Experimental Study on Combing Chloramine and Potassium Permanganate to Inactivate Bacteria

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Abstract: The inactivation efficacy of bacterium is compared with independent of chloramine, potassium permanganate, and the combination of the two using prepared water samples. The results show that, firstly, the combination effect is slightly better than that of individual chloramine disinfection at the same dosage. According to the Berenbaum formula, when the concentration ratio of chloramine and potassium permanganate is 0.71, there is a synergistic effection on inactivating bacterium.

Keywords: Chloramine; Potassium permanganate; Bacterium; Inactivation

I. Introduction

According to "China Environmental State Bulletin" about the water environment,[1] the pollution of representative organic pollutants are still serious. As the social development and the restriction of economic conditions, this situation will continue for a long time [2] Thus, removing organic matter in drinking water and ensure the healthy drinking are the issues demanding prompt solution. Pre-chlorination disinfection is widely used at home and abroad against contaminated water. When water resource is polluted, the types and quantities of microorganisms in water will also dramatically increase. Pre-chlorination disinfection in water can kill or inactivate some part of the pathogenic micro-organisms that harmful to human's healthy, and reduce microbiological risks of drinking water and also act on working as multi-barriers. In addition, it is useful to control odor and prevent the breeding of algae in the water treatment structures, oxidize organic compounds, meanwhile it is also a effective measure to improve the coagulation efficiency. Compared with other disinfectants, chlorination is also an economic, convenient, reliable method ,consequently, it is the most widely used in the world as a disinfection method, and so far none of disinfectants can fully replace it. However, because of high concentrations of organic pollution in water sources, pre-chlorination process is likely to generate a large number of disinfection byproducts which is harmful to human's health, it decreased the chemical safety of treated water. Through reducing the dosage of chloramine during the pre-processing which can reduce by-products will not achieve the desired disinfection effect, worse still is that it would increase the treatment load of the follow-up processing units.

In recent years, Li Guibai et al have achieved excellent results on pollutant removal, coagulant aid and reduce the generation of chlorinated by-products by potassium permanganate; moreover, they bring good social and economic benefits. Therefore, potassium permanganate was proposed to replace the pre-chlorination. However, the effect of potassium permanganate disinfection is less than chloramine disinfection. From the microbiological considerations, , although a single potassium permanganate pre-oxidation have a significant effect on the removal of organic pollutants and the reduce of chlorination by-products, it would increase the pressure of the follow-up water treatment process because of its less effective microbial inactivation, at the meanwhile, it could prevent the multi-barriers working. In recent years for the removal of the respective negative laying in single sterilization and the quest of safe and reliable disinfection, collaborative disinfection attracted the people's great attention, which mean during the disinfection process, more than two disinfectants are used in order to accelerate and enhance the disinfection effect. Nowadays, there are many common disinfection methods being used, such as Halogen synergistic disinfection, the synergy generated free radicals disinfection, oxidants and metal ions coordinated disinfection, ozone and ultrasonic synergistic disinfection, ozone and ultraviolet synergistic disinfection, as well as access to solid-phase sterilization. These methods not only can overcome some shortcomings of individual disinfection, but also can strengthen the effect of sterilization. They are effective ways to improve the sterilization effect. In this paper, take the inactivated bacteria as the research object, the synergistic effect of combining potassium permanganate with chloramine to inactivate bacteria has been studied.

II. Materials and Methods

A. Experimental Water Samples

Prepared water samples are used in this study. A certain amount of sodium bicarbonate (Na_2CO_3) and calcium chloride ($CaCl_2$) are added into distilled water in order to simulate the natural water bodies with the minerals and being not affected by the background elements. Then add a certain amount of bacteria cultivated in laboratory, after mixing them evenly, filtrate them to remove bacterial debris with quantitative medium-speed filter paper. The water temperature was controlled at 25℃ or so, and the pH was maintained at 6.8.

B. Experimental Test Items and Analytical Methods

In the experiment, the total number of bacteria was taken as the detection and analysis indicators and plate count method was used. Took the water samples before and after disinfection, diluted to the appropriate dilution with sterile water, and then, took 1mL sterile water into the sterile cultured dish on the condition of asepsis, poured about 15mL nutrient agar medium which had been melted and cooled to about 45℃ into cultured dish, and spinning petri dish immediately with bottom upwards, finally, put it into the constant temperature incubator at 37℃, calculated the number of bacteria 24h later.

C. Effect of Inactivation Evaluation

The effect of inactivation was determined by the survival rate of microorganisms in water samples at different times, formula (1)

$$\text{Survival Rate} = -\lg(N^t/N^0)$$

Where N^t is the number of bacteria in water samples after a period of time disinfection;

N^0 is the number of control bacteria in the experiment before disinfection in the same water samples

D. Determine the two kinds of disinfectants of the nature

According the Haas[7], and Strub[8], etc. Berenbaum formula to determine the relationship between the two kinds of disinfectants. Base on the formula, if the mixture components do not exist any interaction, then no matter what the dose-effect relationship is, they all satisfy the following formula (2):

$$\sum_{i=1}^{n}\frac{X_i}{Y_i}=1$$

Where Xi is the concentration of each component when the mixture reaches a certain role in disinfection; Yi is the concentration of components when used alone and produced the same effect as the mixture; i is the individual component; n is the number of each components.

