

# The Sterilization Effect of Cooperative Treatment of High Voltage Electrostatic Field and Variable Frequency Pulsed Electromagnetic Field on Heterotrophic Bacteria in Circulating Cooling Water

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**Abstract.** Compared to other treatment of industrial circulating cooling water in the field of industrial water treatment, high-voltage electrostatic field and variable frequency pulsed electromagnetic field co-sterilization technology, an advanced technology, is widely used because of its special characteristics--low energy consumption, nonpoisonous and environmentally friendly. In order to get a better cooling water sterilization effect under the premise of not polluting the environment, some experiments about sterilization of heterotrophic bacteria in industrial circulating cooling water by cooperative treatment of high voltage electrostatic field and variable frequency pulsed electromagnetic field were carried out. The comparison experiment on the sterilization effect of high-voltage electrostatic field and variable frequency pulsed electromagnetic field co-sterilization on heterotrophic bacteria in industrial circulating cooling water was carried out by change electric field strength and pulse frequency. The results show that the bactericidal rate is selective to the frequency and output voltage, and the heterotrophic bacterium can only kill under the condition of sweep frequency range and output voltage. When the voltage of the high voltage power supply is 4000V, the pulse frequency is 1000Hz and the water temperature is 30°C, the sterilization rate is 48.7%, the sterilization rate is over 90%. Results of this study have important guiding significance for future application of magnetic field sterilization.

## 1. Introduction

Chemical sterilization technology widely used to prevent the circulating cooling water treatment system microbial breeding, but chemical residues in the treated water lead to environmental pollution and physical problems. Thus the physical methods for sterilization, especially high-voltage electrostatic field and variable frequency pulsed electromagnetic field co-sterilization technology, is widely needed in order to meet both the pollution-free and better bactericidal effect. The most abundant bacteria in industrial circulating cooling water are heterotrophic bacteria, which can reach up to 106cfu/mL [1] in summer and generate slime that, together with colloidal substances and suspended solids, forms fouling



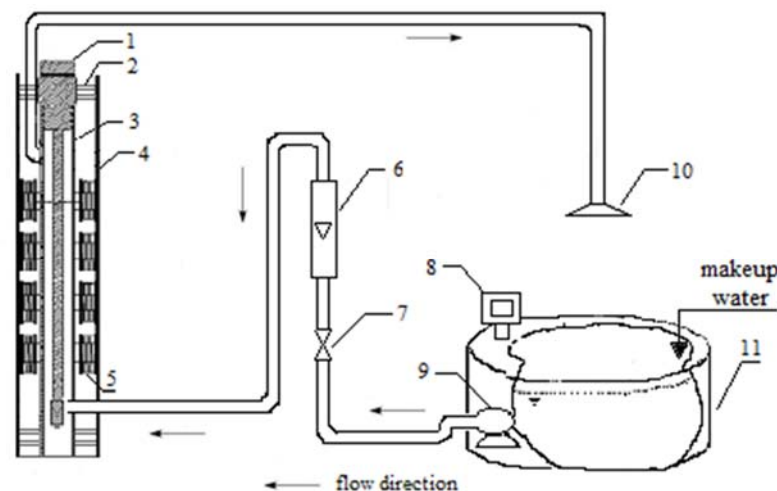
on the inner surface of tubes and other equipment, severely blocking heat exchange. Therefore, one of the significant research subjects in the field of industrial re-circulating cooling water is the method to effectively control the large-scale reproduction of heterotrophic bacteria in the re-circulating cooling water [2].

Based on the review of the previous study at home and abroad, this paper, with the re-circulating cooling water system of one thermal power plant in Hohhot City as the research object, made an experiment of killing heterotrophic bacteria in re-circulating cooling water with the high-voltage electrostatic field and variable frequency pulsed electromagnetic field. In this experiment, the effects of high voltage electrostatic and variable frequency pulsed electromagnetic field on the bactericidal effect were investigated by changing the pulse frequency and high voltage electrostatic field output voltage.

## 2. Experiments and materials

### 2.1. Experimental apparatus

The experimental apparatus is shown in Figure 1, the CS501-SP digital thermostat water bath (hereafter referred to as water bath) was used to keep constant temperature of the water, a flow control valve and flow meter was used to regulate and display the flow speed. The water was pumped from the water bath to the magnetolectricity one-piece collaborative sterilization water treatment equipment then through the flow control valve, the flow meter, the nozzle and then back to the water bath



**Figure 1.** Experimental device 1- high-voltage electrostatic ion bar; 2- support structure; 3- flow tie tube; 4- metal negative tube; 5- electromagnetic coil; 6- flowmeter; 7- flow control valve; 8- temperature control panel; 9- pump; 10- nozzle; 11- digital thermostat water bath.

