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Review Article

A Review: Discussion of Factors Affecting the Efficacy of UV Inactivation

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Abstract

UV can achieve the sterilization of clean and nontoxic by-products, and the article makes clear the way in which data such as irradiance and dose are taken. The article data indicates that higher bactericidal efficacy can be achieved for most bacteria at doses of 4 mJ/cm^2 for irradiance 1.0 mW/cm^2 and 0.06-0.30 mW/cm2 for irradiance 11 mJ/cm^2. The value of irradiance ignored the attenuation of LED during long-term use. By comparing the bactericidal effect of single layered and multi-layered bacteria, the degree of cleanliness achievable by UV bactericidal is illustrated, and it is reminded that safety protection should be taken care of during use.

Key words： ultraviolet C; irradiance; sterilization

Introduction

Ultraviolet sterilization is widely promoted all over the world. The large-scale outbreak of epidemic diseases has made people realize the necessity of ultraviolet sterilization. At the same time, the development of LED brings new development and wider application possibility to UV sterilization. On the other hand, the use of antibiotics has increased bacterial resistance [1]. Many animal experiments have shown that UV is a potential application for superficial treatment of bacterial infections. There were many attempts before, mainly in the bacterial infection of leg wounds. And ultraviolet combining the use of dressing effectively alleviated the infection [2]. For the application of ultraviolet sterilization, not only its advantages and disadvantages but also its damage and problems in the use process should be clear, to ensure safety in use, and to avoid all personnel in ultraviolet places from being affected by the side effects of ultraviolet (ultraviolet damage to cells and skin). The characteristics of ultraviolet sterilization are: clean, convenient, non-toxic by-products. Based on the necessity of sterilization, this article discusses tolerance and different doses of different bacteria that can be achieved by the application of ultraviolet sterilization and explores the reasons for the differences [3].

In the experiment, 265-278 nm UV-LED was used to irradiate a variety of bacteria with different densities in solid culture medium (agar) at 1.3, 4.6 and 8.2 cm for different times. Based on the principle that a bacteria colony is formed by a single cell, colony counting method and fixed absorbance counting were used to count the number of bacteria (cells and CFU) in the fixed area before and after irradiation, and calculate the bactericidal rate. The dose interval and inactivation curve were obtained from single-layer bacteria with different distribution densities, the inactivation effects of irradiance and dose were analyzed, and the value of data, influencing factors of dose difference and the tolerance difference between different bacteria was discussed.

The bactericidal effect of light spot energy determines the colony distribution after irradiation, and the accumulated energy of different irradiance has bactericidal effect. When irradiance is low, dose escalation does not achieve a corresponding bactericidal rate due to proliferation of the bacteria. The irradiance is 0.06-0.30 mW/cm^2, and the bactericidal effect is positively related to the dose. There is a significant tolerance difference between different bacteria. The statistical trend of bacterial inactivation is all nonlinear, and the bactericidal rate gradually increases with the dose, generally slowing down above 80%. Continuing to increase the irradiation time, the inactivation effect tends to be flat, and the energy level increases. It is difficult to completely sterilize, and it is statistically significant for the results of 99%, 99.9% and 99.99% sterilization doses. When the irradiance is 1.0 mW/cm^2, low dose (4 mJ/cm^2) can effectively kill single layer bacteria. The influence of irradiance on liquid sterilization is not clear. The following is a discussion of the factors influencing the results from experimental data.

(1) Factors of the device

The performance parameters of the experimental device itself include its power consumption, UV power, heat dissipation power, wavelength distribution, etc. For the irradiation experiment, the lamp beads are equipped with the aluminum substrate to dissipate heat and are far away (at 4.6 cm - 8.2 cm), and the irradiation time is short (at 1.3 cm) to avoid heat effect. The energy density distribution of the irradiation plane at the same distance is uneven which affected the statistical results of the bactericidal rate. After the device has been used for a period of time, the lamp performance degraded, and the irradiance has no statistical difference. In the actual irradiation, the time to achieve the same bactericidal effect was extended. These objective factors also have a certain impact on the accuracy of the data.

The UV wavelength of the experimental LED is 265-278 nm. It is unclear whether the visible light such as blue violet light has bactericidal effect. Without the use of filters, the effect of UV energy on bacteria is a multiwavelength interaction.

(2) Value taking method

There are three parameters to value the data used in this article, namely, irradiance and dose, bactericidal rate, and the number of bacteria before and after irradiation. The article shows that the irradiance is not uniform on the target surface, and the irradiance in the measuring spot area is generally averaged of multiple points. Doses can be taken in two ways: one is the product of irradiance and exposure time, and the other is to use an irradiance meter to measure the cumulative value of exposure energy. Because the surface of the experimental object was large and the irradiance meter was difficult to fix when it was irradiated, the first calculation method was selected. The number of bacteria was counted by colony counting method. In the process, this data error was reduced through several independent experiments. Data errors cannot be completely eliminated.

(3) Single layer bacteria and multi-layer bacteria

In the dose calibration experiment, the bacteria were all monolayer distributed on the culture medium. The irradiation time given for achieving 99%, 99.9% and 99.99% bactericidal rates of all bacteria was inconsistent, and the doses obtained were different.

The reasons for the difference of different bacterial doses include the morphology, species and structure of bacteria. In terms of species, bacteria are gram-positive and gram-negative, and the dosage has nothing to do with the classification of Gram and cell wall. The ultraviolet absorbing substance in bacteria is mainly nucleic acid, so the main reason for dose difference is genetic material DNA of bacteria.

The difference in bactericidal efficiency at irradiance of 1.0 mW/cm^2 and 0.30-0.06 mW/cm^2 may be due to the difference in the number and rate (molecular activation rate) of bases induced by different ultraviolet energies per unit time.

Corresponding to the colony irradiation experiment, the results showed that there were still a large number of bacteria living after the colony irradiated by ultraviolet light.

This also shows that the ultraviolet ray has a certain penetrability, which can penetrate multiple layers of bacteria. Long time and large dose of ultraviolet cannot achieve a high bactericidal rate. This indicates that it may be difficult to achieve complete sterilization in practical applications, such as the bactericidal effect of biofilm. Therefore, the combination of ultraviolet and other sterilization methods, such as chemical sterilization and drug spraying, is required to achieve the sterilization effect.

UV rays cause damage to the cornea of the eye, and it can lead to blindness. Hence, protective measures shall be taken and dosage shall be reduced during ultraviolet using. The bactericidal data of the article suggested there were distinctions in the dose of different strains of the same species of bacteria. The sterilization data shows that the ultraviolet energy of 11 mJ /cm^2 for most monolayer bacteria can achieve good inactivation effect. It provides reference for the application of sterilization.

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