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Modeling High Rate Phosphorus and Nitrogen Removal in a Vertical Flow Alum Sludge based Constructed Wetlands

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Increased awareness of the impacts of diffuse pollution and their intensification has pushed forward the need for the development of low-cost wastewater treatment techniques. One of such efforts is the use of novel DASC (Dewatered Alum Sludge Cakes) based constructed wetlands (CWs) for removing nutrients, organics, trace elements and other pollutants from wastewater. Understanding of the processes in CWs requires a numerical model that describes the biochemical transformation and degradation processes in subsurface vertical flow (VF) CWs. Therefore, this research focuses on the development of a process-based model for phosphorus (P) and nitrogen (N) removal to achieve a stable performance by using DASC as a substrate in CWs treatment system. An object-oriented modelling tool known as “STELLA” which works based on the principle of system dynamics is used for the development of P and N model. The core objective of the modelling work is oriented towards understanding the process in DASC-based CWs and optimizes design criteria. The P and N dynamic model is developed for DASC-based CWs. The P model developed exclusively for DASC-based CW was able to simulate the effluent P concentration leaving the system satisfactorily. Moreover, the developed P dynamic model has identified the major P pathways as adsorption (72%) followed by plant uptake (20%) and microbial uptake (7%) in single-stage laboratory scale DASC-based CW. Similarly, P dynamic simulation model was developed to simulate the four-stage laboratory scale DASC-based CWs. It was found that simulated and observed values of P removal were in good agreement. The fate of P in all the four stages clearly shows that adsorption played a pivotal role in each stage of the system due to the use of the DASC as a substrate. P adsorption by wetland substrate/DASC represents 59-75% of total P reduction. Subsequently, plant uptake and microbial uptake have lesser role regarding P removal (as compared to adsorption).With regard to N, DASC-based CWs dynamic model was developed and was run for 18 months from Feb 2009 to May 2010. The results reveal that the simulated effluent DN, NH4-N, NO_3-N and TN had a considerably good agreement with the observed results. The TN removal was found to be 52% in the DASC-based CW. Interestingly, NIT is the main agent (65.60%) for the removal followed by ad (11.90%), AMM (8.90%), NH4-N (P) (5.90%), and NO_3-N (P) (4.40%). DeN did not result in any significant removal (2.90%) in DASC-based CW which may be due to lack of anaerobic condition and absence of carbon sources. The N model also attempted to simulate the internal process behaviour of the system which provided a useful tool for gaining insight into the N dynamics of VFCWs. The results obtained for both N and P models can be used to improve the design of the newly developed DASC-based CWs to increase the efficiency of nutrient removal by CWs.