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Modeling the formation of soluble microbial products (SMP) in drinking water biofiltration

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Abstract: Both a theoretical and an empirical model were developed for predicting the formation of soluble microbial products (SMP) during drinking water biofiltration. Four pilot-scale biofilters with ceramsite as the medium were fed with different acetate loadings for the determination of SMP formation. Using numerically simulated and measured parameters, the theoretical model was developed according to the substrate and biomass balance. The results of this model matched the measured data better for higher SMP formation but did not fit well when SMP formation was lower. In order to better simulate the reality and overcome the difficulties of measuring the kinetic parameters, a simpler empirical model was also developed. In this model, SMP formation was expressed as a function of fed organic loadings and the depth of the medium, and a much better fit was obtained.

Key words: *drinking water*; *biofiltration*; *soluble microbial products* (*SMP*); *mathematical modeling*

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1 Introduction

Nowadays biofiltration is widely used in drinking water treatment as a supplement or enhancement of the conventional treatment (Wang and Liu 1999; Urfer et al. 1997). Biofilters have dual functions: one is reducing the turbidity and pathogen particles like the conventional filters, and the other is removing the biodegradable organic matter (BOM) and other bioavailable materials through the microbial metabolism of the biofilm attached to the media. The latter function currently draws more attention because the micro-pollution of source water with BOM has become a common problem in many countries, especially in economically booming ones (Wang and Liu 1999).

The microbes do not only eliminate the substrate from the influent, they can also excrete or release some organic compounds, the so-called soluble microbial products (SMP), into the extracellular environment during substrate utilization and biomass decay (Barker and Stuckey 1999). In fact, SMP were first found and thoroughly investigated in wastewater biological treatment (Barker and Stuckey 1999). It was revealed that SMP sometimes consist of most of the effluent of the wastewater bioreactor. The composition of SMP is very complicated, and includes humic and fulvic acids, polysaccharides, proteins, nucleic acids, amino acids, organic

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acids, steroids, antibiotics, extracellular enzymes, and siderophores (Barker and Stuckey 1999; Manka and Rebhun 1982). SMP in wastewater are usually refractory or less biodegradable, except for some newly formed substrate-utilization-associated products (UAP). Their molecular weight is distributed around “dual peaks” (greater than 100 000 or lower than 1 000) (Kuo and Parkin 1996). SMP can also act as a chelating reagent and have a toxic effect on the activity of the biomass (Kuo and Parkin 1996; Huang et al. 2000).

In contrast to what is known about SMP formation in wastewater treatment, the research on SMP formation in drinking water treatment is very limited. Only a few related references can be found, of which the work by Carlson and Amy (2000) might be the most important. They investigated SMP with mathematical modeling and direct measurement and regarded SMP as an important factor in the underestimation of dissolved organic carbon (DOC) removal in biofiltration. However, many more characteristics of SMP in drinking water biotreatment remain unrevealed. Since drinking water is so important to human health, more work should be done on this theme. In this study, efforts were directed toward establishing models of SMP formation during drinking water biofiltration with acetate as the sole carbon source, based on pilot-scale reactors. Both a theoretical and an empirical model were developed, and the results were compared in order to approach the true SMP profiles.

2 Materials and methods

2.1 Pilot-scale biofilter system

The experimental system contained four parallel biofilters (Figure 1) with ceramsite as the medium. The influent to the reactors was tap water. First, the organic matter in the tap water was removed through granular activated carbon filtration. Then, a sodium acetate solution was fed into the influent as the carbon source. The final concentrations of acetate in the influent were 1.0, 0.5 and 0.2 mg/L, in biofilters A, B and C, respectively. These concentrations of acetate were converted into the concentrations of carbon. Biofilter D was used as the blank control and no acetate was added to it. The other parameters of the biofilters can be seen in Table 1. All four reactors were run for about two months before this study began to guarantee that they would be in a steady state while the study was being conducted.

Table 1 Parameters of biofilters A-D

Item	Value	Item	Value
Empty bed contact time (EBCT)	10 min	Depth of water	1 100 mm
Diameter	60 mm	Interval of adjacent sampling ports	150 mm
Height of the medium (ceramsite)	750 mm	Flow rate	20 L/h
Diameter of ceramsite	2-3 mm	Backwash cycle	24 h

2.2 Analytical method

COD_{Mn} and NH_4^+-N were measured using standard Chinese methods (SEPA 2002).