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Effects of glucose and phenol on soluble microbial products (SMP) in sequencing batch reactor systems

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Abstract

Soluble microbial products (SMP) are ubiquitously present in the effluents of biological wastewater treatment systems. In sequencing batch reactor (SBR) systems, effects of influent concentration and temperature on the amount and the molecular weight (MW) distribution of SMP were investigated for the two substrates, glucose and phenol. The values of effluent SMP/S_0 of phenol were higher than those of glucose at different influent concentrations and temperatures. It was found that the effluent SMP (S_e) was linearly correlated to the influent total organic carbon (TOC) (S_0) for both substrates. The slope and intercept of the equation were affected by the temperature. According to the analysis of the MW distribution, it was shown that there exists a bimodal pattern with the majority of SMP having a MW <1 kDa or >10 kDa. The low MW fraction (<1 kDa) amounts to 47.3–70.4% of the effluent SMP. The high MW fraction (>10 kDa) slightly fluctuates in the range of 21.2–32.8% of the effluent SMP.

Keywords: Soluble microbial products; Activated sludge; Biological wastewater treatment; Sequencing batch reactor; Molecular weight distribution

1. Introduction

Effluents from biological wastewater treatment systems contain a variety of soluble organic compounds, which are mainly composed of soluble microbial products (SMP). SMP is defined as the pool of organic compounds that are released into solution from substrate metabolism (usually with biomass growth) and biomass decay (Barker and Stuckey, 1999). Namkung and Rittmann (1986) grouped SMP into two different categories. One is substrate utilization-associated products (UAP) that are associated with substrate metabolism and biomass growth and are produced at a rate proportional to the rate of substrate utilization. The other is biomass-associated products (BAP) that are associated with biomass decay and are produced at a rate proportional to the concentration of biomass.

The existence of residual microbial products originating from microorganism in the process of wastewater treatment was demonstrated as early as 1961 (Gaffney and Heukelekian, 1961). Since then many researchers (Grady et al., 1972; Daigger and Grady, 1977; Siber and Eckenfelder, 1980; Gaudy and Blachly, 1985; Rittmann et al., 1987; Sollfrank et al., 1992; Noguera et al., 1994; Schiener et al., 1998; Goorany and Ozturk, 2000; Lu et al., 2002; Aquino and Stuckey, 2004; Holakoo et al., 2006) have recognized that the majority of the soluble organic matter in effluents from biological treatment processes is actually SMP. Hence, the presence of SMP has an effect on achieving current discharge standards and setting the lower limits of discharge standards of the effluent. The formation of SMP affects both the selection and performance of the subsequent treatment processes, and the ultimate environmental impact of the treated wastewater. In addition, the presence of SMP influences the reuse of wastewater and the treatment of drinking water, because of that some components of SMP can be more toxic than those in the influent wastewater, the precursors of methane trihalides and other disinfected by-products (Namkung and Rittmann, 1988), and bring about the proliferation of microbes in the systems of water supply. Therefore, it is of

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great significance to study the formation of SMP in the processes of biological wastewater treatment for instructing the design and operation of the processes of wastewater treatment, the selection of the subsequent treatment methods, and the formulation of wastewater discharge standards.

The objectives of this research were to investigate the effects of substrate type, influent concentration and temperature on the amount of SMP in sequencing batch reactor (SBR) system, to characterize the molecular weight (MW) distribution of SMP produced under different culture conditions, and to disclose the mechanisms of SMP formation.

2. Materials and methods

2.1. Stock culture

The activated sludge used in this study was obtained from Wastewater Treatment Plant of East China University of Science and Technology, Shanghai, PR China and was acclimated in a 10 LSBR reactor for several months. Glucose served as substrate. The composition of the feed water was as follows: influent chemical oxygen demand (COD) 500 $mg\,l^{-1}$, NH_4Cl 100 $mg\,l^{-1}$, KH_2PO_4 400 $mg\,l^{-1}$, and Na_2HPO_4 630 $mg\,l^{-1}$. All components were dissolved in tap water to supply other mineral elements. The reactor was operated at room temperature and maintained at sludge retention time (SRT) 7 days, pH 6–8, dissolved oxygen (DO) 4–7 $mg\,l^{-1}$.

2.2. Experimental plan

Three sets of experiments were conducted, each employing six SBR reactors. In the first set, all reactors were operated at 15 °C, three different concentrations of glucose 500, 750, 1000 $mg\,l^{-1}$ as COD and three of phenol. After 3–4 weeks, they were monitored to ensure that they had reached their steady-state performance for 3–4 days before sampling. In the second and third sets, all reactors were operated at 25 and 35 °C, respectively, with the other conditions the same as the first set.