The experimental apparatus including: digital thermostat water bath, with a volume of 16L; LZB-15 glass rot meter with a precision of 4.0%; magnetolectricity one-piece collaborative sterilization water treatment equipment. During the experiment, the water is pumped out of the water bath from the digital thermostat water bath, followed by the water flow control valve, the flow meter and the magnetolectricity one-piece collaborative sterilization device. Finally, the water is returned to the constant temperature water bath through the nozzle to complete the cycle. Which with constant temperature water bath temperature control of the water temperature.

In the sterilization processing device, the high-voltage electrostatic ion bar generates high-voltage electrostatic field, and the electromagnetic coil winding generates a pulsed magnetic field, they can be operated singly or simultaneously, and can cooperate with each other. While the flow tie tube acts to ensure that the flow rate of the device is consistent.

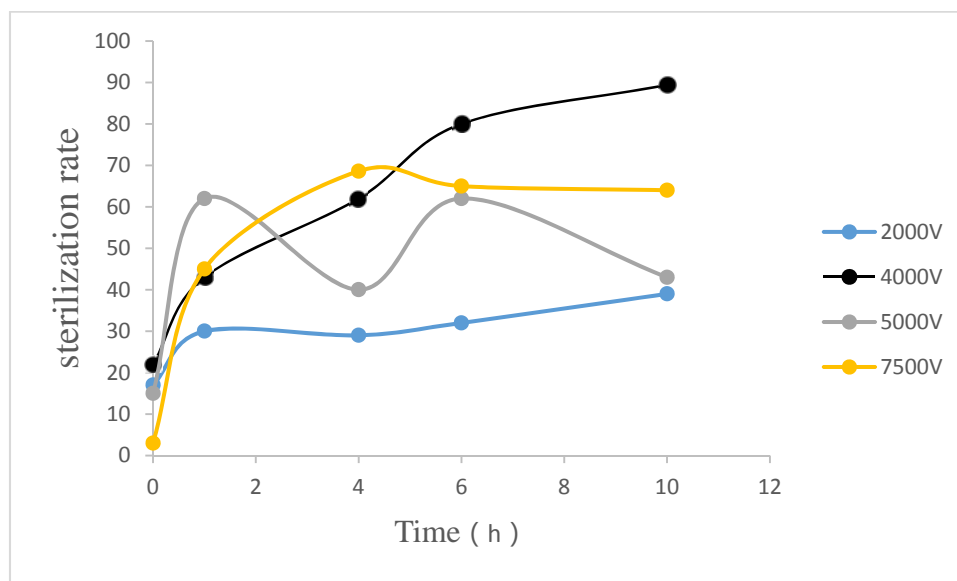
## 2.2. Voltage of high-voltage electrostatic field

The collected circulating cooling water was incubated with nutrients for 20 hours, so that the number of heterotrophic bacteria reached 107/mL. 17L water samples were added to the experimental group and control group, under the same conditions to carry out experiments. Adjust the flow velocity, water temperature and other parameters of the two groups of experiments, change the output voltage and frequency, and experiment. After the normal operation, the samples were taken at 5 minutes, 1 hour, 4 hours, 6 hours and 10 hour time points. The average of the three experiments was carried out in each group. The water samples were diluted and inoculated, and the peptone beef extract medium was used. Incubate at 37°C for 24 h in a thermostatic incubator and count out and calculate the sterilization rate by the formula. The formula to calculate inhibiting effect was as follows

$$\eta = \frac{C_0 - C_1}{C_0}$$

Wherein, stands for average number of live heterotrophic bacteria in the control group (cfu/mL), and stands for that in the sterilizing group (cfu/mL).

By changing the voltage of the high pressure electrostatic water treatment device, the best bactericidal parameters of the high voltage electrostatic sterilization experiment device are given. At the output voltages of 2000V, 4000V, 5000V, 7500V, the sterilization rate curve is shown in Fig. 2.

