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High Voltage Pulsed Electric Field Technology to Kill Bacteria or Pathogens in Sewage

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Abstract: With the aggravation of water pollution and the serious shortage of fresh water resources, sewage sterilization treatment has become the focus of attention. Traditional sewage treatment methods cannot produce good killing effect on bacteria or pathogens in sewage, so it is urgent to explore and develop new environmental protection and efficient sewage sterilization technology. The application of high-voltage pulsed electric field technology in food sterilization has been developed rapidly. In order to explore the effect of high-voltage pulsed electric field technology on sewage sterilization and provide a new method for sewage sterilization, this study selected common domestic sewage as the experimental object, and investigated the influencing factors of high-voltage pulsed electric field technology sterilization and the inactivation effect of main microorganisms in sewage. A series of experiments were carried out with pH value, electric field intensity and treatment time as independent variables and total microbial mortality as dependent variables. The results showed that the sterilization effect of high-voltage pulsed electric field was significant, and pH value, electric field intensity and treatment time had great influence on the sterilization effect. In each experiment, one factor was selected as the only independent variable, and the other parameters remained the same. Because of the complexity of bacteria species in sewage, Escherichia coli and Salmonella were selected as two kinds of bacteria with high proportion, and their inactivation effect was taken as the main index. When the pH value was 3.98, the lethal effect was the best, the logarithm of death reached 2.1 and 3.41 respectively; when the electric field intensity was 30 kV/cm and the treatment time was 120 s, the lethality of Escherichia coli and Salmonella reached the highest.

1. Introduction

1.1. Background Significance

Traditional sewage treatment mostly focuses on the content of heavy metals and phosphorus in sewage. In fact, there is a kind of pollution factor which can easily affect human health and life, that is, pathogens including bacteria. If the sewage is not sterilized, it will bring very serious consequences. The emerging high-voltage pulsed electric field technology in sterilization technology, with its good sterilization effect and fast sterilization speed, has become the new favorite of the major food sterilization processing plants [1]. It is particularly important to introduce this technology into sewage sterilization, improve the efficiency of sewage sterilization and reduce the pressure for the lack of fresh water resources.

1.2. Related Work

As a new sterilization technology, high-voltage pulsed electric field technology has been concerned by researchers all over the world to explore its equipment settings, influencing factors and sterilization effect in various fields. Chen, T used high-intensity pulsed electric field to treat tea samples under different conditions, accelerate the ripening of Pu'er tea, and detect the contents of tea polyphenols and caffeine in tea [2]. His research did not consider the influence of pulse waveform and material pH value. Suchanek, M. used contrast-enhanced low field magnetic resonance imaging (MRI) to study the effect of high-voltage pulsed electric field (PEF) on potato tubers, and to monitor the spatial distribution of damage caused by pulse and its evolution with time [3]. His high-voltage pulsed electric field system processing room is not perfect and needs to be further improved. Mikhaylin, S. used environmentally sustainable high-voltage electrical treatment (HVET, pulsed electric field and arc) to improve the sensitivity of β - lactoglobulin to enzymatic hydrolysis [4]. The theory used in his research is not perfect and needs further adjustment and verification.

1.3. Innovative Points in This Paper

In order to explore the killing effect of high-voltage pulsed electric field treatment technology on bacteria or pathogens in sewage, so as to provide a new idea for sewage sterilization and improve the treatment efficiency of sewage sterilization, the high-voltage pulsed electric field treatment technology was introduced into the sewage sterilization experiment. First of all, microbial detection was carried out on the sewage samples provided by the sewage treatment plant, and the best culture time was obtained. After the microorganism was cultured, the pH value of sewage sample was adjusted by reagent, and the influence of pH value on the sterilization effect of high voltage pulsed electric field treatment technology was studied. Then, the relationship between the electric field intensity and the treatment time and the bacterial lethality was studied by taking the electric field intensity and treatment time as the only independent variables. The experimental results show that pH value, electric field intensity and treatment time will affect the sterilization effect of high-voltage pulsed electric field treatment technology. When the pH value is slightly acidic and the electric field intensity is 3030kv / cm, the bacterial mortality rate of sewage after 90 s treatment is the highest. In order to achieve the best effect, it is necessary to pay attention to the setting of these parameters in practical application.

