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Construction of Rotated Disinfection-Box for Degree Certificates with Ultraviolet C

Prin Nachaisit[a], Jattupon Pongkun[b], Ratinun Luampon[b] and Bundit Krittacom[b*]

Abstract

The rotated disinfection-box for degree certificates with UVC was constructed to study the Ultraviolet dose ($H_{UV,exp}$) and determine the appropriate killing rate (KR) for the disinfection of degree certificates. The degree certificate disinfection-box was rotated at three different speeds (N), namely: 6, 8, and 10 rpm. The radiation intensity values were measured by the UVC meter at the grille in 4 measurement positions: $y_0 = 0$ m, $y_1 = 0.19$ m, $y_2 = 0.39$ m, and $y_3 = 0.59$ m. In a rotated disinfection-box measuring 120 cm x 120 cm x 200 cm, an Ultraviolet Germicidal Irradiation system (UVGI) with a wavelength of 254 nm, a power of 32 W, and eight UVC lamps were employed. The UV rate constant (z) is set at 0.079 m^2/J and the SARS-CoV-2 virus was killed with a criterion of radiation exposure of more than 134 J/m^2. The results revealed that in all situations, $H_{UV,exp}$ would be larger than 134 J/m^2 in the case of T_m greater than 50 s, and KR would reach 100% in 26 s. As a result, the UVC-constructed rotated disinfection-box for degree certificates may sterilize certificates with confidence.

Keywords: Ultraviolet radiation, Disinfection system, Rotated Disinfection-Box, Killing rate.

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Nomenclature

b_i	Constant of multiple linear regression equation (-)
D	Distance between the UVC lamp center and the measuring point (m)
$H_{UV,\,exp}$	Ultraviolet radiation dose of the experiment (J/m^2)
$H_{UV,\,pred}$	Ultraviolet radiation dose of the prediction (J/m^2)
I_{UVC}	UVC intensity (W/m^2)
KR	Killing rate (%)
L	length of UVC lamp (m)
N	Speed (rpm)
P_{UVC}	power of UVC light (W)
T_m	Exposure time (s)
y_i	Measurement positions the UV intensity (m)
z	UV rate constant (-)
α	Angle (Degree)

1. Introduction

The Rajamangala University of Technology Isan (RMUTI) in Thailand holds a graduation certificate ceremony on March 4th, 2022. The spread of the Coronavirus (Covid-19) is continuing all over the world, and human pathogen exposure is the most important determinant in infection transmission [1]. As a consequence, the university recognizes the necessity for attendees of this event to be safe first to protect against the growth of the SARS-CoV-2 virus. Therefore, a study of the microorganism that causes the infection in the degree certificate has been conducted. Since infectious agents are microorganisms or small organisms that rely on the bodies of other organisms for their development and reproduction, These bacteria can infect the body, whether it's plants, animals, or humans, and cause illness and potentially fatal sickness [2-4]. Disinfection can be accomplished in two ways: 1) Studies on direct infectious agents have been limited and difficult to conduct. 2) Studied on the Ultraviolet Germicidal Irradiation (UVGI) system disinfection rate, which is easily assessed against a wide range of pathogens and is based on radiation intensity [5-8]. The UVGI system's UVC radiation disinfection in the air and on the surfaces of objects is dependent on the pathogen's exposure period and the UV intensity. The UVGI system employs short-wave ultraviolet light about 220-280 nm to disinfection virus, fungal, and bacterial pathogens by producing photodimers in nucleic acids (DNA and RNA), blocking both transcription and replication as shown in Fig.1 [9]. It has previously been acknowledged and recommended for excellent bioaerosol removal in HVAC systems, which represents around 27% of all systems used by UVGI [7].

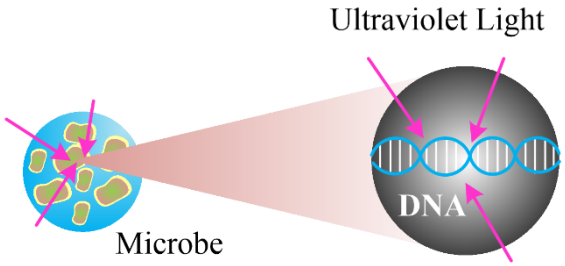

Fig. 1. Ultraviolet Germicidal Irradiation (UVGI) [9].

