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A simulation model of nitrogen transformation in reed constructed wetlands

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Abstract

Nitrogen has been considered as one of important elements in domestic wastewater and resulted in frequent algal blooms over a wide range of water body. In this study, a dynamic system was constructed to simulate nitrogen transformation in reed constructed wetlands. The various nitrogen forms in the system were considered as the parameters. The effects of mineralization, nitrification, denitrification, plant uptake and plant decay were investigated. The overall performance of the model was validated with different data sets of parameters from the case study spanning 3 years. The results indicated a good fit between the simulated and observed data. It appears that the model can give a reliable prediction for nitrogen removal performance in reed constructed wetland.

Keywords: Constructed wetlands; Dynamic system; Wastewater treatment; Nitrogen removal

1. Introduction

Untreated or insufficiently treated wastewaters containing high concentrations of nitrogen effluents into receiving rivers are undesirable, for enrichment of nitrogen is one of the worst polluting agents for aquatic life resulting in serious eutrophication of lakes and rivers [1]. For developing countries, some conventional treatment techniques of wastewater have several disadvantages, such as expensive cost, continuous addition of toxic chemicals, extensive space and side effects of secondary pollution. In the 21th century, the new technologies have focused on natu-

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ral systems, especially constructed wetlands (CWs). The CWs are engineered systems by applying various technological designs to treat domestic wastewater, using natural wetland processes, associated with wetland hydrology, soils, microbes and macrophytes. Due to low cost of construction and operation, CWs have generally been regarded as an effective method of removing nitrogen from domestic wastewater, especially sub-surface flow CWs, which have gained increased attention for on-site treatment of domestic wastewater.

The main processes of nitrogen transformation in CWs such as ammonification, nitrification, denitrification and biological uptake are understood. However, the effect of different physical and biological conditions on nitrogen removal performance is not clear. Despite the complexity of CWs, some researchers, using the method of dynamic system, have established many models for nitrogen transformation in wetlands. Ikeda and Adachi [2] constructed a dynamic model of the nitrogen cycle in an aquatic system (idealized lake) and evaluated the effects of human interventions on the cycles. Under the conditions that an artificial ecosystem system is closed to nutrients, differential equations used the modeling approach for describing the dynamics of ecosystems [3]. Recently, a considerable number of works [4–6] have focused on the efficiency of nitrogen removal using CWs.

In this paper, by laboratory study and numerical stimulation, a simulation modeling of nitrogen transformation in reed CWs was studied. The objectives of this study were: 1) to establish a model for description of transformation and removal of nitrogen in our CWs; 2) to calibrate the unknown coefficients for prediction of total nitrogen (total N) removal efficiency in CWs; 3) to modify design parameters of CWs for improving the efficiency of nitrogen removal.

2. Materials and methods

2.1. Site description

The study was conducted in 3-year CWs systems located in the National Institute for Environmental Studies of Tsukuba, Japan (Fig. 1). Two treatment cells using a subsurface flow design for treating artificial domestic wastewater which composed of dextrine, bact peptone, yeast extract, meast extract, sodium chloride (NaCl), potassium chloride (KCl), magnesium sulfate hepta hydrate ($MgSO_4 \cdot 7H_2O$), urea ($(NH_2)_2$-CO) and potassium dihydrogen phosphate (KH_2PO_4). The treatment cells planted with *Phragmites australis* (reed)

Fig. 1. Location of Tsukuba in Japan.