2. High Voltage Pulsed Electric Field Treatment Technology and Sewage Sterilization

2.1. Source and Treatment of Sewage

Different types of sewage have different characteristics, and their specific indicators are not the same. The treatment of sewage needs to consider the water quality, discharge requirements, cost and other factors.

(1) Urban and rural sewage

Urban sewage generally has the characteristics of high concentration of organic matter and high content of nitrogen and phosphorus. If it is not treated properly, it will easily lead to eutrophication. For this kind of wastewater, the general measures are chemical phosphorus removal, activated sludge process, membrane bioreactor technology and so on. The main principle of chemical phosphorus removal method is to convert the soluble phosphorus ions in sewage into insoluble phosphorus containing particles [5]. Activated sludge process belongs to biological treatment process. Currently, anaerobic anoxic aerobic (A/A/O) technology is commonly used, which can effectively treat urban sewage, and has a good effect of phosphorus and nitrogen removal; there is also sequencing batch activated sludge (SBR) technology, which can complete various reactions of sewage treatment in a treatment tank. Membrane bioreactor (MBR) technology is the use of membrane for wastewater filtration selection, combined with biological treatment method can effectively treat sewage, reduce the output of activated sludge, but the cost of membrane is high, it is difficult to popularize and apply, only suitable for small sewage treatment facilities.

In urban domestic sewage, there is a kind of sewage with complex composition, difficult treatment and easy to harm human health, that is, landfill leachate wastewater. At present, in addition to the common sewage treatment methods mentioned above, there are leachate reinjection method, chemical reagent oxidation method, chemical reagent flocculation method, adsorption method and so on. No matter which method is adopted, the purpose is to reduce the chroma, odor and NH4 +-N content of landfill leachate.

Rural sewage includes domestic and industrial sewage, which has a wide range of pollution, low concentration of organic matter, weak alkaline water quality and high phosphorus content. Some urban sewage treatment technologies can be used in rural sewage treatment, but they are not very suitable. At present, the rural sewage treatment mainly includes anaerobic biogas digester, soil infiltration system and constructed wetland system. Anaerobic biogas digester can not only purify sewage, but also realize resource recovery and utilization with high benefit. Soil infiltration system can improve soil efficiency, but it has higher requirements for soil quality. Constructed wetland system can effectively purify sewage by combining physical, chemical and biological methods, but it is easily affected by climate.

(2) Industrial sewage

The pollutants in industrial wastewater are different in composition, difficult to degrade, and most of them are toxic. The treatment mode of domestic sewage can not be directly applied, and the treatment mode of combining multiple methods is generally adopted. For example, biodegradation, chemical oxidation, coagulation and sedimentation point hydrolysis oxidation, anaerobic technology and so on, are to reduce the chemical oxygen demand of sewage and improve its biodegradability. In industrial wastewater, there is a kind of industrial wastewater containing highly toxic heavy metals, which has its special treatment methods, such as chemical precipitation method, ion exchange method and adsorption method [6].

Chemical precipitation method is easy to produce a large amount of sludge, which increases the treatment cost. Ion exchange method can not only reduce the amount of sludge, but also reuse the heavy metals produced by the exchange. However, the treatment effect is easily affected by many factors. The adsorption method will not cause secondary pollution to the sewage, is very friendly to the environment, the operation process is very simple, and the removal of heavy metal ions efficiency is high, low cost, its adsorption effect mainly depends on the performance of the adsorbent.

(3) Medical sewage

Medical sewage is mainly discharged by hospitals and pharmaceutical industry, which contains various kinds of bacteria and antibiotics and other complex components, which is easy to affect the ecological balance and threaten human health. At present, the commonly used treatment methods include membrane bioreactor and chlorine dioxide disinfection.

Membrane bioreactor (MBR) can effectively treat bacteria and organic pollutants through membrane separation and biological treatment, but it is expensive and complex to use. As an efficient disinfectant, chlorine dioxide has a wide range of treatment, fast speed and obvious effect, and has a good killing effect on bacteria or pathogens in sewage.

2.2. Traditional Sterilization Technology

(1) Ozone sterilization technology

Ozone is a kind of gas sterilization agent. It is light blue at room temperature and has special odor. There are many ways to obtain ozone, such as high voltage discharge, electrochemistry, photochemistry and atomic radiation. The basic principle is to decompose and polymerize oxygen in the air by high voltage electric power or chemical reaction, so as to form ozone.

