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Research Article

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Influence of different combination modes of UV and NaClO on disinfecting effect of hospital sewage

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ABSTRACT

Combined disinfection with UV radiation and sodium hypochlorite was applied in disinfection the effluent after secondary treatment of hospital sewage. The inactivation effect of different combination modes and sequences of UV and sodium hypochlorite was studied. The contrast experiments of disinfection effect and the levels of residual chlorine were conducted by adding different dosage of sodium hypochlorite and exposing on different UV radiation time. The results of first experiment showed that the removal rate of fecal coli-group was ascending with the increase of the dosage of Sodium hypochlorite. When the dosage was 18 mg L^{-1}, the fecal coliforms cannot be detected. When the dosage was less than 6 mg L^{-1}, the total residual chlorine could meet the emission limits. And the results of next experiment showed that the removal rate of fecal coliforms was ascending with the increase of ultraviolet dosage. When the ultraviolet dosage was 0 J/m^2, the fecal coliforms cannot meet the Chinese discharge standard. When the dosage was more than 100J/m^2, the disinfection effect was not influenced by ultraviolet dosage.

Key words: combined disinfection process of UV+NaClO; hospital sewage; contrast experiment; disinfection effect; total coli-group; total residual chlorine

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INTRODUCTION

With the improvement of Chinese discharge standard of water pollutants for medical organization, leading to a range of further studies on various sewage treatment technologies, the economical and applicable technology of hospital sewage disinfection have become hot point and the research focal point of the control of water pollution by many countries. To achieve better disinfection effect, most of the researches are focused on the optimization of technical parameters, the development of new alternative technology and combined disinfection technology. Combined disinfection method, such as Cl_2+ClO_2, UV+O_3, UV+H_2O_2, UV+H_2O_2+O_3 and UV+TiO_2, can improve the disinfection effect of sewage treatment system substantially, is the best available technology to control DBPs. There has been a considerable amount of researches at home and abroad on combined disinfection technology and the synergetic sterilization. The disposal techniques of liquid chlorine cooperating with chlorine dioxide is feasible used to disposing the drinking water[1]. Compared with single disinfection method, the combination of chlorine and chlorine dioxide(ClO_2) for disinfection of drinking water can significantly improve bactericidal capacity [2], the inactivation of *Bacillus subtilis spores* in wastewater with liquid chlorine and chlorine dioxide was enhanced significantly[3,4]. It also has some continual sterile effect[5], and effectively reduce disinfection byproducts, including THMs and ClO^{2-}[6,7]. And there has been a study showed that the removal rate of *Dichloroacetic acid* and *Trichloroacetic* was reduced by 20% ~ 63% and 35% ~ 20% respectively using combined disinfection method[8]. There have been some researches focused on combined disinfection method of free chlorine and chlorine

dioxide in drinking water[9,10] and the combination of chlorine dioxide(ClO_2) and sodium hypochlorite for disinfection of drinking water. The studied results showed that combined disinfection method could achieve better disinfection effect and decrease disinfection by-products[11]. Some studies was made too on the combined pretreatment technology by using potassium permanganate and chlorine or chloramines in wastewater treatment process [12,13]. And some researchers examined the inactivation effect of Bacillis subtilis spores in natural water samples with individual chlorine disinfection, individual zone disinfection and sequential disinfection with ozone followed by free chlorine[14].The results of UV, O_3, Pulse electrolysis and O_3-UV disinfection for the bacterial in the wastewater shows that the reaction time is relatively long with single disinfection method[15]. Kruithof JC. etc[16,17] proved that UV+H_2O_2 combination can not only kill microorganisms and organic pollutants in water, but also can effectively improve the degradation rate of pollutants and control disinfection by-products; Prodos. etc [18] concluded that the performances in sterilization of H_2O_2+O_3 is best by comparing the disinfection effect of three kinds of methods (Fe^{3+}+H_2O_2, H_2O_2+O_3 and UV+H_2O_2+O_3). The experiment about TiO_2 combined with ultraviolet and dispersion optical fiber combined with TiO_2 suspension were made too[19]. In addition, experimental study on the treatment of secondary effluent by ultrasound combined with sodium hypochlorite was conducted[20]. And ultrasound(US) , ultraviolet(UV) and synergistic efficiency were applied to inactivate E.coli[21]. There have been many researches on synergetic disinfection of UV and chlorine. Some research results showed that the combination of UV and chlorine can improve the inactivation effect compared with single chlorine disinfection[22], and different combination modes and different doses of UV and chlorine affected the disinfection effect[23,24]. There are some scholars proved high chlorine dose has high inactivation rate during disinfection with UV followed by chlorine[25]. The inactivation effect of UV-ClO_2 was better than that of ClO_2-UV[26].