According to the aforementioned, it was found that many groups of researchers have paid attention to and examined UV disinfection. Kowalski et al. [10] presented a mathematical model of the UV Decay Curves using the UV susceptibility constant and the UVC dose to determine the decomposition of microorganisms. Sung and Kato [5] proposed methods to calculate the UV dose of the UR UVGI system at a wavelength of 254 nm based on the principle

of ventilation efficiency by simulations to estimate system disinfection results with CFD. Beggs et al. [11] investigated the UV susceptibility constant for Serratia marcescens in the UR UVGI system, which has been determined under complete aeration conditions using a complete mixing model. Warissarangkul and Karuchit [12] have investigated the optimum design and operation of an ultraviolet germicidal irradiation (UVGI) system for a tuberculosis (*TB*) isolation room modified from a patient's room of the type found in community hospitals in Thailand. Wanapaisan [13] has tested the effectiveness of killing COVID-19, which causes severe acute respiratory syndrome, or SARS-CoV, with UVC radiation at a wavelength of 254 nm.

This research has been interested in studying the disinfection efficiency of the UVGI system for COVID-19 in combination with the 360-degree rotation of diplomas to achieve disinfection that covers the area by using the rotation principle of research on vertical turbines that rotate along the axis [14-15]. As a solution, the researcher has constructed a rotating disinfection box for degree certificates with UVC in order to estimate Ultraviolet dose ($H_{UV,\,exp}$) and killing rate (*KR*).

2. Facility description

2.1 Degree certificate

Fig. 2 shows the Rajamangala University of Technology Isan degree certificate was made of silk, measuring 20 cm x 24 cm x 0.8 cm, which has particular qualities to tolerate heat up to 150 ˚C and can be UV intensity.

Fig. 2. A photograph of the Rajamangala University of Technology Isan degree certificate.

2.2 UVC light meter

Fig. 3 shows the UVC light meter that was used to measure real-time the I_{UVC}, model: UVC-254SD which has been ISO-9001, CE, and IEC1010 certified. Can be calculated the UVC intensity (I_{UVC}) as follows:

$$I_{UVC} = \frac{P_{UVC}}{2DL\pi^2}(2\alpha + sin(2\alpha)) \quad (1)$$

Here I_{UVC} is the UVC intensity of UVC light meter (W/m^2), P_{UVC} is the power of UVC light (W), D is the distance between the UVC lamp's center and the measuring point (m) and L is the length of UVC lamp (m).

Fig. 3. UVC light meter Model UVC-254SD [16]

2.3 Ultraviolet dose ($H_{UV, exp}$)

The ultraviolet radiation dose ($H_{UV, exp}$) was shown as the result of multiplying the amount of UVC intensity (I_{UVC}) and the exposure time (T_m). Can be calculated as follows:

$$H_{UV,exp} = I_{UVC} \times T_m \quad (2)$$

2.4 Killing rate (KR)

The killing rate (*KR*) [5] was used to calculate the mortality rate of COVID-19 with the UV rate constant (*Z*). The *KR* is determined as follows:

$$KR = 1 - e^{-Z \times H_{UV,exp}} \quad (3)$$

2.5 Multiple Linear Regression

The multiple linear regression method [17] was used to predict the $H_{UV,pred}$ by The ordinary least square approach. The corresponding regression coefficients, b_0, b_1, and b_2 in eq. (4) were calculated as follows:

$$H_{UV,pred} = b_0 + b_1 y_i + b_2 T_m \quad ; i = 0,1,2,3 \quad (4)$$

Here y_i is the measurement positions the UV intensity by using the UVC meter at the grille (m), T_m is exposure time (s).

3. Experimental equipment

The experiment equipment of the rotated disinfection box for degree certificates with UVC, as shown in Fig. 4, consists of, a breaker with an electric current of 30 A was used to prevent electric circuit shock. A limit switch was installed at the door of the disinfection box to prevent human exposure to the UV light. The exposure time was controlled by timer switch, the speeds (N) of motor was controlled by the invertor. Eight UVC lamps with the wavelength 254 nm and power of 36 W were used to generate UV light and was installed an aluminum foil for reflect UV light. The degree certificate's 32 sheets were installed on the 4 steel gratings in 1 test cycle and the UVC light meter that was used to measure real-time the I_{UVC}.