The mechanism of ozone sterilization can be summarized as follows: acting on the cell membrane, enhancing its permeability, making the substances in the cell flow out and losing its vitality; making the enzyme which is the basic metabolism and synthesis function lose the activity; destroying the genetic material in the cell. Ozone can destroy the DNA or RNA of virus directly. As for microorganisms, they damage the cell membrane first, resulting in metabolic disorders, inhibiting growth, and penetrating the membrane tissue [7].

Ozone has a certain killing effect on bacteria, mold, virus and microorganism, but it is easily affected by the temperature and humidity in the operating environment, and if the ozone concentration is lower than 0.2mg/l, it has no bactericidal effect.

(2) Heat sterilization

Generally, thermal sterilization is not used for sewage sterilization, but a commonly used sterilization technology in food industry. It mainly relies on heat source to heat food directly or indirectly to achieve sterilization effect. Thermal sterilization can be divided into traditional thermal sterilization and new thermal sterilization. In the process of sterilization, different methods should be adopted according to the heat resistance characteristics, pH value and packaging materials of microorganisms and bacteria.

Traditional thermal sterilization technology can be divided into pasteurization, high temperature sterilization and ultra-high temperature instantaneous sterilization according to the temperature. As the name implies, the sterilization temperature is getting higher and higher. Pasteurization temperature is lower than 100 ℃. It was first used to kill tuberculosis bacteria in milk. It is also applicable to products with pH value less than 4.6. The pasteurized products still need to be refrigerated. When the temperature of high-temperature sterilization is over 100 ℃, and the heating medium is hot water or steam, it needs to meet the high-pressure conditions. It is mainly applicable to the food with pH value greater than 4.6, which is widely used in the canning industry. The temperature of ultra-high temperature instantaneous sterilization is generally about 140 ℃. After maintaining the instantaneous high temperature for about 5 seconds, it can immediately cool down to 30 ℃. It can kill microorganisms instantly and retain the original quality and nutritional value of the video as much as possible [8].

Ohmic sterilization and microwave sterilization are commonly used in the new thermal sterilization technology. Ohmic sterilization, also known as resistance heating, uses the dielectric properties of food to produce heat sterilization when the current passes through the food. It has the advantages of uniform heating, no pollution and easy operation. Microwave sterilization is the result of both thermal and biological effects of microwave. Microwave can denature microbial proteins until death, change the distribution of transmembrane potential, change the permeability of cell membrane, inhibit microbial growth, and even lead to gene mutation and chromosome breakage.

(3) Irradiation sterilization

Irradiation sterilization technology mainly irradiates all kinds of light from the irradiation source to sterilize the materials in the irradiation field. These radiation directly or indirectly affect the genetic material, internal structure and bioactive substances of microorganisms, thus affecting the normal physiological activities and metabolism of microorganisms, and eventually lead to microbial death. However, irradiation sterilization also has disadvantages. If the radiation intensity is too high, it will bring changes to the treatment material itself when killing microorganisms, and even harmful components may appear [9].

Radiation sterilization can process materials at room temperature, basically does not change the temperature of the treatment object, so it is suitable for surgical instruments and other items that cannot be sterilized at high temperature. It has strong penetrability, fast sterilization speed, complete sterilization, simple operation, continuous execution, and suitable for large-scale sterilization. However, irradiation sterilization is not suitable for all food and pharmaceutical products, and various factors need to be considered. And in the process of irradiation sterilization, it is necessary to protect the safety and health of operators.

2.3. High Voltage Pulse Sterilization Technology

(1) Sterilization mechanism

High voltage pulsed electric field (PEF) sterilization technology, its working process is to use high-voltage pulsed power to generate high-voltage pulse, adding high-voltage pulse to the electrode in the sterilization treatment room, forming a pulsed electric field in the sterilization treatment room. The sterilization of food was completed by pulsed electric field. There are various hypotheses about the mechanism of sterilization.

Theory of electric disintegration effect: under the action of pulsed electric field, with the increase of electric field, the squeezing force attracted by different charges in cell membrane increases. If the pressure exceeds the repair force of membrane, the cell membrane of microorganism will split and the microorganism will die [10].

Electroporation Theory: high voltage pulsed electric field makes pores appear on the surface of cell membrane, which changes the permeability of cell membrane, resulting in cell irreversibility and eventually death.