The study on the combined disinfection method has become a hotspot research in recent years. But up to now, not only the inactivation effect and mechanism of different combination mode is rare, but the impact of exposure sequences to UV and chlorination is limited. There are few reports about the disinfection effect of UV+NaClO for hospital sewage treatment. In this paper, combined disinfection with UV radiation and sodium hypochlorite was investigated by adding different dosage of sodium hypochlorite and exposing on different UV radiation time, the inactivation effect of different combination modes and sequences of UV and sodium hypochlorite was compared. The study will provide scientific reference and basis to improve disinfection methods and parameter' determination for the engineering application of disinfection equipment for treating hospital sewage.

EXPERIMENTAL SECTION

1.1 WATER QUALITY

Water sample was taken from the effluent of contact oxidation pool in People's Hospital of Gao County in Sichuan province, China. In order to reduce the influence of of SS on the UV ray transmittance and the oxidation of sodium hypochlorite, the SS was pretreated by sand filtration. The water quality parameters was shown in table 1.

Table 1 the quality of sewage in the experiment

Indexes	COD_{Cr} (mg·L^{-1})	BOD_5 (mg·L^{-1})	SS (mg·L^{-1})	pH	*Fecal coliforms*
Value	50	14	7	6.8	2.2×10^5

1.2 MEASURED ITEMS AND METHODS

In the experiment, the number of fecal coliforms and residual chlorine are monitored. Monitoring items and methods are as follows:

Water temperature: mercury thermometer. Residual chlorine: DPD method. Number of fecal coliforms: multi-tube fermentation method. PH: pH meter. COD_{Cr}: potassium dichromate method. BOD_5: dilution inoculation method. Suspended solid (SS) : gravimetric method.

1.3 EXPERIMENT DEVICE

1.3.1 ULTRAVIOLET DOSAGE

Sterilization ability of UV disinfection reactor is measured by the radiation dosage. Different doses of UV affect the inactivation effect of microorganism, the ultraviolet dosage and time for the inactivation of microorganism is shown in table 2. At present, the design standard of the ultraviolet dosage from *Chinese discharge standard of water pollutants for medical organization* (GB 18466-2005) is 300J/m^2 (30000 μJ/cm^2).

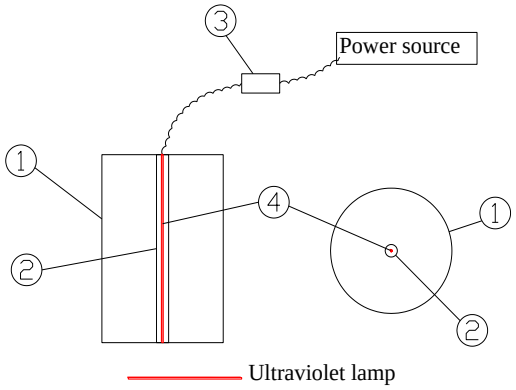
Table 2 the ultraviolet dosage and time for the inactivation of microorganism

Microbe species	Ultraviolet dosage(μJ/cm^2)	Radiation time(s)	Microbe species	Ultraviolet dosage（μJ/cm^2）	Radiation time(s)
Escherichia coli	6000	0.20	*Influenza virus*	6600	0.22
Typhoid bacillus	7600	0.25	*Tetanus virus*	22000	0.73
Shigella dysenteriae	4200	0.14	*Hemolytic Streptococcus*	5500	0.18
Vibrio cholerae	6500	0.22	*Viridans Streptococci*	3800	0.13
Corynebacterium diphtheriae	20000	0.67	*E. coli phagocyte*	6600	0.22
Tubercle bacilli	20000	0.67	*Salmonella*	10000	0.33
Aspergillus flavus	9900	0.33	*Bacillus subtilis*	40000	1.33
Aspergillus niger-spores	600000	20.00	*Staphylococcus aureus*	12000	0.40

Compared the data in table 2, it is concluded that ultraviolet disinfector has good ability to inactivate most of bacteria and viruses, but no effect to spores. Sewage disinfection focuses on killing intestinal bacteria, so it is an effective approach to using ultraviolet disinfector for sewage secondary treatment.

