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Disinfection of synthetic and real municipal wastewater effluent by flow-through pulsed UV-light treatment system

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ABSTRACT

This study was undertaken to characterize the efficacy of flow-through pulsed UV light for inactivation of *Escherichia coli* and *Bacillus subtilis* spores in synthetic (SMWE) and real municipal wastewater effluent (RMWE). The results show that complete inactivation was observed with a 10 L/min flow rate for *E. coli* and 6 L/min flow rate for *B. subtilis* using one-pass pulsed UV treatment and SMWE. For two-pass treatment, complete inactivation was observed in SMWE with a 16 L/min flow rate for *E. coli* and 10 L/min flow rate for *B. subtilis*. On the other hand, complete inactivation was observed with 10 L/min flow rate treatments for *E. coli* in RMWE, whereas 4.15 Log reduction was observed at 6 L/min for *B. subtilis* in RMWE for one pass. The raw wastewater was also treated under flow-through pulsed UV light at 10 L/min flow rate and complete inactivation was observed. The treatment resulted in significant chemical oxygen demand (COD) and total organic carbon (TOC) reductions. These results clearly indicate that pulsed UV not only successfully disinfects the wastewater effluent, but also reduces the organic load of municipal wastewater effluent. Therefore, pulsed UV technology can be an alternative for chlorine and conventional UV light for municipal wastewater effluent.

1. Introduction

Disinfection of treated wastewater effluent is needed as the primary step to prevent the spread of waterborne diseases to downstream users and the environment. Municipal wastewater has been identified as one of the main sources of pathogenic agents and the potential vector of diseases as a result of accidental consumption of untreated or poorly treated wastewater, skin contact, or ingestion of food species exposed to wastewater. Although primary and secondary wastewater treatment might eliminate 90–99.9% of enteric microorganisms, and tertiary treatment such as filtration may contribute further reductions, wastewater effluents can still contain significant surviving populations of these microorganisms [1]. For example, Koivunen et al. reported that typical indicator microorganism concentrations in wastewater inlets are 10^7–10^8 CFU/100 mL, and biological nutrient removal processes usually result in 2–3 log reductions [2]. Hence, disinfection of wastewater is mandatory as the minimum treatment before their release to natural water streams [3]. The cost of treating wastewater to conform to high microbiological standards can be so prohibitive that in many developing countries untreated wastewater is effectively unregulated [4]. The United States Environmental Protection Agency (USEPA) and the US Agency for International Development have recommended strict guidelines for wastewater use [5]. Chlorination is the conventional wastewater disinfection method used around the world because chlorine is an effective disinfectant against many enteric bacteria, but it has lower efficiency against viruses, bacterial spore-formers, and protozoan cysts [6]. In recent years, the use of chlorination has been decreasing, mainly due to toxic, mutagenic, and/or carcinogenic disinfection by-products (DBPs) formed in the disinfection process and chlorine residuals [6,7]. Thus, a number of alternative disinfectants have been researched and implemented, such as ozone and ultraviolet (UV) light [8]. Ozone can inactivate microorganisms, but requires maintaining a residual ozone concentration of 0.1–2.0 mg/L in a plug-flow type contact vessel for periods of 1–30 min, depending upon the target microorganism [9], and also produces DBPs. On the other hand, UV irradiation can require a shorter exposure time for effective disinfection, and does not involve the maintenance of a chemical residual or production of DBPs [10–13]. This makes