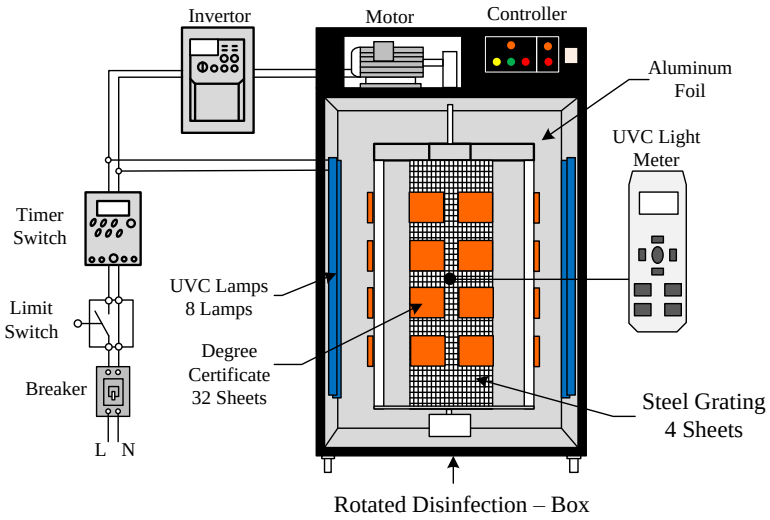

Fig. 4. Diagram of experiment equipment.

The UVC intensity inside a rotated disinfection box for degree certificates was measured at the y-axis location point, (y_i), which is the point at the center of the steel grating. They are defined as positions y_0, y_1, y_2 and y_3 with distances of 0 m, 0.19 m, 0.39 m, and 0.59 m, respectively, as shown in Figure 5.

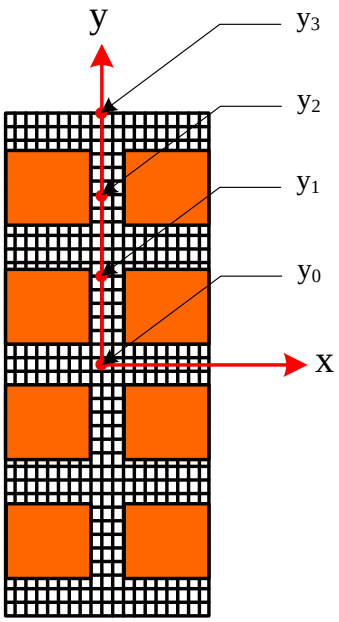

Fig. 5. The UVC intensity measurement location

4. Result and discussion

4.1 Influence of speed (N)

Fig. 6 shows the relationship of the exposure time (T_m) and UVC dose ($H_{UV,\,exp}$) at the experimental condition of measurement positions (y_i) of 0 m, the 3 different speeds (N) of 6, 8, and 10 rpm. From the experiment, It was found that the ultraviolet dose ($H_{UV,\,exp}$) was determined to be greater than 134 J/m^2 at T_m = 38 s, which has been considered to be the intensity of the radiation that exceeds the SARS-CoV-2 disinfection threshold. And when considering the effect of speeds on $H_{UV,\,exp}$, it was found that at low speeds, $H_{UV,\,exp}$ had the highest mean. because, at low speeds, the degree certificate has more exposure time.

Fig. 7 illustrates the relationship between the exposure time (T_m) and the killing rate (KR) calculated by Eq. (3). Regarding the result of Fig. 6, the trend of KR was increased to 100% at T_m equal to 22 s. Therefore, according to the killing rate equation Eq. (4), the SARS-CoV-2 sterilization can kill 100 percent from 22 s onwards.

