International Biodeterioration & Biodegradation 125 (2017) 37–44

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

A simulation of sewer biodeterioration by analysis of different components with a model approach

Tzu-Yi Pai [a,*], Shun-Cheng Wang [b], Huang-Mu Lo [b], Li Chen [c], Terng-Jou Wan [d], Ming-Ray Lin [a], Ching-Yuan Lin [b], Pei-Yu Yang [b], Wei-Jia Lai [b], Ya-Hsuan Wang [a], Tien-Hsuan Lu [a]

[a] Master Program of Environmental Education and Management, Department of Science Education and Application, National Taichung University of Education, Taichung, 40306, Taiwan, ROC
[b] Department of Environmental Engineering and Management, Chaoyang University of Technology, Wufeng, Taichung, 41349, Taiwan, ROC
[c] General Education Center, Shuzen College of Medicine and Management, Luju, Kaohsiung City, 82144, Taiwan, ROC
[d] Department of Environmental and Safety Engineering, National Yunlin University of Science and Technology, Douliou, Yunlin 64002, Taiwan, ROC

ARTICLE INFO

Article history:
Received 3 April 2017
Received in revised form
17 July 2017
Accepted 9 August 2017
Available online 29 August 2017

Keywords:
Sewer biodegradation rate model
Heterotrophic microorganism
Biofilm
Hydrogen sulfide
Nitrogen
Degradation

ABSTRACT

This paper represents the first study to simulate the biodegradation rates (BDRs) of several components in the sewer using the sewer biodegradation model (SBDM). In order to verify the fitness between the experimental values and model values, experiments were conducted in a 21 m long sewer pilot plant and the results showed high fitness (All correlational coefficient values were greater than 0.91). Since the SBDM was validated, the biodegradation rate (BDR) was simulated. The production of hydrogen sulfide was also simulated. The results revealed that aerobic growth of heterotrophs in biofilm predominated the biodegradation. The growth rate of heterotrophs in biofilm was greater than the decay rate from initial time to the 3rd hour, but it changed after the 4th hour because of low substrate concentration. During the experimental period, the BDRs were greater than the supply rate for five components. For two components, the supply rates were greater than the BDRs. The BDR of dissolved oxygen was greater than the supply rate before the 3rd hour but that reversed after the 3rd hour. According to the results, the sewer biodeterioration could be simulated using SBDM.

1. Introduction

Water resource is important for agricultural, industrial as well as domestic usage. However, various types of water body are polluted by the effluent discharged from industrial and domestic sectors (Tung and Pai, 2015). To preserve water resource, sewer systems are installed and used to transport wastewater from households, industries, or commercial area to wastewater treatment facilities (WWTF). The wastewater contains complex components including carbon, nitrogen, and phosphorus with different oxidized states. Meanwhile the water level in sewer is shallow, and the bottom of sewer is always attached by biofilm. Because a large amount of wastewater with high strength was discharged into the sewer, the degradation of different components in sewer becomes more important.

Wastewater components are degraded due to biological reactions as flowing through sewer. The degradation of particulate and soluble components occurs in the water as well as in biofilm. The wastewater components are degraded under either aerobic or anaerobic conditions which are mainly determined by the oxygen level. Several previous researches have investigated these biodegradation for wastewater components and biomass (Butler et al., 1995; Hvitved-Jacobsen et al., 1998a, 1998b; Pai et al., 2010a, 2013; Vollertsen and Hvitved-Jacobsen, 1998). Many mathematical models based on the kinetics from the activated sludge model (Henze et al., 2000; Pai et al., 2001, 2004a, 2004b) were proposed to describe the microorganisms' biodegradation under various conditions in sewer. According to other studies, sulfate-reducing bacteria and fungi are significant contributors to the biodeterioration of sewer (Hernandez et al., 2002; Nica et al., 2000; Park et al., 2014; Herisson et al., 2013; Wei et al., 2010; Davis et al., 1998; Long et al., 2017; Lors et al., 2017; Abdikheibari et al., 2016; Roberts et al., 2002; Leemann et al., 2010; Vincke et al., 2002; Vupputuri et al., 2015;

* Corresponding author.
E-mail address: bai@ms6.hinet.net (T.-Y. Pai).

http://dx.doi.org/10.1016/j.ibiod.2017.08.003
0964-8305/

Hughes et al., 2014; Gu et al., 1998.).

Although previous studies have discussed the biodegradation of different components in sewer, the studies about the biodegradation rates (BDR) of components in sewer are less. The BDRs in sewer are unclear, but well understanding on BDRs is helpful to the operation of WWTF and maintenance of sewer. Therefore, the study on BDRs in sewer is worthwhile and important. With this view, it is better to seek a method for understanding the BDRs in sewer more clearly, and the model simulation is a good choice. Since the BDRs were not clearly discussed in previous researches, this paper represents the first study to simulate the BDRs for carbon, nitrogen as well as hydrogen sulfide in sewer. The objectives of the present paper are described as follows. (1) To establish a sewer biodegradation model (SBDM) based on the kinetic of several models including ASM (Henze et al., 2000; Pai et al., 2001, 2004a, 2004b), Taiwan Extension Activated Sludge Model (TWEA) (Pai, 2007, 2009a, 2009b, 2009c, 2010b, 2010c, 2013, 2014), and Hvitved-Jacobsen et al. (1998a, 1998b) to describe the BDRs in sewer. (2) To validate the proposed SBDM by exploring the fitness between the MVs (model values) and EVs (experimental values) of different components. If high fitness revealed, the SBDM can be validated. (3) To simulate the BDRs in the sewer by using the SBDM.