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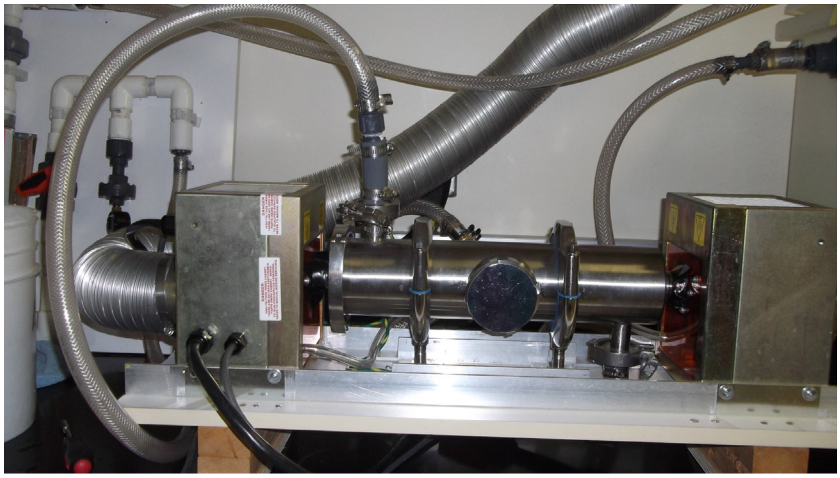

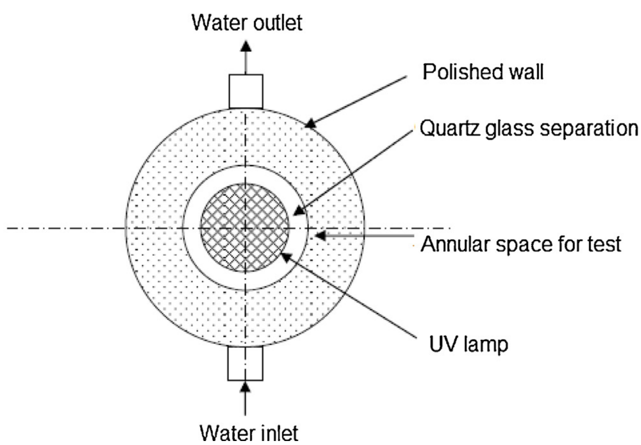

Fig. 1. Picture and schematic diagram of the flow-through pulsed UV chamber (Xenon Corp., Wilmington, MA).

Table 1
Inactivation of *E. coli* and *B. subtilis* in synthetic municipal wastewater effluent (SMWE) by using flow-through pulsed UV system.

	E. coli		*B. subtilis*	
Flow rate(L/min)	Log_{10} reduction 1st pass	Log_{10} reduction 2nd pass	Log_{10} reduction 1st pass	Log_{10} reduction 2nd pass
2	7.23[a]	–	7.13[a]	–
4	7.35[a]	–	7.08[a]	–
6	7.37[a]	–	7.05[a]	–
8	7.29[a]	–	3.89	–
10	7.25[a]	–	3.49	–
12	4.65	–	3.01	4.39
14	4.59	–	2.65	3.66
16	4.09	–	1.75	2.69
18	3.31	5.02	1.25	2.43
20	2.75	4.96	1.03	2.04

[a] Complete inactivation.

UV an attractive alternative to chemical disinfection for water and wastewater disinfection, and the number of wastewater treatment plants using UV disinfection applications has been increasing in recent years [14].

The major factors that affect the design of a UV system for wastewater disinfection are UV transmission, suspended solids, flow rate and/or hydraulics, iron, hardness, lamp aging, UV dose, and wastewater pretreatment. The UV dose produced by a UV system is what disinfects the water. A standard method was developed to determine this UV dose so that different systems can be compared and to ensure that the proper UV dose was delivered to the wastewater [15,16]. The most important factor in achieving disinfection for water reuse and discharge is overcoming any shielding of the microorganisms from the UV light.

Despite these advantages of UV irradiation over chemical disinfection, the use of conventional UV light has several shortcomings. These include poor penetration depth, low emission power, and potentially longer treatment times [17]. Also, the UV doses used for disinfection are too low to generate significant amounts of photoproducts [18], which limit the effectiveness of UV light. Furthermore, high suspended solids in wastewater negatively affect UV disinfection efficacy. An emerging technology, pulsed UV light,