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Increase of microbial growth potential in municipal secondary effluent by coagulation

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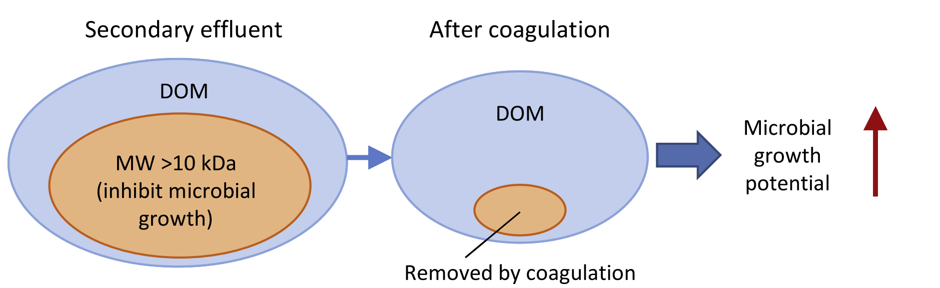
HIGHLIGHTS

- A significant increase of AOC in secondary effluents is observed after coagulation.
- High MW (>10 kDa) organic component have an inhibitory effect on microbial growth.
- The removal of high MW matters causes the increase of microbial growth potential.
- Polysaccharides and/or proteins are the key matters affecting the microbial growth.

GRAPHICAL ABSTRACT



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ABSTRACT

Microbial growth is a big issue of concern in the use of reclaimed water. In this study, the variation of microbial growth potentials of municipal secondary effluents after coagulation was evaluated by measuring assimilable organic carbon (AOC). Surprisingly, the AOC levels increased significantly (55–667%) after coagulation with poly-aluminum dosages of 60 mg L^{-1} for the samples investigated in this research. By ultrafiltration membrane fractionation, the microbial growth potentials of the fractions with different molecular weight (MW) were measured. The results revealed that the maximum cell densities of microbial growth in secondary effluents were lower than those in their fractions with MW < 10 kDa. Meanwhile, the organic component with MW > 10 kDa in biological treated effluents was proved to have an inhibitory effect on microbial growth. Therefore, the removal of those high MW organic matters was the main reason for the increase of microbial growth potential in secondary effluents during coagulation. Furthermore, polysaccharides and/or proteins in secondary effluents were easily removed by coagulation and were thought to be the possible key organic substances affecting the microbial growth potential during coagulation. It is suggested that post treatments would be needed after coagulation to maintain the biological stability of reclaimed water.

1. Introduction

Freshwater shortage is becoming increasingly serious in many big cities or arid areas all over the world because of population growth, climate change, and degradation of existing sources of water. That makes the reuse of municipal wastewater a necessity.

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Wastewater reclamation and reuse has become a common practice in some big cities.

Microbial growth in reclaimed water is one of the most important issues attracting much attention (Ryu et al., 2005; Jjemba et al., 2010; Thayanukul et al., 2013). Microbial growth in storage and distribution systems is a practical problem that could generate undesired odor and color (Narasimhan et al., 2005), corrode the pipeline of distribution and cooling systems (Li et al., 2011; Wang et al., 2012), and pose potential health risks to human (Jjemba et al., 2010).

Organic nutrient in reclaimed water is an important factor related to microbial growth. The organic matter, especially the fraction called biodegradable organic matter (BOM), is generally the limiting nutrient for microbial growth in reclaimed water (Funamizu et al., 1998). Assimilable organic carbon (AOC) is largely used as a significant indicator for the growth potential of heterotrophic microorganisms in water. AOC is determined by measuring the maximum growth of the test bacterial strains inoculated in water samples. Many researchers have reported the relationship between AOC concentrations and microbial regrowth or biofilm formation in drinking water and reclaimed water distribution systems (LeChevallier et al., 1996; Volk and LeChevallier, 1999; Escobar et al., 2001; Thayanukul et al., 2013). It should be noted that, AOC levels represent the microbial growth potential other than a simply direct measurement of BOM in the samples, because some organic compounds in water may inhibit the microbial growth (Chudoba, 1985; Ross et al., 1998; Ichihashi et al., 2006).

Coagulation is a widely used conventional technique in drinking water and reclaimed water treatment processes. Some researchers have studied the variation of AOC in drinking water during coagulation, but the results were inconsistent. Some results revealed that the AOC concentration decreased after coagulation and filtration (maximum 36–75%) (Charnock and Kjonno, 2000; Kasahara and Ishikawa, 2002; Lehtola et al., 2002; Liang and Ma, 2009; Lou et al., 2012), while other researchers reported that the removal efficiency of AOC was low by the conventional treatments (Volk et al., 2000; Shu et al., 2008; Tian et al., 2008).

