A study on UVC irradiance emitted by various types of UVGI products

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Abstract. There are many types of Ultra Violet Germicidal Irradiation (UVGI) products available in the market used in many applications such as sterilization and disinfection. These products are popular during the spread of pandemic COVID-19 and become an option of disinfection method for surface and air such as in office, hospital, hotel room and car. The objective of the study is to investigate the UVC lamps of the UVGI products based on their wavelength. This is to validate whether the product samples are using UVC lamp as stated in the specification which normally has 253.7 to 254 nm wavelength. Besides that, the UVC intensity level has been measured to determine the irradiance emitted by the lamps. The measurement was carried out at various distance to see the effectiveness of the UVGI in disinfection process at different size of spaces. UVC is categorised as non-ionising radiation and has potential health effects due to excessive exposure specially to eye and skin. The equipment used for the irradiance measurement is IL 1700 radiometer with UVC sensor and the measurement data recorded in microwatt/cm\textsuperscript{2}. The irradiance level of the samples was compared with the permissible exposure limit to the members of public by International Commission on Non-Ionizing Radiation Protection (ICNIRP).

1. Introduction
Ultra Violet Radiation (UVR) referred as optical radiation which contain three type of UVR; UVA, UVB and UVC. UVC emits by germicidal lamps for disinfection purpose which is highly in demand during this pandemic of Covid-19 affecting globally. Non-Ionizing Radiation Group (NIR) had conducted test to the various type of UVGI products to determine the effectiveness of the UVGI and study on the related safety aspects by analyzing the irradiance and compared to the ICNIRP recommendation permissible exposure limit for UVR. This study involved of 6 products, with 3 types of UVGI with different lamp power. The relation between the irradiance with distance and the time for a complete disinfection with distance were studied.

The objective of this research was to validate the product samples are using UVC lamp as stated in the specification by investigating the products based on their wavelength and to analyse the intensity of UVC from the sample products used as Ultra-Violet Germicidal Irradiance (UVGI) in irradiance.
2. Methodology
Irradiance of UVC from UVGI products was measured by using Research Radiometer IL1700 attached with UVC Probe SED240. The measurement was conducted by adjusting the distance of UVC probe with the UVGI products by 10cm. Started with 10cm until 180cm and continue at 350cm until 400cm. The measurement process was repeated twice. Relation between the reading of irradiance in µW/cm\(^2\) with distance in cm was recorded in the results. Time to reach 1 J/cm\(^2\) was calculated by using the formula below:

\[ t = \frac{1}{E} \]  \hspace{1cm} (1)

where \( t \) is time in second, \( E \) is the measured irradiance in Wcm\(^{-2}\). The calculated time converted to minutes and the relation between the time in minutes and distance in cm was plotted.

![Figure 1. Set-up of equipment for the measurement of Irradiance from the UVGI products: (A) Wall Mounted UV Lamp 32W, (B) Wall Mounted UV Lamp 16W, (C) UV Mobile Lamp 75W, (D) UV Mobile Lamp 40W, (E) UVGI Lamp 16W, (F) UVGI Lamp 8W.](image)

3. Results and discussion
The plot in Figure 2 shows the relation between the reading of irradiance (µW/cm\(^2\)) with distance (cm) for 6 products of UVGI.
According to recent studies, 1 J/cm\(^2\) is the sufficient dose for disinfection process of Covid-19. The relation between the time (minutes) to reach 1 J/cm\(^2\) with the distance (cm) was plotted in Figure 3.

Figure 2. A plot of irradiance (µW/cm\(^2\)) against distance (cm) for 6 products of UVGI.

Figure 3. A plot of time to reach 1 J/cm\(^2\) (minutes) against distance (cm) for 6 products of UVGI.
The measured irradiance was compared to the exposure limit for workers and public provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for duration of 8 hours. The comparison plot is as indicated in Figure 4.

Figure 4. A plot of irradiance ($\mu$W/cm$^2$) against distance (cm) for 6 products of UVGI and their comparison with ICNIRP exposure limit.

The maximum irradiance for all products was measured at the distance of 10 cm and the minimum irradiance was measured at the distance of 400 cm. The maximum and minimum of irradiance with the time to reach 1 J/cm$^2$ and the comparison with exposure limit for UVC was listed in Table 1.

Table 1. Maximum and minimum of irradiance, time to reach 1 J/cm$^2$ and the comparison with exposure limit for each product.

| Product                  | Maximum Irradiance ($\mu$Wcm$^2$) | Time to reach 1 J/cm$^2$ (minutes) | Minimum Irradiance ($\mu$Wcm$^2$) | Time to reach 1 J/cm$^2$ (minutes) | Comparison of Maximum Irradiance with exposure limit for UVC (exposed for 8 hours) |
|--------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------------------------------------------------------|
| UV Mobile Lamp 40W       | 5780.00                           | 2.88                              | 11.00                             | 1515.15                           | $1.7301 \times 10^3$ times higher                                                |
| UV Mobile Lamp 75W       | 7550.00                           | 2.21                              | 1.00                              | 16666.67                          | $1.3245 \times 10^3$ times higher                                                |
| UVGI Lamp 8W             | 1753.00                           | 9.51                              | 1.00                              | 16666.67                          | $5.7045 \times 10^4$ times higher                                                |
| UVGI Lamp 16W            | 1758.00                           | 9.48                              | 4.00                              | 4166.67                           | $5.6883 \times 10^4$ times higher                                                |
| UV Lamp 16W              | 324.00                            | 1.00                              | 1.00                              | 16666.67                          | $3.0864 \times 10^4$ times higher                                                |
| UV Lamp 32W              | 343.00                            | 1.00                              | 1.00                              | 16666.67                          | $2.9155 \times 10^4$ times higher                                                |
4. Conclusion

Six sample UVGI products are validated for using UVC lamp as stated in the specification which has 253.7 to 254 nm wavelength. Based on the measurement and analysed data, the irradiance of UVC light decrease inversely proportional to the distance from the source. This means that the further the distance from the source, the lower the intensity of the UVC. The time to reach the dose of 1 J/cm² which indicate the time for a complete disinfection process is increases with the distance from the source, which implies that the further the source, the longer it takes to reach the dose of 1 J/cm². The reading of UVC from the products are exceed the permissible exposure limits by ICNIRP if it is exposed for duration of 8 hours at all distances. The hazard warning signs for UVC exposure, restriction of access and the need for personal protection while operating this device must be applied to avoid unnecessary exposure of UVC to personnel.

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