Electrolysis product effect: the electric field ionizes the electrolytes in the materials near the electrode, and the ionized products combine with the intracellular substances, resulting in cell death.

Viscoelastic polarity formation model: under the action of high-voltage electric field, cells will not only vibrate violently, but also produce plasma, which will produce shock wave and kill microorganisms.

Ozone effect: liquid through the action of electric field, electrolytic formation of ozone, ozone through its strong oxidation of microbial cell membrane membrane, so that microbial death.

(2) Equipment composition

The structure of different high-voltage pulse sterilization devices will be different, but the four parts of the standard are indispensable: high-voltage pulse power supply, sterilization treatment room, liquid flow control device and detection device [11]. The power supply and sterilization room are the core equipment.

High voltage pulse power supply, which can produce high voltage pulse to meet the sterilization requirements, is composed of main power circuit and power control circuit. Among them, the main circuit of the power supply provides DC high voltage, and the control circuit is responsible for the task of forming the control power supply to meet the specific conditions, which controls the high-voltage pulse of frequency, pulse width, polarity and waveform.

Sterilization treatment room is the place where high-voltage pulsed electric field is formed, which is the core of the whole equipment. After flowing into the laboratory, the liquid is subjected to the pressure of pulsed electric field to achieve the purpose of sterilization.

The liquid flow control device can transfer the liquid to the treatment room, and then transport it to the transmission channel, solenoid valve and transfer pump in the liquid storage tank after the treatment. By controlling the switch of solenoid valve, the flow direction of liquid food can be controlled and the continuous automatic processing of liquid can be completed.

The device is used to detect the working condition of equipment, the temperature change of liquid and the change of air pressure in the device.

(3) Influencing factors

There are many factors that affect the inactivation effect of high pressure pulse sterilization. The change of one parameter may affect the effect of another parameter. Equipment parameters, including electric field intensity, processing time, pulse parameters, etc. Generally speaking, increasing the intensity of electric field and prolonging the treatment time can enhance the inactivation effect of microorganisms. Pulse parameters have a specific impact on the treatment effect of high-pressure pulse sterilization technology. Pulse energy, pulse width, pulse frequency and frequency were positively correlated with the effect of high pressure pulse sterilization on inactivated microorganisms. With the increase of pulse intensity, the effect of high pressure pulse sterilization was better. According to the different high-voltage pulse sterilization circuit system, there will be a variety of pulse waveforms. The general pulse waveform includes square wave, attenuation wave and oscillation wave. Square wave has the highest mortality and high energy efficiency, followed by attenuation wave and oscillation wave.

The sample parameters mainly include the determination of liquid concentration, conductivity and pH value, which affect the effect of high voltage pulse sterilization technology. Low concentration and low electrical conductivity contribute to the elimination of microbial active environment by high voltage pulse. The electrical conductivity of the material affects the heating degree of the material in the process of high-voltage pulse sterilization to a certain extent. The lower the electric field intensity is, the higher the energy utilization rate of high-voltage pulse sterilization is, and the better treatment effect can be obtained.

The sensitivity of microorganisms to high-pressure pulse sterilization mainly depends on the cell characteristics such as microbial species, growth conditions, growth period and initial pollution degree. Different types of microorganisms have different tolerance to high voltage pulses. If the growth cycle of microorganisms is different, the sensitivity to high voltage pulse is also different. The growth conditions also affect the germicidal efficacy of high voltage pulse. In general, Gram-positive bacteria and Gram-negative bacteria are more resistant to high-pressure pulse sterilization than yeast cells. The cell wall thickness of Gram-positive bacteria is about 20-80 nm, and its chemical composition is single, but it contains 90% peptidoglycan. The cell wall of Gram-negative bacteria is thin, about 10-15nm, containing peptidoglycan, lipopolysaccharide, lipid, protein and other components; yeast cell wall is thick, but the cell wall does not contain peptidoglycan [12]. The toughness of cell wall varies with the structure of microorganism. Compared with Escherichia coli and yeast, Staphylococcus aureus contains more peptidoglycan and is more resistant to high-pressure pulse sterilization. The bacterial cells in fixed growth stage were more tolerant to high pressure pulse sterilization than exponential growth cells. Temperature, composition of growing medium, oxygen concentration and recovery conditions may affect the tolerance of microorganisms to high-pressure pulse sterilization.