There are significant differences in organic composition and concentration between municipal secondary effluent and drinking water. Natural organic matter (NOM) accounts for the majority of organic component in drinking water sources, but the secondary effluent of the biological wastewater treatment process contains a variety of soluble microbial products (SMP) (Barker and Stuckey, 1999; Shon et al., 2006). The difference in water quality between them may lead to different behaviors of microbial growth potential after coagulation. However, the knowledge about the impact of coagulation on AOC in secondary effluents is very limited. One study performed by Thayanukul et al. (2013) investigated the AOC level of reclaimed water produced by different full-scale treatment processes. Their results revealed that coagulation could reduce AOC in secondary effluents in most cases. In order to give a clearer understanding on the effect of coagulation on microbial growth potential of secondary effluents, more studies are in great need.

Table 1
Characteristics of secondary effluent samples investigated in this study.

Parameters[a]	Range of values	Average
pH	7.3–8.1	
DOC (mg L^{-1})	8.1–13.9	10.3
UV_{254} (m^{-1})	10.0–15.8	11.5
NH_3–N (mg L^{-1})	0.1–0.4	0.2
TN (mg L^{-1})	8.7–24.5	16.4
TP (mg L^{-1})	2.2–2.7	2.5

[a] DOC, dissolved organic carbon; UV_{254}, the absorbance at 254 nm; NH_3–N, ammonia nitrogen; TN, total nitrogen; TP, total phosphorus.

This study systematically investigated the apparent AOC behavior in municipal secondary effluents during coagulation. By fractioning the organic matters in secondary effluents into different molecular weight (MW) fractions, MW distribution variation of microbial growth potential was determined so as to elucidate the mechanisms of the changes of AOC during coagulation. Furthermore, the removal of specific organic contents by coagulation was measured to identify the key substances related to the changes of microbial growth potential.

2. Materials and methods

2.1. Water samples

In this research, water samples were collected from the effluents of secondary sedimentation tanks of three municipal wastewater treatment plants (WWTPs) in Beijing, China. Following primary sedimentations, the secondary biological treatment processes of the WWTPs are all anaerobic–anoxic–oxic (A^2O) processes. Fourteen samples were collected from July 2012 to May 2013 (WWTP1: samples A–K; WWTP2: samples L and M; WWTP3: sample N). Each sample of 10–20 L was collected into organic carbon-free glass bottles, transported to laboratory within 1 h and stored at 4 °C. The water quality was analyzed on the day of collection. The characteristics of water samples collected in this study are summarized in Table 1.

2.2. Jar test

The coagulation tests were performed by using a jar test apparatus in laboratory. The coagulants used in this research were polyaluminum chloride (PACl), $FeCl_3$ and $Al_2(SO_4)_3$. PACl was obtained from a wastewater treatment plant, and other chemical reagents were of analytical grade. Prior to coagulation experiment, the secondary effluent sample was brought to room temperature (20–25 °C). Then 1 L of the sample was poured into a glass beaker and the glass beaker was placed into the jar test apparatus. The coagulation procedure consisted of a rapid mix stage at 200 rpm for 30 s, followed by a second stage at 150 rpm for 2 min after the addition of a certain dosage of coagulant and a third stage at 50 rpm for 10 min. The final step was the sedimentation period continuing for 30 min. The coagulant dosages were 10–60 mg L^{-1}. After coagulation, the sample was filtered by a 0.2 μm nylon membrane (Whatman, England) to remove the flocs and the pH was adjusted to neutrality for AOC measurement.

2.3. Molecular weight fractioning

MW distribution of organic matter in the sample was measured using regenerated cellulose ultrafiltration membranes with MW cut offs of 1, 10 and 100 kDa (Millipore, US). And parallel processing of samples through different membranes was chosen due to its smaller error in determining MW distribution (Logan and Qing, 1990).

Before filtration, the sample was filtered by a 0.2 μm membrane to remove the particulate matters, and enough Milli-Q water was filtered through the membrane until there was not any organic carbon in the filtrate. Then, 350 mL of the sample was poured into the stirred ultrafiltration cell (Model 8400, Millipore, US), and the cell was placed on the magnetic stirring table. Membrane filtration was driven by pure nitrogen at an operation pressure of 0.05–0.4 MPa according to the type of the membrane. Filtration was stopped before the volume of the sample in the cell reduced to 50 mL. Then the filtrate with low MW organic matters was collected for analysis.

In order to obtain the fractions with high MW organic matters, the residual sample in the cell, which still comprised low MW or-