III. Results and Discussion

A. The bactericidal effect of combination chloramine with potassium permanganate

Table1 reflects the bactericidal effect of combined application of chloramine with potassium permanganate at different dosages, individual chloramine disinfection and potassium permanganate. As can be seen from the table, the effect of chloramine inactivation is better than that of individual potassium permanganate, the effect of combined is better than that of used alone. 1.0 mg/L chloramine role in 30min, the number of inactivated bacteria are 3.35 pairs of class, while the same dosage of potassium permanganate role in the same time, it increased to 1.09 pairs, combined 1.0mg/L of chloramine with 1.0mg/L of the potassium permanganate can inactivated 4.44 log class in 15min (100% inactivation), which increased the rate of inactivation.

It can also be seen from Table1 and Figure 1, The effect of inactivated bacterial at 1.0mg/L chloramine is identical with 0.5mg/L chloramine +0.5 mg/L of potassium permanganate, at the meanwhile the same dosages of potassium permanganate instead of chloramine had no effect on the bacteria removing even to help to increase.

TABLE I. Inactivation of Escherichia coli with different doses of the effect of disinfectant

Disinfectant	Dosage (mg/L)	Reaction time (min) 5	10	15	20	25	30
		Survival rate（－log Nt/N0)					
Chlorine	0.5	1.50	1.84	2.14	2.44	2.48	2.56
	1.0	2.41	2.65	2.75	2.90	3.20	3.35
	1.5	2.98	3.44	3.50	4.14	4.44	4.44
Potassium permanganate	0.5	0.08	0.12	0.20	0.32	0.38	0.44
	1.0	0.39	0.51	0.70	0.90	1.00	1.09
	1.5	0.6	0.82	0.9	1.27	1.30	1.44
Chlorine + potassium permanganate	0.5	2.18	2.55	2.64	3.20	3.33	3.74
	1.0	3.48	4.05	4.44	4.44	—	—
	1.5	4.44	4.44	—	—	—	—

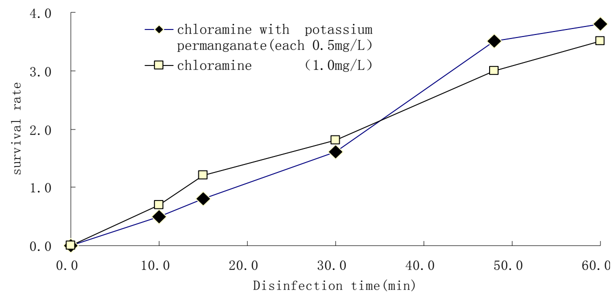

Figure 1. The bactericidal effect between combined application of chloramine with potassium permanganate and chloramine

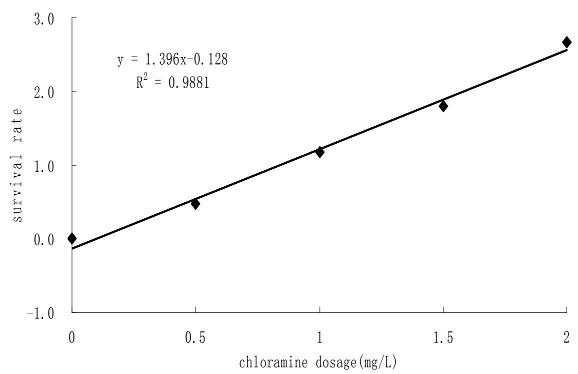

Figure 2. The relation between survival rate of bacteria and chloramine dosage

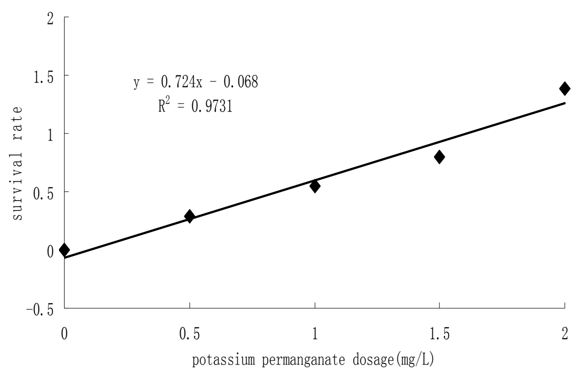

Figure 3. The relation between survival rate of bacteria and potassium permanganate dosage

B. The bactericidal effect of combined application of potassium permanganate with chloramine

Selected 1.0 mg/L chloramine, and 1.0mg/L potassium permanganate as a mixed system, then the X_1 (chloramine) =1.0mg/L, X_1 (potassium permanganate) =1.0mg/L. The data we can see from table 1 was that the role of this compound system, the number of inactivated bacteria was 4.44 log class (100% inactivation) in 15min, and therefore, take 4.44 Log class inactivated bacteria in 15min as the reference to value Yi. Figures 2 and 3 was the regression curves about the total survival rate of bacteria during chloramine and potassium permanganate disinfection (respectively)in 15min, from Figure 2 it is known that the projection Y_1=1.81mg/L, from Figure 3 Y_2 = 6.23mg/L. According to the formula (2), the calculated result is less than 1, thus it can be judged that the combination's role on reducing the bacteria was synergistic effect.

IV. Conclusions

- By comparing the total dosage same circumstances, the disinfection effect of combination are almost the same whit chloramine alone and sometimes even slightly better than it. Thus, potassium permanganate can reinforce the role of chloramine on the inactivation of bacteria.
- Comparing the effect of chloramine and potassium permanganate alone and the combination of the two， and according to the Berenbaum formula, when the concentration ratio of chloramine and potassium permanganate is 0.71, there is a synergistic effection on inactivating bacterium.

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