(3) Advantages and disadvantages

Compared with the traditional sterilization methods, high-voltage pulsed electric field has the following advantages. First of all, the sterilization effect is good, which can effectively kill most of the bacteria and microorganisms, and almost make its survival rate to zero; secondly, the sterilization speed is fast, which can be completed in microseconds; if applied to food sterilization, it can better preserve the nutritional components and flavor of food; the sterilization process is easy to operate and post-processing, without complex steps; low energy consumption Compared with thermal sterilization technology, it can reduce energy consumption by almost half; it will not cause secondary pollution to the environment, and will not form three wastes, which is very environmentally friendly.

Although high-voltage pulsed electric field sterilization has many advantages, the following problems should be paid attention to in the use process, so that the effect can reach the ideal state.

High voltage pulse power supply is one of the core settings of the whole sterilization system and plays an important role in the whole equipment. Due to the different pulse power supply used, its waveform can be divided into square wave, attenuation wave, oscillation wave and so on. According to the research, square wave has the highest sterilization efficiency, followed by exponential decay wave and oscillation wave. However, the development of high-power and high-voltage square wave pulse power needs to spend a lot of money, so most of the power supply used in the laboratory is exponential decay wave pulse power supply. Therefore, the development of square wave high-voltage pulse power supply with appropriate price and adjustable parameters is one of the keys to the commercial application of this technology.

Most of the treatment rooms designed at present do not meet the requirements of industrial use. The main problems to be solved are as follows: the cross-sectional area of the liquid flowing in the dynamic treatment chamber is small, the flow rate is low, the voltage rise causes partial discharge, and the current increases rapidly; the reasonable mathematical model of temperature field and electric field spatial distribution has not been established, which cannot accurately find the dangerous point, which will bring a lot of disadvantages to the design of cooling channel and cooling method. Due to the electrode design and other reasons, the electric field distribution is not uniform, and the local electric field strength between the two electrodes is very different.

There must be a reliable measuring device to measure the transmission capacity of each pulse, including pulse frequency, to identify possible partial discharge.

Before the application of high-voltage pulsed electric field sterilization technology in the field of food industry, it is necessary to further understand its impact on the chemical and nutritional components of food, and conduct full verification to ensure the safety of food.

3. Sterilization Experiment of Sewage by High Voltage Pulsed Electric Field Treatment Technology

3.1. Experimental Materials

(1) Subjects

Domestic sewage is provided by a domestic sewage treatment plant. The bacteria in the natural sewage.

The culture medium was nutrient agar medium. The preparation method was as follows: 3g beef extract, 4g sodium chloride, 8g peptone and 800ml distilled water were put into the beaker for heating, and then the heating was stopped to supplement water. Adjust the pH value to about 7.3 with 5% sodium hydroxide, add agar and boil until boiling. After the agar was completely melted, the agar was filled with water, filtered, packed and labeled, and sterilized at 110 ℃ for 10 minutes.

(2) Instrument and equipment

High voltage pulsed electric field equipment, S-570 scanning electron microscope, fluorescence microscope, pH test paper for laboratory, constant temperature water bath pot, historical vacuum sealing machine, electronic balance, culture dish, test tube number, alcohol lamp, oscillator, etc.

3.2. Experimental Methods

(1) Microbial detection of sewage samples

Firstly, the samples were diluted and cultured. Put 20ml test sample into 180ml normal saline, mix it fully to make 1:10 uniform diluent; then use pipette to inject 1ml of previously diluted test sample into 9ml of normal saline, mix evenly to make 1:100 diluent; according to the situation of sewage, repeat 10 times dilution operation, select appropriate diluent, and put it in aseptic culture dish, do two culture for each dilution Dish; 10 ml nutrient agar medium was poured into the culture dish, mixed evenly, and incubated in the incubator at 35 ℃ for 48 hours.

Count the colonies in the dish. A magnifying glass can be used to record the number of colonies in each culture dish, and the average number of colonies with the same dilution can be obtained.