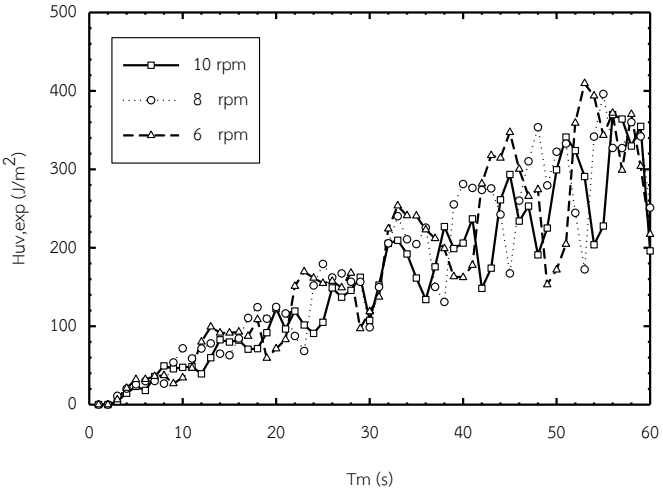

Fig. 6 The relationship of the exposure time (T_m) and UVC dose ($H_{UV,\,exp}$) with y_0 = 0 m.

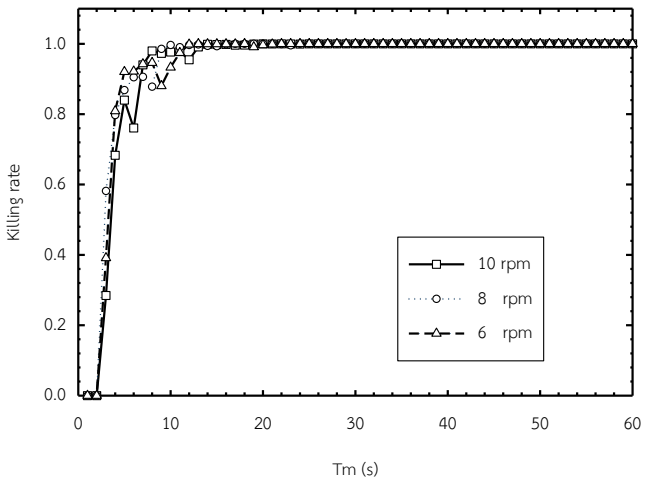

Fig. 7 The relationship between the exposure time (T_m) and the killing rate (KR) with y_0 = 0 m.

4.2 Influence of measurement positions the UV intensity. (y_i)

Fig. 8 reveals the relationship between the exposure time (T_m) and UVC dose ($H_{UV, exp}$) at the experimental condition of speeds of 6 rpm, with four positions of measurements of the UV intensity (y_i), namely: y_0 = 0 m, y_1 = 0.19 m, y_2 = 0.39 m, and y_3 = 0.59 m. From the result, It was found that the ultraviolet dose ($H_{UV, exp}$) was determined to be greater than 134 J/m^2 at T_m = 50 s, which has been considered to be the intensity of the radiation that exceeds the SARS-CoV-2 disinfection threshold. Considering the influence of y_i, the rotated disinfection box for the degree certificate can be sterilized with T_m of no less than 50 s.

Fig. 9 illustrates the relationship between the exposure time (T_m) and the killing rate (KR) calculated by Eq. (3). Regarding the result of Fig. 8, the trend of KR was increased to 100% at T_m equal to 26 s. Therefore, according to the killing rate equation Eq. (4), the SARS-CoV-2 sterilization can kill 100 percent from 26 s onwards.

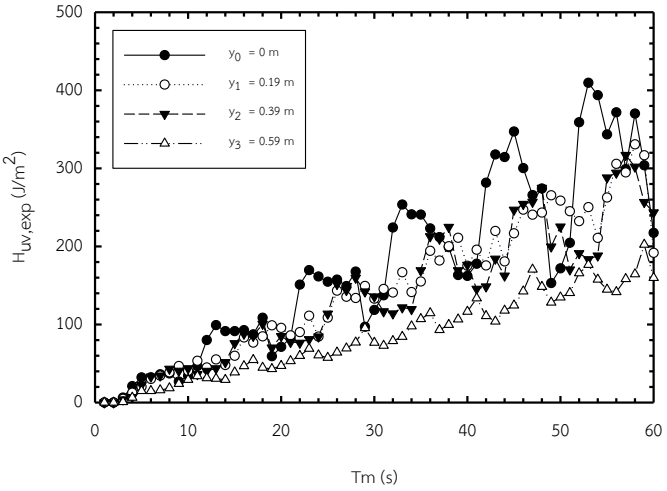

Fig. 8 The relationship of the exposure time (T_m) and UVC dose ($H_{UV, exp}$) with N = 6 rpm.