1.3.2 THE SIZE OF DEVICE

The tube-in-tube structure with concentric cylinders in similar with pipeline type ultraviolet disinfector was used in experimental device. A simple reactor with UPVC pipe (DN200, length 0.3 m) was made, submerged disinfection reactor (KCJ-10W) as ultraviolet generator is composed of Ultraviolet lamp, Quartz tube and Ballast, the schematic diagram of the ultraviolet disinfection device is shown in figure 1.



Note: 1-UPVC reactor; 2-Quartz tube; 3-Ballast； 4-Ultraviolet lamp.
Figure 1 Schematic diagram of the ultraviolet disinfection device

RESULTS AND ANALYSIS

2.1 CONTRAST EXPERIMENT OF DIFFERENT DOSEGE OF SODIUM HYPOCHLORITE

The sewage from contact oxidation pond, which was pretreated by sand filtration, was disinfected for 42s by the ultraviolet disinfection device. After 90 minutes, the number of fecal coliforms and the levels of residual chlorine were measured by adding different dosage of sodium hypochlorite (0 mg Ł$^{-1}$, 6 mg Ł$^{-1}$, 10 mg Ł$^{-1}$, 14 mg Ł$^{-1}$, 18 mg Ł$^{-1}$ and 22 mg Ł$^{-1}$).The measured results were shown in table 3.

Table 3 Effect of the dosage of Sodium hypochlorite on the disinfection effect and the levels of total residual chlorine

Items	The dosage of Sodium hypochlorite (mg Ł$^{-1}$)					
	0	6	10	14	18	22
Ultraviolet dosage (J/m^2)	300	300	300	300	300	300
Fecal coliforms	360	340	245	126	0	0
Total residual chlorine(mg Ł$^{-1}$)	0	0.4	2.8	6.2	8.8	9.2

(1) Effect of the dosage of Sodium hypochlorite on the disinfection effect

When the ultraviolet dosage was 0 J/m^2, the effect of the dosage of sodium hypochlorite on the disinfection effect was described as shown in figure 2.

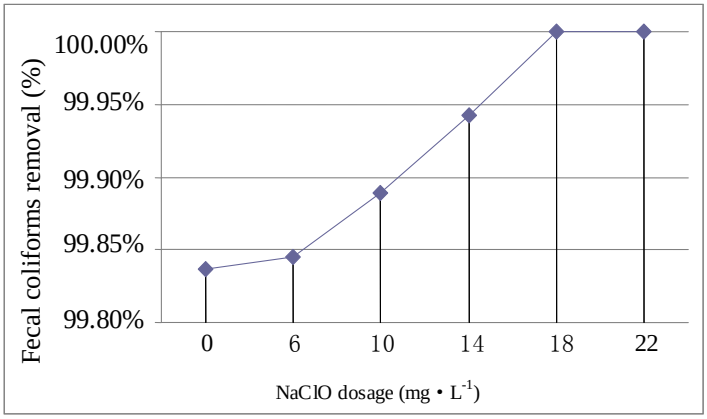


Figure 2 Effect of the dosage of Sodium hypochlorite on the disinfection effect

When the dosage of sodium hypochlorite was 0 mg Ł$^{-1}$, the results of ultraviolet disinfection was shown in figure 2 and table 3, the fecal coliforms of the effluent could meet *Chinese discharge standard of water pollutants for medical organization* (GB 18466-2005). In the contrast experiment of adding different dosage of sodium hypochlorite, the removal rate of fecal coliforms was ascending with the increase of the dosage of Sodium hypochlorite of unit sewage, when the dosage is more than 18 mg Ł$^{-1}$, the indicators of fecal coliforms was not detected.