The detection procedure is shown in Figure 1:

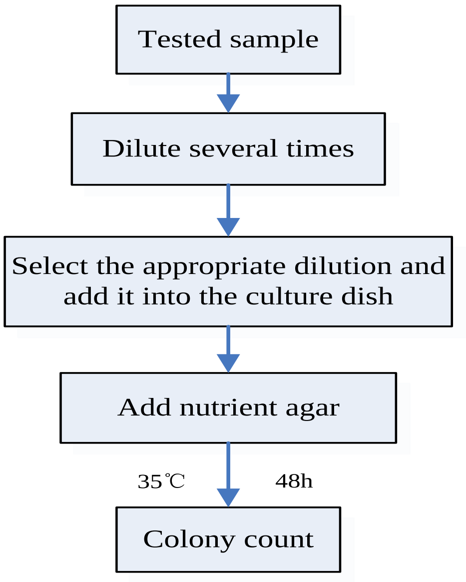

Figure 1. Microbial detection process

(2) Preparation of tested samples with different pH values

In order to test the effect of pH value on sterilization effect, sterile water with different pH values was prepared with 5% NaOH and 2% HCl; the cultivated sewage bacterial liquid was added respectively, and then the bacterial suspension with different pH value was prepared and treated by high-voltage pulsed electric field.

In order to ensure that only pH value is an independent variable, other factors need to be consistent. Therefore, in the high-voltage pulsed electric field treatment, the parameters of pulse width, electric field intensity and pulse number are consistent, which are 9 μ s, 25 kV/cm and 3000 respectively, and the processing time is 90s.

(3) The killing of bacteria

Firstly, the electric field intensity is controlled as an independent variable. An electrode chamber with an inner diameter of 8mm is used. The liquid flow rate is 15.2ml/s, the frequency of high-voltage pulsed electric field is 4kHz, the pulse width is 9 μs, and the pulse parameter is 3000. The electric field intensity is 10kV/cm, 15kV/cm, 20kV/cm, 25kV/cm, 30KV/cm. The treatment time was 90s. The lethal rate was determined by high voltage pulsed electric field treatment.

Taking the processing time as an independent variable, an electrode chamber with an inner diameter of 8mm was used. The liquid flow rate was 15.2ml/s, the frequency of high-voltage pulsed electric field was 4kHz, the pulse width was 9 μs, the pulse parameter was 3000, and the electric field intensity was 25kV/cm. The treatment time was 30s, 50s, 70s, 90s, 120s and 180s, respectively. The lethality was determined by high-voltage pulsed electric field treatment.

3.3. Model of Killing Effect of High Voltage Pulsed Electric Field Technology on Microorganisms

(1) Hülsheger model

Hülsheger model describes the relationship between pulsed electric field and killing effect, and the killing effect is expressed by residual activity rate. The relationship is shown in Formula 1 and 2:

$$\ln(S) = -b_E(E - E_0) \tag{1}$$

$$S = \frac{m}{M} \tag{2}$$

Where m is the number of microorganisms before treatment, M is the number of microorganisms after treatment, b_E is the regression coefficient, E is the electric field strength, E_0 is the critical electric field strength, the unit is kV/cm.

(2) Peleg model

Peleg model also describes the relationship between microbial residual activity and electric field intensity, and the relationship is shown in Formula 3:

$$S = \frac{1}{1 + e^{\frac{E - E_0}{K}}} \tag{3}$$

In this equation, K is the dynamic constant. The smaller the value of K, the more deviating from the inactivation rate curve, the lower the sensitivity to pulsed electric field, the better the killing effect. E is the electric field strength and E_0 is the critical electric field strength in kV/cm.

4. Discussion on Sterilization Effect of High Voltage Pulsed Electric Field Technology for Sewage

4.1. Microbial Growth of Sewage Samples

The growth of Escherichia coli and Salmonella in the microorganism of sewage sample was observed. The OD value at 500nm of liquid medium was measured every 5 hours to determine the culture time of the two bacteria. The results were as follows:

Table 1. Growth of escherichia coli and salmonella

Species / Time	5h	10h	15h	20h	25h	30h
Escherichia coli	0.02	0.14	0.148	0.15	0.152	0.157
Salmonella	0.03	0.11	0.32	0.41	0.44	0.45

As shown in Table 1, the OD value of Escherichia coli tends to be stable after 10 hours, while that of Salmonella tends to be stable after 20 hours, and enters the stable period. In order to avoid special circumstances, the culture time of Escherichia coli and Salmonella can be determined as 12h and 22h respectively.

