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基于主成分分析的水平潜流湿地磷去除模型

Modeling phosphorus removal in horizontal subsurface constructed wetland based on principal component analysis

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中文摘要:

通过对水平潜流湿地（HSSF－CW）3a运行效果进行研究，分析了HSSF－CW不同处理单元单位面积总磷（TP）去除率对水温的响应变化曲线，利用正弦函数对各处理单元不同时间单位面积TP去除率变化过程进行了拟合，并通过主成分分析（PCA）和冗余分析（RDA）筛选影响磷去除的主要环境因子，进而利用人工神经网络（ANN）对各处理单元出水总磷浓度（TPo）进行了模拟。结果表明：水温较低时（<20℃），单位面积TP去除率对水温变化不敏感，随温度升高（>20℃），单位面积TP去除率升高并出现较大波动，最高达3.27 g/(m2?d)；单位面积TP去除率与水温之间存在一定的多项式函数关系（R2=0.1082, p=0），不同处理单元拟合关系存在一定差异（R2=0.318～0.350）；不同月份单位面积TP去除率符合正弦变化规律（R2=0.231，p=0），夏季去除率高于秋季，平均单位面积去除率为（0.331±0.132）g/(m2?d)，8月份出现最大值（0.397±0.125 g/(m2?d)）；通过PCA和RDA对不同环境因子与单位面积TP去除率之间的关系进行分析，发现单位面积TP去除率与进水TP质量浓度、水温、流量、溶解氧和蒸散发之间呈一定的正相关性，而与水深之间无显著相关关系；选取影响磷去除效果的主要环境因子进水TP质量浓度、水温、流量、溶解氧、pH值和蒸散发作为输入参数，构建ANN预测模型，通过反向学习算法和交叉验证对模型构型进行了构建和筛选，结果表明输入层、隐含层和输出层中神经元最佳构型分别为6-3-1；利用层次分析法将数据集分为训练集和验证集两部分，通过对比不同处理单元TPo实测值和模拟值，表明模型能够基本反映TPo的变化趋势和范围（R2=0.677～0.800）。该研究可为管理和改善水平潜流湿地运行效果提供参考。

英文摘要:

Abstract: Performance of a horizontal subsurface constructed wetland (HSSF－CW) running for three years was studied. Response curves of the area removal of total phosphorus (TP) to the changes in water temperature were analyzed for different treatment cells. The temporal changes in the area removal of TP in different treatment cells were simulated by the sinusoidal function. Based on the statistical methods of principal component analysis (PCA) and redundancy analysis (RDA), the main environmental factors influencing the removal of TP were selected. Afterwards, the effluent TP concentration (TPo) was simulated and predicted through the artificial neural network (ANN). The results suggested that the area removal of TP was insensitive to water temperature changes when the water temperature was low (<20℃), while great fluctuations combined with an increase of the area removal of TP occurred as the water temperature increased to a higher degree (>20℃). The highest value of area removal TP (3.27 g/(m2?d)) was reached at the temperature of 24.5℃. The relationship between the area removal of TP and the water temperature in different treatment cells was described by the polynomial function, and consequently reasonable accuracy was obtained (R2=0.1082, p=0.000). The variation of area removal of TP in different months was found to be in line with sinusoidal changes (R2=0.231, p=0.000). The area removal of TP with a plateau of 0.397±0.125 g/(m2?d) observed in August was higher than that in autumn. The average area removal of TP was 0.331±0.132 g/(m2?d) in summer. With the method of PCA and RDA, the relationship between the area removal of TP and different environmental factors was analyzed. As a result, the main impact factors including the influent TP concentration (TPi), wastewater temperature (Temp), flow rate (Flow), dissolved oxygen (DO), pH and evapotranspiration (ET) were found, and subsequently selected as the input parameters for ANN modeling. Comparison of the actual and simulated TPo values indicated a certain accuracy of the model in predicting the trend and scale of TPo in the HSSF－CW (R2=0.677-0.800). The results of this research could provide scientific support for the improvement and management of HSSF－CWs.