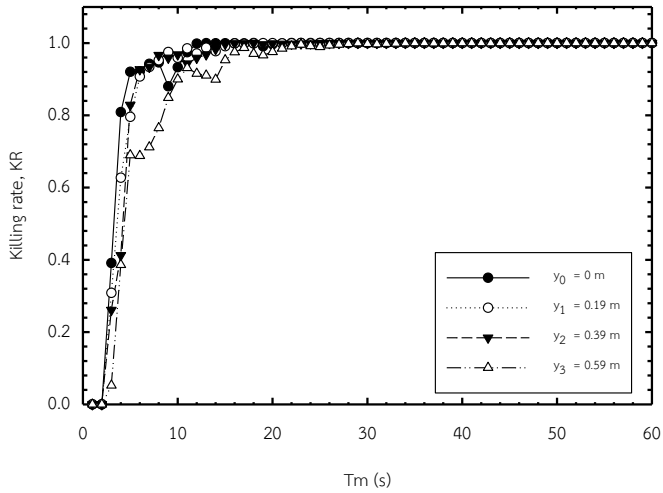

Fig. 9 The relationship between the exposure time (T_m) and the killing rate (KR) with N = 6 rpm.

4.3 Multiple linear regression (MLR)

Fig. 10 shows the equation of multiple linear regression (MLR) was calculated from the result of Fig. 7. It was found that the result of MLR is expressed in Eq. (4) with the parameter of b_i namely: $b_0 = 6.1706$, $b_1 = -20.8626$, and $b_2 = 4.4268$, which can be calculated $H_{UV,pred}$ as follows Eq. (5).

$$H_{UV,pred} = 6.1706 - 20.8626 y_i + 4.4268 T_m \quad (5)$$

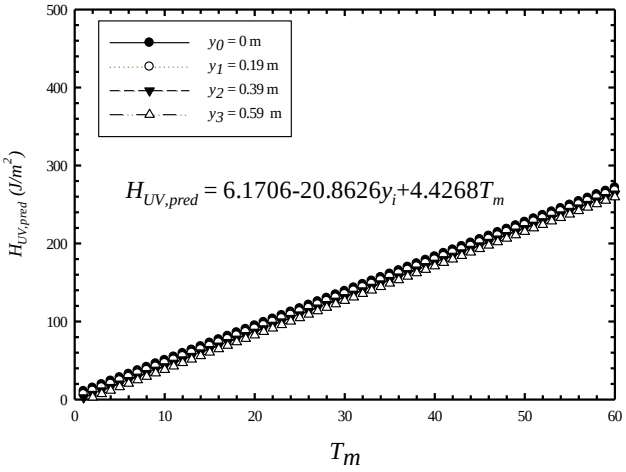

Fig. 10 shows the equation of multiple linear regression (MLR)

5. Conclusion

From this research, the rotated disinfection box for degree certificates with UVC of Rajamangala University of Technology Isan (RMUTI) was experimented with to study the influence of UV dose on the disinfection rate of the SARS-CoV-2 virus in the case of the speeds of the rotating disinfection box, namely 6, 8, and 10 rpm, and four measurement positions: $y_0 = 0$ m, $y_1 = 0.19$ m, $y_2 = 0.39$ m, and $y_3 = 0.59$ m. It can be concluded that the UV dose of the UVC light in this research can kill the SARS-CoV-2 virus in all cases of y_i with $T_m = 50$ s because the result of the $H_{UV,exp}$ of the calculation was more than the radiation intensity dose of the criteria value of killing the SARS-CoV-2 virus, 134 J/m^2 and when considering the killing rate (*KR*), it was found that *KR* reached 100% in 26 s. Therefore, the rotated disinfection box for degree certificates with UVC of this research can be reliably sterilized. The multiple linear regression equation generated from this research is $H_{UV,pred} = 6.1706\text{-}20.8626 y_i + 4.4268 T_m$.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal connections that might have influenced the research presented in this study.

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