4.2. Effect of PH Value of Sewage on Sterilization Effect

In this experiment, pH value was taken as the only variable, which were 3.98, 4.55, 5.21, 6.25 and 7.1, respectively.When the frequency of high-voltage pulsed electric field is 4kHz, the pulse width is 9 μ s, the pulse parameter is 3000, and the electric field intensity is 25 kV / cm, the bacterial suspension with different pH values is treated by pulse for 90 s, and the lethality of Escherichia coli and Salmonella is detected. The results were as follows:

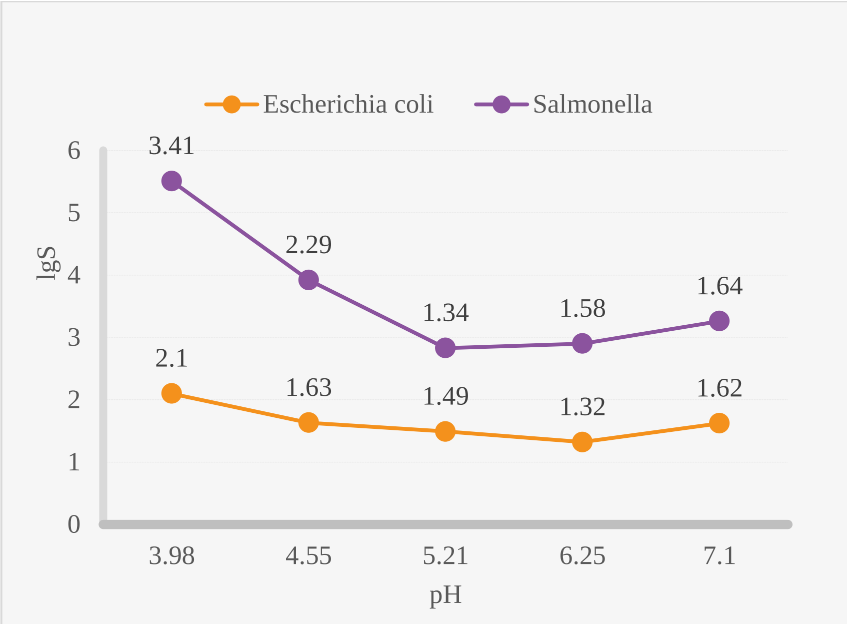

Figure 2. Effect of pH value on bacterial lethality

As shown in Figure 2, when the pH value is 3.98, the lethal effect of the two bacteria is the best, with the lethal logarithm of 2.1 and 3.41 respectively. When the pH value was 7.1, the lethal rate was slightly higher than that at pH 6.25 and 5.21. This shows that the pH value of sewage has a certain influence on the sterilization effect of high-voltage pulsed electric field treatment, but it is not that the higher or lower the pH value, the better the effect. Moreover, under the same pH value, the lethal effect of high-voltage pulsed electric field on Salmonella was better than that of Escherichia coli.

4.3. Effect of Electric Field Intensity and Treatment Time on Sterilization Effect

(1) Effect of electric field intensity on sterilization effect

Under the condition that other factors remain unchanged, the electric field intensity is taken as the only variable, which are 10kV / cm, 15kV / cm, 20kV / cm, 25kV / cm, 30KV / cm respectively. After 90 s of high-voltage pulsed electric field treatment, the lethality of bacteria was detected, and the lethality of Escherichia coli and Salmonella was taken as reference. The results were as follows:

