Safety of Post-UV Disinfection of Wastewater: Bio-stability in Reuse Water Pipelines

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ABSTRACT

Ultraviolet (UV) disinfection was found not to be able to maintain its disinfection effect over a few days, such that, the total bacterial count increased up to the same level as that for non disinfected samples in only five days. Higher temperature enhanced the increase of bacteria in UV treated samples, while at the same time decreasing that for non disinfected samples. The biofilm concentrations of bacteria in the effluent for UV or chlorine treated samples was different, but reached the similar values after 18 days. UV disinfection led to no significant differences in the microorganism community, as compared to other disinfection treatments, such as chlorine.

Key words: UV disinfection; reclaimed water; pipelines; bio-stability

INTRODUCTION

Continuous population growth and economic development increase the water demand and force agencies to look for alternative water sources. It is forecasted that future demands for water will not be met by traditional sources, such as surface water and groundwater. In order to handle the increased water demand and with more serious attention to water pollution, purified wastewater must be reused (Hu et al., 2005; Lazarova et al., 1999). Public health is the first important issue when considering water reclamation; hence, disinfection of wastewater becomes a necessary part of the treatment to ensure the safety of water for reuse.

Although chlorine has been widely used throughout the world, the advantages of ultraviolet (UV) disinfection over chlorine are: (1) absence of toxic disinfection byproducts and (2) safe and sound operation. However, a disadvantage is possible reactivation of UV-damaged microorganisms, including photo¬reactivation and dark repair (Hijnen et al., 2006). Photo-revival has gained considerable attention, not only in the field of disinfection, and it is well documented. Dark repair is less popular because it is a less important repair mechanism, as compared to photoreactivation (Lindenauer et al., 1994; Kashimada et al., 1996; Oguma et al., 2004). One issue that needs to be addressed is that, during transport of the reused water, there might be enough time for the UV injured microorganisms to be repaired and hence raising a possible risk to public health. So the phenomenon of dark repair in the pipelines for reused water pipelines is worth paying attention to.

It is known that the issues of biofilm and the microbial community in potable water distribution systems have attracted considerable attention and have been studied extensively. Meanwhile, wastewater, especially reclaimed water, is not given much attention. Since reused water is becoming another water resource, besides potable water, the safety of reused water is as important as that of drinking water.

There have been no studies focused on the impact of UV disinfection on biofilm growth in reclaimed water distribution systems, and the four articles found in the literature paid attention to that in the potable water distribution systems（Pozos et al., 2004; Camper, 2001; Momba, 1998; Lund, 1995）.

The objective of this study is to investigate whether the effluent of wastewater that has been disinfected with UV technology can keep its biostability in pipelines for reused water and to what extent possible regrowth of microorganisms occurs.

METHODOLOGY AND MATERIALS

Wastewater

Tertiary effluent of a biological wastewater treatment plant in China was collected as water samples used in this study. The water quality such as COD, DOC, UV_{254}, turbidity and pH were determined on the day water samples was collected.

Disinfection Treatment

Part of the tertiary treated wastewater was disinfected with

UV dose of 5, 20 and 40 mJ/cm^2. Experiments were performed using a collimated beam apparatus with a low-pressure UV lamp, as described by Bolton and Linden (2003). One water sample disinfected with chlorine (10 mg/L) and was used as a contrast control.

Simulated Static Water Pipeline

Brown bottles (500 mL) were used to simulate pipelines for reused water. Polyvinyl chloride slides (7cm×1cm) were put into bottles to simulate the pipeline walls. Water samples were mixed during the experiment in order to keep the microorganisms in suspension in the water.

Microbial Investigation

The total number of bacteria in water were measured for 5 days and in the biofilms for 18 days. Enumeration of the microorganisms in the biofilms was carried out as follows. Slide samples were scraped with sterilized cotton sticks which then were put into 10 mL sterilized PBS solution and sonicated for 10 min with power of 30 W. The enumeration of microorganisms used the method of spread plate count and membrane filtration at the same time. Triplicate samples were applied.

DNA Extraction and Analysis

Single-Strand Conformation Polymorphism (SSCP) analysis method was processed as described by Sunnucks et al. (2000).

RESULTS AND DISCUSSION

Tertiary treated effluent of a biological wastewater treatment plant was used in the study. The quality of the effluent was as follows:

Table 1: The quality of tertiary effluent used in the experiment

COD (mg/L)	DOC (mg/L)	UV_{254}	Turbidity (NTU)	pH
66	3.89	0.11	0.30	7.29

From **Table 1**, it can be seen that the organic matter contained in the effluent was low.

