizontal subsurface flow (HSF) constructed wetlands (CWs), under Mediterranean conditions, is presented. The Visual MODFLOW family computer code, based on the finite difference method, was used for the numerical simulation of flow in five pilot-scale HSF CW units containing various vegetation and porous material types, and operating under various temperature and hydraulic residence time (HRT) conditions. BOD fate and transport was simulated using the MT3DMS computer code. Experimental data from these CW units were used in estimating the BOD removal coefficient, required in the above modeling effort. Values of this removal coefficient were found to depend on temperature and HRT. Relations are presented for the prediction of this coefficient. The model was calibrated and verified using the measured BOD concentrations, and was used in test runs comparing performance under various vegetation, porous media size, temperature and HRT conditions. Model performance was found acceptable, indicating its usefulness in the simulation of BOD fate in CWs and in the design of these facilities.

1. Introduction and background

Constructed wetlands (CWs) are considered to be a good solution for the treatment of municipal wastewater from small settlements. The use of these systems has become popular in many countries [1–4]. Proper design of these systems is important, aiming to maximize the removal efficiency while minimizing the size and the construction cost.

Design is often based on empirical equations, and modeling is rather simplistic. Therefore, numerical modeling of flow and pollutant fate in CWs gained interest in recent years [5–7]. The main objective of the modeling work is to increase the insight on the dynamics and functioning of the complex CW systems, and therefore, facilitate the design of these facilities. An overview of the current developments on numerical modeling of subsurface flow CWs, based on modeling work and model development, has been presented by various authors [5,8–10].

According to Langergraber et al. [6], CWs are engineered systems designed to optimize the wastewater treatment possibilities found in natural environments. A large number of physical, chemical and biological processes take place in parallel, and mutually influence each other. CWs are complex systems that are difficult to understand. As already stated by Langergraber et al. [6], most efforts in predicting removal rates from constructed wetlands, have been either based on "black-box" approaches, thus ignoring physical and biochemical processes taking place inside these facilities, or were based on the simple approach of a uniform, one-dimensional velocity field. The development and validation of more sophisticated numerical models may provide some insight on processes taking place inside constructed wetlands, and can be used to design these facilities."

Proper modeling of BOD removal is crucial in subsurface flow constructed wetland design [8,11]. Several authors have proposed linear regression equations [2,12–15], obtained by statistical analysis of experimental data. Another black-box model, although

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