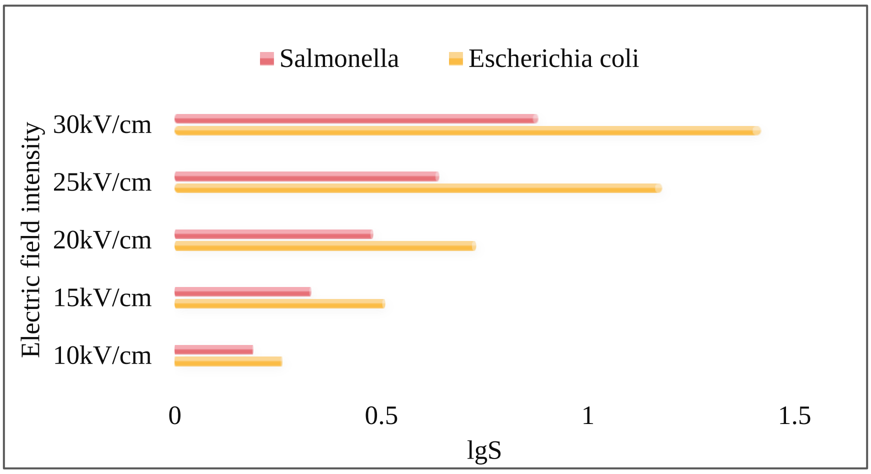

Figure 3. Effect of electric field intensity on bacterial lethality

As shown in Figure 3, when the electric field intensity is the same, the inactivation effect of high-voltage pulsed electric field on Escherichia coli is better than that of Salmonella, which may be due to the different cell structure of the two. When the electric field intensity increased to 30kV/cm, the lgS of Escherichia coli and Salmonella were 1.42 and 0.88, respectively. This indicated that the electric field intensity had a significant effect on the lethality of Escherichia coli and Salmonella. With the increase of electric field intensity, the lethality of both bacteria increased.

(2) Effect of processing time on sterilization effect

Under the condition of keeping the other parameters unchanged, the treatment time was taken as the only variable, which was 30s, 50s, 70s, 90s, 120s and 180s, respectively. The lethality of Escherichia coli and Salmonella was determined by high-voltage pulsed electric field treatment. The results were as follows:

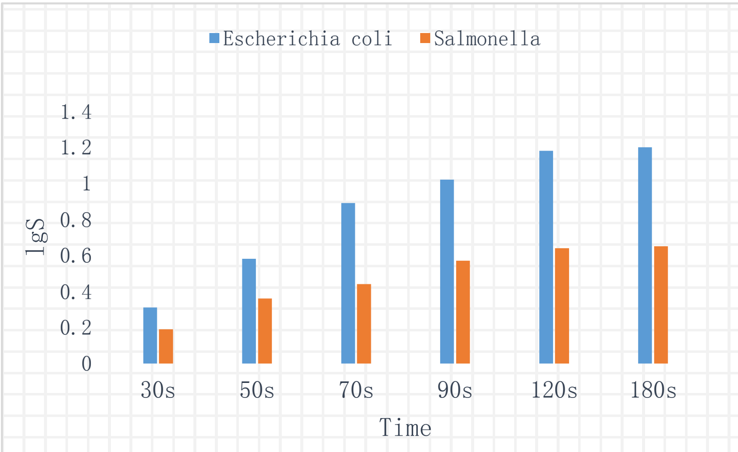

Figure 4. Effect of treatment time on bacterial mortality

As shown in Figure 4, when the treatment time is the same, the killing effect of high-voltage pulsed electric field on E.coli is better than that of Salmonella, and when the time is extended to 180s, the lethality of them reaches the highest. However, it can be seen that in the period of 120s to 180s, the growth rate of lethality rate is very slow, and the best effect has been achieved in 120s, and there is no need to extend the treatment time. The results showed that the treatment time had a significant effect on the lethality of Escherichia coli and Salmonella. With the increase of the treatment time of high-voltage pulsed electric field, the lethality of Escherichia coli and Salmonella increased.

5. Conclusion

Efficient and environmentally friendly sewage treatment can greatly improve the quality of sewage treatment, so that the original cannot be used into recycling, save fresh water resources, improve economic benefits. High voltage pulsed electric field treatment technology in food sterilization, has the advantages of fast speed, high efficiency, green environmental protection. If it can be reasonably applied to sewage sterilization, it can bring a new direction for sewage sterilization technology.

In the experiment of applying high-voltage pulsed electric field treatment technology to sewage sterilization, we found that the pH value of sewage, the intensity of high-voltage pulsed electric field and the treatment time all greatly affect the sterilization effect of high-voltage pulsed electric field treatment technology. Acidic pH value will increase the lethality of Escherichia coli and Salmonella. When the electric field intensity is high and the treatment time is 120 s, the high-voltage pulsed electric field treatment technology has the best killing effect on Escherichia coli and Salmonella.

However, due to limited time and knowledge, this study only tested the killing effect of Escherichia coli and Salmonella in sewage samples, but the actual sewage contains a variety of bacteria, which is complex. In addition, the amount of wastewater in wastewater treatment is much larger than the content of test tube in the experiment. Once the sample volume increases, it is not known whether it will bring challenges to the high-voltage pulsed electric field treatment technology, which remains to be solved in the next research work.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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