2.3. Experimental reactors

The experimental reactors were graduated cylindrical glasses containing a liquid volume of 1 l. Six reactors were operated simultaneously with a 24-h time controller. At 8:30 am everyday, 600 ml of supernatant was removed from the reactor after settling for 90 min, then a portion of the mixed liquor was removed from the reactor and discarded to maintain SRT of 7 days. It was continuously aerated for 8 h from 10:00 am to 6:00 pm after adding the feed water, and then aerated 15 min every 2 h until 8:30 am the next day, just before removing the supernatant. In all cases, the reactor walls were scraped frequently to minimize the effects of wall growth. Other process parameters were the same as the acclimatization of stock culture.

Carbon was the growth-limiting nutrient, and glucose or phenol served as the sole source of carbon and energy. NH_4Cl was added as the source of N. The ratio of C to N was maintained at 20:1. The solution of phosphates (KH_2PO_4 400 $mg\,l^{-1}$, Na_2HPO_4 630 $mg\,l^{-1}$) was used as a pH buffer and acted as the source of P. Ca, Mg and Fe were supplemented with the addition of $CaCl_2$ 20 $mg\,l^{-1}$, $MgSO_4 \cdot 7H_2O$ 20 $mg\,l^{-1}$ and $FeCl3 \cdot H_2O$ 0.5 $mg\,l^{-1}$, respectively. All components were dissolved in deionized water, and trace elements were supplied by adding 10 ml of tap water to each reactor once daily.

2.4. Analytical procedures

The schematic diagram of sample processing used to determine MW distribution of SMP in samples is illustrated in Fig. 1. After samples were removed from supernatant of the experimental reactors, they were filtrated through 0.45 μm filter membrane by vacuum filter. Portions of these permeates were used to determine TOC and the concentration of residual substrate (glucose or phenol). Others were used for ultrafiltration (UF) to get the MW distributions. MW distributions were determined by using a 300 ml ultrafiltration stirred cell with 80-mm ultrafiltration membranes. Two membranes with nominal MW of 1 and 10 kDa were used in a parallel procession to cut the MW into three sections (MW < 1 kDa, 1 kDa < MW < 10 kDa, MW > 10 kDa) and then measured the TOC. Glucose was determined using the enzymatic microdetermination method (Salomon and Johnson, 1959). Phenol was measured according to the APHA standard methods (APHA, AWWA and WCF, 1998). Total SMP in effluent was the difference of TOC_1 and TOC_R, which can be calculated from the residual concentration of glucose or phenol in effluent. The fractions of MW < 1 kDa, 1 kDa < MW < 10 kDa and MW > 10 kDa were the differences of TOC_2 and TOC_R, TOC_3 and TOC_2, TOC_1 and TOC_3, respectively.

3. Results and discussion

3.1. Effect of substrate type on the amount of SMP

Generally the release of microbial products is related to the microbial culture, which is composed of various microbes when activated sludge is acclimatized by feeding different kinds of substrate. It is shown in Tables 1 and 2 that effluent SMP/S_0 is slightly different when glucose is used as substrate compared to phenol, which is an inhibitory substrate. At the temperatures of 15, 25, and 35 °C, it can be seen that the values of SMP/S_0 of phenol were higher than those of glucose at any influent concentration of COD. This result is in accordance with that reported from Boero et al. (1991). However, the values of SMP/S_0 of glucose are remarkably higher. It is attributable to the long SRT and different experimental conditions. Therefore, as an inhibitory substrate (Fedorov et al., 1992), phenol showed higher SMP/S_0 than the

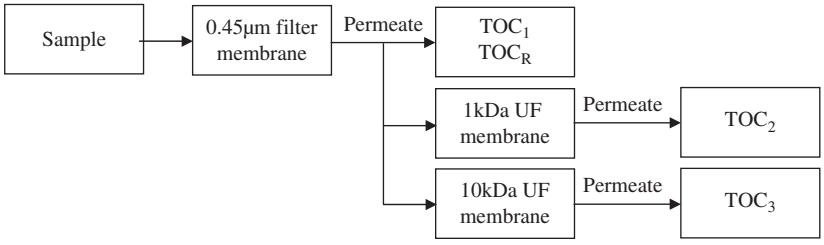

Fig. 1. Schematic diagram of sample processing used to determine MW distribution of SMP.