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Quantitative study of degradation coefficient of pollutant against the flow velocity*

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Abstract: The pollutant degradation coefficient is one of the key parameters to describe the water quality change, for establishing a reasonable water quality model and to determine the water carrying capacity and the environmental capacity. In this research, the environmental channel experiment is conducted to simulate the degradation evolution of the COD and NH_3-N under different flow velocity conditions in typical pollution water. It is shown that the processes of the COD and the NH_3-N's concentration over time are quite consistent with the first-order kinetic equation and the degradation coefficients increase with the increase of the flow velocity. When the flow velocity varies from 0 $m{\cdot}s^{-1}$ to 0.87 $m{\cdot}s^{-1}$, the degradation coefficients of the COD and NH_3-N increase from 0.011 d^{-1} to 0.071 d^{-1} and 0.038 d^{-1} to 0.258 d^{-1}, respectively. Moreover, the COD and NH_3-N's degradation coefficients both have excellent correlation with the reaction time. There is a good linear relationship between the COD degradation coefficient and the flow velocity as well as a good power exponential function between the NH_3-N degradation coefficient and the flow velocity. The comparative analysis of the Youth canal prototype monitoring and the calculation results shows that the quantitative formula obtained from the indoor water channel experiments gives results very close to the prototype observation results, which could reflect the degradation of pollutants in river water with varying flow velocity.

Key words: Degradation coefficient, carrying capacity, prototype observation, flow velocity

Introduction

The water pollution becomes a serious issue with the long-term industrialization and the rapid urbanization in China in recent two decades, imposing a real challenge to the river system[1,2]. At present, the water environment management in China is under a change from the concentration control to the total amount control, with a water function area system being set up, to strictly control the total amount of the sewage flows to rivers and lakes[3].

The calculation and the evaluation of the water carrying capacity and the environmental capacity become the key factor to control the total amount[4,5]. The contaminant degradation coefficient reflects the capacity of the specific water body to degrade the pollutants at a certain time and space. It is not only one of the key parameters for a water quality calculation model but also the important parameter to calculate the water environment capacity and the sewage carrying capacity[6]. Furthermore, it plays an important role in the total-amount-control of pollutions within the regional planning, the scientific allocation of the total load index, and the management of controlling process[7]. Methods commonly used to determine the contaminant degradation coefficient include the empirical formula estimation method, the data analysis analogy method, and the indoor experiment and prototype

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observation method[8,9]. However, the empirical estimation method is more subjective than the others and is hard to reflect the internal pattern of the pollutants degradation, which has a great impact on the reliability of the calculated result. The indoor experiment is usually conducted in a volume container, which is hard to reflect the hydraulic characteristics and the behaviors of the river course, and as a result, the measurement result is often smaller than the actual value. While the results of the prototype observation method are often applied in a particular time period for a particular river, its wide range of the pollutant degradation coefficient brings about many difficulties in practical applications. In addition, the pollutant degradation coefficient could be influenced by many factors, such as the water temperature, the pollutant characteristics, the microbial magnitude and species, the aquatic plant absorption and sediment adsorption[10-15], and especially, the hydraulic condition, which directly affects the spreading and the degradation of pollutants in the water body[16]. Quantitative research reports about the pollutant degradation coefficient and the flow rate of the hydraulic parameters are few.

This paper focuses on the COD and NH_3-N, simulates the pollutant degradation process at different flow rates through the indoor environment channel model experiment, to obtain the quantitative relationship between the pollutant degradation coefficient and the water flow velocity. The result would provide a scientific basis for the accurate calculation of the water body's carrying capacity and the water environmental capacity.

1. Materials and methods

1.1 *Study area and materials*

The experimental raw wastewater is sampled from Huangdong village of the Beijiang River Basin, and it includes the rural domestic sewage and the agricultural effluent with typical characteristics of the non-point source pollution in the Guangdong province. DR2800 spectrophotometer is used to analyze the sample concentration, and all chemical reagents come from HACH Company. The flow velocity is monitored through the rotary paddle flow meter. The experiment is conducted for 23 d in total. The water samples are taken from fixed places of the channels at the same time everyday. The water temperature, the flow velocity, the NH_3-N and COD concentrations are monitored at a same time in a daily basis in the experimental channels.

1.2 *Environmental channel experiments*

The environmental test channels are self-made on the basis of the open channel hydraulics principle, and the photographs of the test channels are shown in Fig.1. There are five different slope sinks made of Perspex sheet, and the flow velocity is controlled by the adjustment of the slope. The channel water is circulated with the use of the QZ-144 type mixed submersible pumps. The slope is adjusted to make the water flowing freely and make sure that the flow of the pump is equal to that of the channel in order to avoid the hydraulic jump and the aeration which might interfere with the study. Design parameters of the environmental channel are shown in Table 1 in a descending order of the velocities. The dimension of each of the five channels is 14 m long, 0.6 m high and 0.1 m wide, while the water depth is 0.4 m. The water velocities of the five channels are 0 $m \cdot s^{-1}$, 0.17 $m \cdot s^{-1}$, 0.36 $m \cdot s^{-1}$, 0.60$m \cdot s^{-1}$ and 0.87 $m \cdot s^{-1}$, respectively. The static water (5# channel) is to imitate the hydrostatic lakes and reservoirs, while the rest could represent different flows of plain rivers. The temperature of the sewage in the channels is about 20°C during the experiments.

Fig.1 The environmental test channels for measuring the pollution decaying coefficients with water flowing

Table 1 Parameters of experimental channels and hydraulic characteristic

No.	Average velocity/ $m \cdot s^{-1}$	Length/ m	Width/ m	Depth/ m	Test water depth/m
1#	0.87				
2#	0.60				
3#	0.36	14	0.1	0.6	0.4
4#	0.17				
5#	0.00				

2. Results and discussions

The pollutant concentration degradation with time can be described by a first-order kinetics model[2,17-19], in the form as follows

$$L = L_0 e^{(-kt)} \quad (1)$$