(2)Effect of the dosage of Sodium hypochlorite on the total residual chlorine
The effect of the dosage of Sodium hypochlorite on the total residual chlorine was described in figure 2.

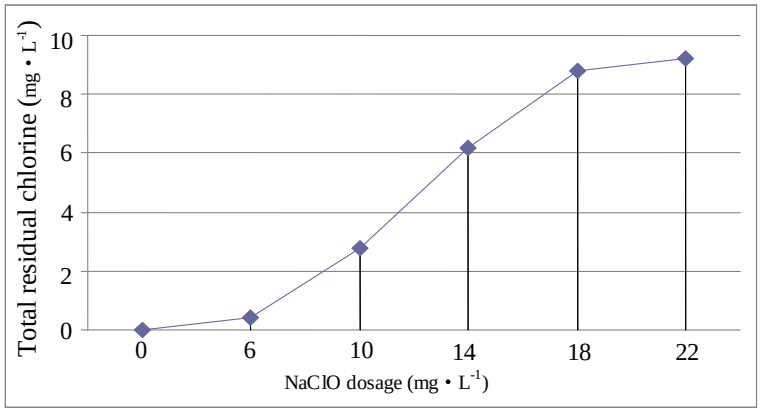


Figure 3 Effect of the dosage of Sodium hypochlorite of unit volume of sewage on the total residual chlorine

The content of total residual chlorine was ascending with the increase of the dosage of sodium hypochlorite of unit volume of sewage(Figure 3 and table 3) after adding the sodium hypochlorite. When the dosage is 6mg/L, the content of total residual chlorine is lower than the *discharge standard of water pollutants for medical organization* (GB 18466-2005), the dechlorination agent was not required.

2.2 CONTRAST EXPERIMENT OF DIFFERENT ULTRAVIOLET DOSAGE

The sewage from contact oxidation pond, which was pretreated by sand filtration, was disinfected in the ultraviolet disinfection device. The radiation time was adjusted for 0s, 14s, 21s, 28s, 35s, 42s and 49s, the corresponding ultraviolet dosage was adjusted for 0J/m^2, 100J/m^2, 150J/m^2, 200J/m^2, 250J/m^2, 300J/m^2 and 350J/m^2, respectively. After 90 minutes, 6 mg Ł$^{-1}$ of sewage was filled in a beaker, the number of fecal coliforms and the levels of residual chlorine in water sample were measured by adding different dosage of sodium hypochlorite. The results were showed in table 4.

Table 4 Effect of the ultraviolet dosage on the disinfection effect and the total residual chlorine

Index	Radiation time(s)						
	0	14	21	28	35	42	49
Ultraviolet dosage (J/m^2)	0	100	150	200	250	300	350
Sodium hypochlorite(mg Ł$^{-1}$)	6	6	6	6	6	6	6
Fecal coliforms	2340	430	393	370	366	340	320
Total residual chlorine(mg Ł$^{-1}$)	0.4	0.3	0.3	0.3	0.4	0.3	0.4

(1)Effect of the ultraviolet dosage on the disinfection effect
The effect of the UV radiation dose on the disinfection effect was described in figure .4

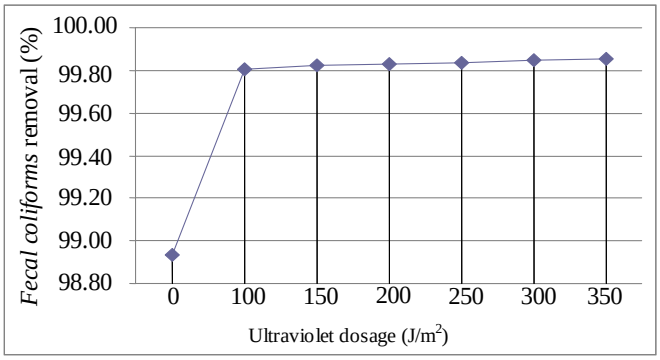


Figure 4 Effect of ultraviolet dosage on the disinfection effect

In the contrast experiment, when the ultraviolet dosage was 0 J/m^2, the fecal coliforms of the effluent cannot meet discharge standard of water pollutants for medical organization (GB 18466-2005) (figure 4). It showed that ultraviolet radiation was the dominant influencing factor for disinfection effect under the condition of these experiment parameters. When the ultraviolet dosage was 100 J/m^2, the removal rate of fecal coliforms was ascending with the increase of the ultraviolet dosage, but the variation tendency was not obvious, it showed that ultraviolet radiation is not dominant factor for disinfection effect when the ultraviolet dosage was over 100 J/m^2.