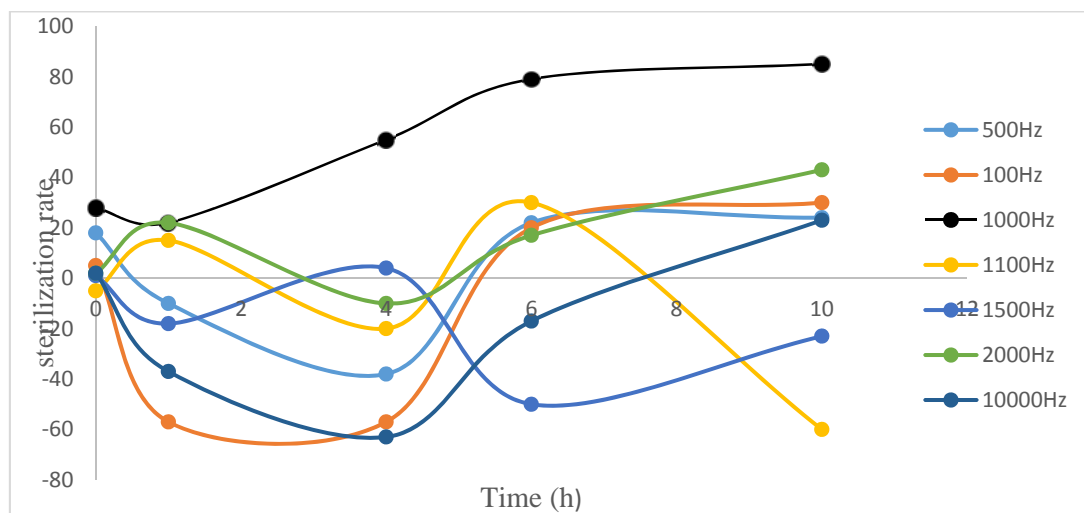


**Figure 2.** Sterilization rate curve of different output voltages.

As can be seen from Figure 2, the sterilization rate at different voltages is different and varies with time. The output voltage of 4000V sterilization effect is better, the curve is more stable, and the sterilization rate increases with time, 10 hours sterilization rate reached 89.4%.

## 2.3. Frequency of variable frequency pulsed electromagnetic field

The experimental waveform selects the pulse square wave with a duty cycle of 50%, an output voltage of 10 Vpp, and a water temperature of 30°C. The different pulse frequencies of 100Hz, 500Hz, 1000Hz, 1100Hz, 1500Hz, 2000Hz and 10000Hz were selected, and the samples were taken for 5min, 1h, 4h, 6h and 10h respectively. The changes in sterilization rate over time at different frequencies is shown in Figure 3.

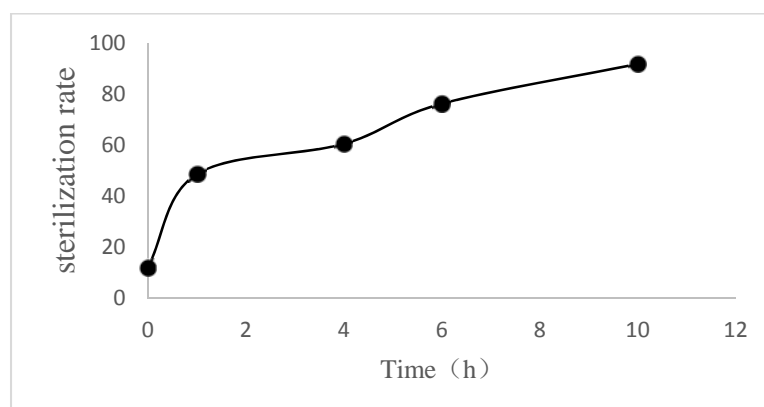


**Figure 3.** Sterilization rate at different frequencies.

Therefore, it can be seen that when the frequency of the pulsed magnetic field resonates with the natural frequency of the heterotrophic bacteria in the water, the physiological structure of the heterotrophic bacteria is destroyed to kill the bacteria. And if the selected frequency is the absorption frequency of the heterotrophic bacteria, the pulse frequency will stimulate the bacteria to multiply. When the pulse frequency was 1000Hz, the germicidal rate was kept in positive growth state, and the sterilization rate increased with time, and the sterilization rate reached 84.47% at 10 hours.

#### 2.4. Parameter settings of magnetoelectricity one-piece collaborative sterilization water treatment equipment

Through the previous experiments, the best experimental parameters of high voltage electrostatic sterilization and pulsed magnetic field sterilization were obtained. Thus the experiment parameters of the device were set as follows: the voltage of the high voltage power supply was 4000V, the pulse frequency 1000Hz, water temperature 30 °C. Use these data as the experimental device operation parameters, the magneto electric synergistic water treatment sterilization experiment was carried out. And the sterilization rate of each time period shown in Fig. 4.



**Figure 4.** Sterilization rate of magnetoelectricity one-piece collaborative sterilization water treatment.

It is clear that the bactericidal effect of the magnetoelectricity one-piece collaborative sterilization water treatment equipment is obvious, the sterilization rate is 48.7% at 1h, and it reached 91.8% when the experiment was carried out for 10 hours.

### 3. Conclusion

The sterilization rate is selective for the frequency and output voltage, and only in the sweep frequency range and the output voltage of the appropriate conditions to the heterotrophic bacteria play a better role in killing. In the high voltage 4000V, pulse frequency 1000Hz conditions, running 10 hours sterilization rate of more than 90%, got a good sterilization effect.

### Acknowledgments

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