Bulk Fluid Concentrations of Microorganism

It usually takes several days for reused water to reach the consumers; hence, the concentration of microorganisms in the water was investigated for 5 days. It was also known that this process might be affected by temperature, hence, temperature of 12℃, 20℃ and 30℃ were selected for the experiment. The bulk fluid concentrations of microorganisms are presented in **Figure 1**.

Figure 1 indicated that the primary concentration of total bacteria was very low just after UV disinfection, which proved the high disinfection efficiency of the UV treatment. But the total bacterial count of UV treated samples increased with time. The lower the UV dose was, the quicker the concentration of bacteria increased. And low UV dose treated samples led to high final concentration of bacteria at the end of experiment. At the same time, the total bacterial count of the control sample decreased moderately. Temperature enhanced both of the processes. The higher the temperature was, the quicker the concentration of bacteria increased and the total bacterial count of the control sample decreased. So when the temperature was 12℃, the final total bacterial counts for samples that were UV treated or not were nearly the same. However, the UV treated samples showed higher total bacterial counts than the control, when temperature was 30℃.

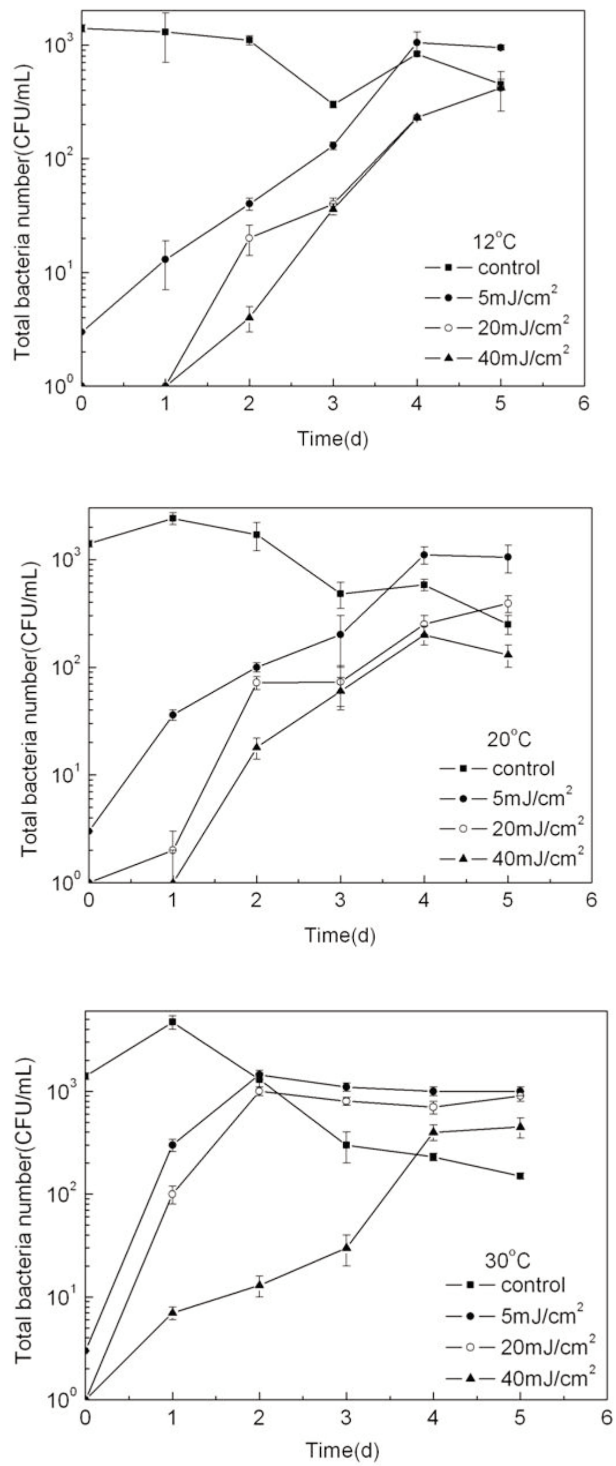

Figure 1: Bulk fluid concentration of total bacteria in the tertiary effluent after UV disinfection.

The results showed that UV disinfection can achieve a good instant disinfection effect, but cannot maintain this effect. There is a steady increase of microorganism counts to the same level as that in the non disinfected water samples. This is possibly due to its lack ability to sustain disinfection, in contrast to chlorine residual. Water treated with a higher UV dose was able to maintain a good disinfection effect for a longer period of longer time, comparing to samples receiving a lower UV dose. Dark repair may be one of the possible reasons for the increase of microorganisms after extensive incubation. More details need to be confirmed before sound measures can be proposed.