2. Materials and methods

2.1. Sewer pilot plant

A 21 m long plastic sewer pilot plant was installed to carry out the experiments, as shown in Fig. 1. The flowrate of the synthetic wastewater and slope of the sewer pilot plant could be adjusted. The synthetic wastewater temperature in sewer pilot plant was maintained at 20 centigrade. The synthetic wastewater could be recirculated using a pump installed between the head water tank (HWT) and tail water tank (TWT). The DO (dissolved oxygen) level was monitored using a DO meter installed in the recirculation tank (RT). All units including synthetic substrate tank, HWT, recirculate tank, and TWT were sealed to avoid the recirculated wastewater from being oxygenated.

2.2. Experimental procedure

The synthetic substrate was synthetized using major constituents, as tabulated in Table 1. The major constituents were dissolved in 1 L distilled water. Besides, the NaOH solution was used to control the pH of synthetic substrate at 7–7.5. The synthetic substrate was pumped into sewer pilot plant at a certain amount periodically to be mixed with the synthetic wastewater in sewer pilot plant.

Table 1
Constituents of synthetic substrate.

Constituents	Weight (mg)
Milk powder	163.2
NH_4Cl	40.0
CH_3COOH	37.6
$CO(NH_2)_2$	30.0
$C_{12}H_{22}O_{11}$	16.2
KH_2PO_4	15.0
$FeCl_3$	0.1

The activated sludge was seeded in the sewer pilot plant under a fixed flow velocity. When effluent concentrations from the sewer pilot plant were maintained at constant values, the biofilm was regarded as steady condition and biofilm grew stably on the sewer bottom. After finishing each experiment, the biofilm was acclimated under a fixed flow velocity again. The flow velocity and the pH for acclimation were controlled at 0.6 m s^{-1} and 6.0–7.2, respectively. The synthetic wastewater of 500 ml was taken from the sampling port on the RT every 1 h and the concentrations of DO, soluble organic nitrogen, ammonia, nitrate, and substrate of fast biodegradation (C_S) were investigated.

2.3. Model development

When the sewer system was modelled, several assumptions and limitations were made in order to make the sewer biodegradation model tractable. (1) The nature of the organic matter within any given fraction did not change. (2) The coefficients in the rate equations were assumed to have constant values. (3) The heterotrophic and autotrophic microorganisms' biomass was homogeneous and did not undergo changes with time.

Table 2 shows the definitions of components in SBDM. The rate equations of SBDM are shown in Table 3. In SBDM, the stoichiometry coefficients, kinetic coefficients, and kinetic rate equations from ASM (Henze et al., 2000; Pai et al., 2001, 2004a, 2004b), TWEA (Pai, 2007, 2009a, 2009b, 2009c, 2010b, 2010c, 2013, 2014), and sewer models (Hvitved-Jacobsen et al., 1998a, 1998b) were adopted. For simulating the production of hydrogen sulfide, the stoichiometry and kinetic process rate equations for hydrogen sulfide from previous studies were also adopted (Park et al., 2014; Abdikheibari et al., 2016). By combining the stoichiometry coefficients and rate equations in Table 3, the complete BDR equations for different components in SBDM can be described as follows.

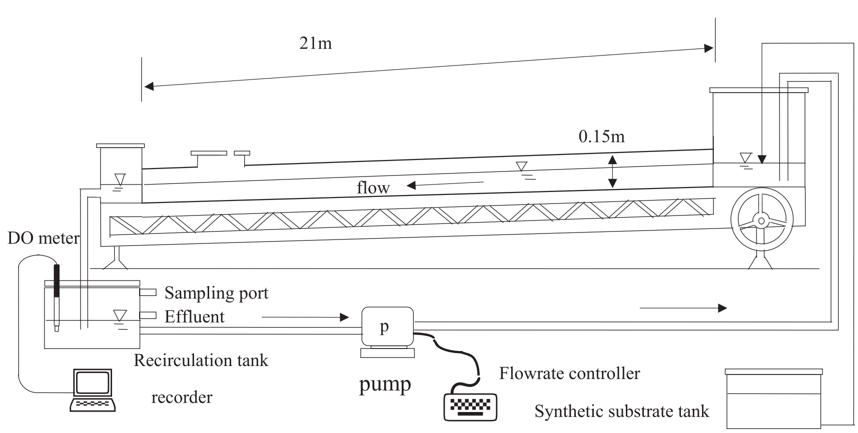

Fig. 1. Sewer pilot plant.