(2)Effect of ultraviolet dosage on the total residual chlorine.
The effect of ultraviolet dosage on the total residual chlorine was described in figure.5

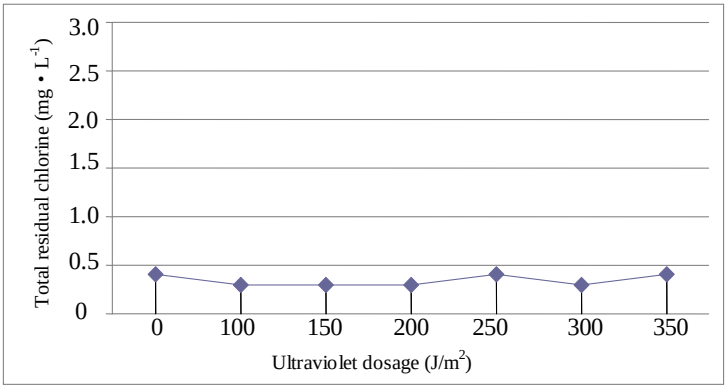


Figure 5 Effect of ultraviolet dosage on the total residual chlorine

When the dosage of sodium hypochlorite of unit volume of sewage was fixed as 6mg/L, the content of total residual chlorine were all lower than the emission limits of discharge standard of water pollutants for medical organization (Figure 5 and table 4) with the changing of ultraviolet dosage, the dechlorination agent is not required. The variation tendency of the total residual chlorine was not obvious with the increasing of ultraviolet dosage, it showed that ultraviolet dosage was not the main influencing factors of the content of total residual chlorine.

CONCLUSION

Combined disinfection with UV and sodium hypochlorite was investigated by adding different dosage of sodium hypochlorite and exposing on different UV radiation time, the inactivation effect of different combination modes and sequences of UV and sodium hypochlorite was compared.

1)In the contrast experiment of different dosage of sodium hypochlorite, UV radiation time was 42s, the ultraviolet dosage was 300J/m^2. After 90 minutes, the number of fecal coliforms and the levels of residual chlorine were measured by adding different dosage of sodium hypochlorite of unit volume of sewage (0 mg Ł$^{-1}$, 6 mg Ł$^{-1}$, 10 mg Ł$^{-1}$, 14 mg Ł$^{-1}$, 18 mg Ł$^{-1}$ and 22 mg Ł$^{-1}$, respectively). The removal rate of fecal coli-group was ascending with the increase of the dosage of Sodium hypochlorite. When the dosage was 18 mg Ł$^{-1}$, the fecal coliforms cannot be detected. When the dosage was less than 6 mg Ł$^{-1}$, the total residual chlorine could meet the emission limits, the

dechlorination agent was not needed.

2) In the contrast experiment of different ultraviolet dosage, the dosage of sodium hypochlorite of unit volume of sewage without dechlorination treatment in the front experiment was fixed as 6 mg L^{-1}. The radiation time was adjusted for 0s, 14s, 21s, 28s, 35s, 42s and 49s, the corresponding ultraviolet dosage was regulated for 0J/m^2, 100J/m^2, 150J/m^2, 200J/m^2, 250J/m^2, 300J/m^2 and 350J/m^2, respectively. When the ultraviolet dosage was 0 J/m^2, the fecal coliforms of the effluent cannot meet discharge standard of water pollutants for medical organization. When the ultraviolet dosage was 100 J/m^2, the removal rate of fecal coliforms was ascending with the increase of the ultraviolet dosage, but the variation tendency was not obvious, it showed that ultraviolet radiation is not dominant factor for disinfection effect.

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