Biofilm Microorganism Densities

The total bacteria counts in the biofilm were investigated. Chlorine disinfection was also applied as contrast (see **Figure 2**). The results showed that the total bacteria count in the biofilm kept nearly constant during the experimental period, while that of UV treated sample varied, increasing at first and then decreasing to the same level as the control. The result of chlorine treated sample was a little different. The concentration increased slowly and up to the same value as that of the control after 10 days. The detention of the bacterial increase was possibly due to its residual disinfection effect. But the further disinfection effect was time limited, and it could not prevent the bacterial increase.

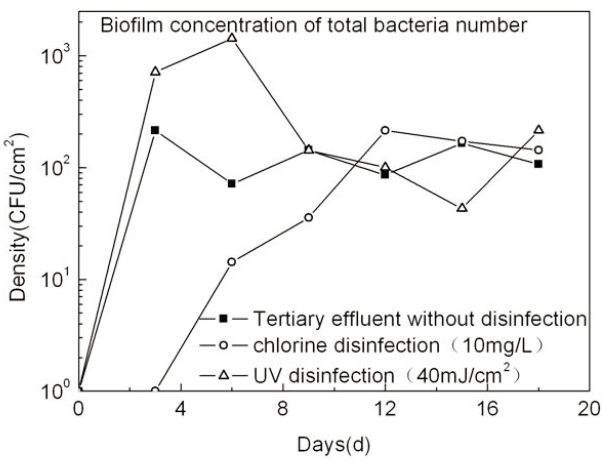

Figure 2: Total bacterial count of the biofilm after UV disinfection

Community composition of the bulk fluid and the biofilm

The main kinds of bacteria in the liquid and the biofilm of the effluent with and without disinfection were determined using the SSCP technique (shown in Figure 3). The result showed that there were three kinds of bacteria present in the liquid. It made no difference as to the variety of bacteria whether the effluent was disinfected or not, disinfected by chlorine or UV. But the shade of the colour of band told an approximate story that the bacterial counts in the effluent with chlorine or UV disinfection was lower than that for the effluent without disinfection. That was in accordant with the results and common sense.

However, the bacterial composition of the biofilm was different. There were also three bands in one biofilm sample except for the biofilm with chlorine disinfection, which showed none. But the position of first band (from up to down in **Figure 3**) in the biofilm of the effluent was a little higher than in the liquid, which meant that they represented two different kinds of bacteria. For the biofilm with UV disinfection, the positions of three bands were the same as that for the effluent with UV disinfection. Both biofilm samples showed a lighter colour of bands, indicating a lower concentration of bacteria. The reason that no band was showed in the biofilm sample with chlorine disinfection might be because of its high disinfection efficiency and residual disinfection effect.

From the primary results it can be concluded that, different modes of disinfection can lead to different community composition in the liquid and the biofilm. More work should be carried out to obtain a more detailed picture of the composition change.

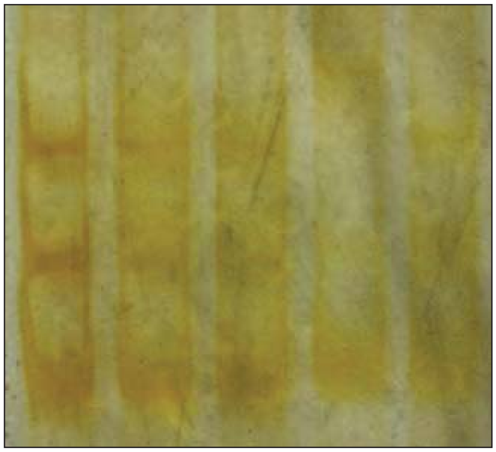

Figure 3: The DNA electrophoresis result of bacterial species in liquid and the biofilm after disinfection (from left to right: tertiary effluent; effluent with chlorine disinfection; effluent with UV disinfection; biofilm of tertiary effluent; biofilm of effluent with UV disinfection)

CONCLUSIONS

It was found that UV disinfection can not maintain its disinfection effect after a few days and that the total bacterial count could increases up to the same level with non disinfected sample in five days. The biofilm concentrations of bacteria in the effluent and UV or chlorine treated samples varied differently, but reached nearly the same value at the end of 18 days. UV disinfection led to no significant difference of microorganism community from other disinfection treatments, such as chlorine.

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