Effects of extra-cellular polymeric substances on organic pollutants biodegradation kinetics for A-step of adsorption-biodegradation process

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Abstract: The features of organic pollutants degradation mainly characterized by bio-flocculation for step-A of adsorption-biodegradation (AB) process were studied. By investigating the relationship of extracellular polymeric substances (EPS) with bioflocculation and introducing kinetic model of organic pollutant degradation into EPS, the kinetic model of organic pollutant degradation for step-A bioflocculation was deducted. And through the experiments, the kinetic constants were calculated as follows: $k_1 = 0.005$; $k_2 = 1710.7$ and $V_{max} = 10$ min$^{-1}$.

Key words: AB process; organic pollutants biodegradation; kinetics; EPS

1 INTRODUCTION

Adsorption-biodegradation (AB) process is an innovative biological treatment process developed in 1970s and has been widely applied all over the world in recent years. Compared with conventional activated sludge process, it has a lot of advantages such as high efficiency and steadiness, significant energy saving and low capital investment. One of its most eminent technical features is that the primary sedimentation tank can be omitted prior to the A-step, which is operated normally under the condition of high organic loading higher than 2 kg BOD$_5$/kg MLSS·d, low hydraulic retention time (t$_{HR-7}$) at about 30 min, low dissolved oxygen (DO) level at about 0.5 - 1.0 mg/L and short sludge age for only 0.5 - 0.7 d. A lot of researchers thought that the main mechanism of organic pollutants biodegradation was bioflocculation for A-step, 2/3 organic pollutants were removed by bioflocculation and biosorption and about 1/3 organic pollutants were removed by biodegradation. The traditional kinetics of activated sludge process mainly characterized by biodegradation cannot illustrate the effects of bioflocculation on the removal of organic pollutants. Organic pollutants biodegradation kinetics contributed by bioflocculation is studied and the main kinetic constants are determined by investigating the relationship of extracellular polymeric substances (EPS) and bioflocculation.

2 EXPERIMENTAL INSTALLATION AND METHOD

2.1 Experimental installation

The experimental installation is shown in Fig.1, consisting of a sequence batch reactor (SBR), a timer, air pump, turbulent flow meter and fine bubble aeration sand aerator. The effective volume of the reactor is about 4.5 L, with a size of 30 cm in height and 15 cm in inner diameter. The experiment is operated with intermittently feeding and decanting. Oxygen is aerated through the sand aerator from the air pump and the time is used for time control.

Fig. 1 Schematic configuration of lab-scale activated sludge reactor used in the experiment

1—Timer; 2—Air pump; 3—Turbulent flow meter; 4—Reactor; 5—Magnetic stirrer

2.2 Experimental method

Sludge from Step A was loaded, the sludge
concentration was controlled at about 3.2 g/L. Domestic wastewater was used as the experimental wastewater, with a concentration of 357 - 624 mg/L, and when reaction lasted for 5 min, 15 min and 50 min respectively, samples were taken and sent to test for chemical oxygen demand (COD).

The EPS were extracted from the activated sludge by mixing with a cation exchange resin E4-6] and the other measurements were carried out by standard methods ET?.

3 RESULTS AND DISCUSSION

3.1 Hypotheses of biodegradation kinetic model for A-step of AB process

According to the operational characteristics and the organic pollutants biodegradation mechanism in A-step, it is assumed that:

1) both the quality and quantity of influent is steady;
2) the materials are completely mixed when entering reactor and the system is steady;
3) when hydraulic retention time (t_HRT) is 1 - 15 min, only the action of bioflocculation is considered while the action of biodegradation is out of considerationE8-~°;
4) when t_HRT is in the range of 15 - 50 min, only action of biodegradation is considered while the action of bioflocculation is not taken into consideration;
5) pollutants removed by bioflocculation is mainly determined by the concentration of EPS but not by the quality of influent, mixed liquor suspended solid (MLSS) and aerating time and so on.

3.2 Organic pollutants biodegradation kinetics for A-step of AB process

The materials in the reactor of A-step of AB process are completely mixed, as shown in Fig. 2.

Based on Fig. 2, Eqn. (1) can be obtained: [C_o - C_e] = \frac{Q}{V} \frac{dC}{dt} = 0 \quad (1)

Eqn. (2) can be obtained after deducing:

\frac{dC}{dt} = \frac{Q(C_o - C_e)}{V} \quad (2)

where \frac{dC}{dt} is biodegradation rate of organic substrates; Q is flow rate of wastewater (m^3/d); C_o is concentration of substrate of influent (mg/L); C_e is concentration of substrate in mixed liquor after reacted for time t (mg/L); R is concentration of substrate in mixed liquor of effluent (mg/L); R is ratio of sludge recirculation; V is volume of reactor (L).

Eqn. (3) can be obtained based on the equation of Michaelis-Menten:

\frac{dC}{dt} = \frac{C}{K + C} \quad (3)

where \frac{dC}{dt} is velocity of substrate biodegradation, \frac{C}{K + C} is the maximum velocity of biodegradation of the substrate, \frac{C}{K + C} is concentration of the substrate (mg/L); K is saturated constant, namely half-velocity constant.

According to its physical meaning, the specific biodegradation rate of substrate can be calculated by Eqn. (4):

\frac{dC}{dt} = \frac{C}{K + C} \quad (4)

where \frac{C}{K + C} is concentration of MLSS, which is mixed liquor suspended solid (g/L).

Based on Eqns. (3) and (4), Eqn. (5) can be obtained:

\frac{dC}{dt} = \frac{C}{K + C} \quad (5)

The kinetic model of A-step in AB process can be divided into the following two aspects:

1) When t_HRT is 1 - 15 min, only the action of bioflocculation and biosorption is considered because the bioflocculation is only related to EPS. Replacing X in the Eqn. (5) with EPS, Eqn. (6) can be obtained:

\frac{dC}{dt} = \frac{C}{K + C} \quad (6)

where \frac{dC}{dt} is degradation rate of substrate by biosorption and bioflocculation; X_{EPS} is concentration of EPS in the substrate (mg EPS/L); K is saturated constant during the course of bioflocculation; C_e is concentration of the substrate (mg/L).

When sewage is contacted with activated sludge for above 15 min, biodegradable suspended solids and colloids are little in the liquid and C_e is far smaller than K and C_e, so that it can be ignored in Eqn. (6). Then Eqn. (6) can be simplified as follows:

\frac{dC}{dt} = \frac{C}{K + C} \quad (7)

If the effects of loading rate N_s, dissolve oxy-