Relevant Key Parameters to Migrate Hg Lamps to LEDs, in the UV Range for Fluence Determination

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Ultraviolet disinfection technologies are based on artificial emission of germicidal ultraviolet light (UV-C), traditionally by discharge gas lamps. Ultraviolet (UV) light has been used in many applications ranging from water disinfection, UV curing in polymers, medical diagnostics (e.g., blood gas analysis) to phototherapy (discovered by Niels Finsen, Nobel Prize in Medicine in 1903). The disinfection process for water, air or surface, is basically a bio-photochemical reaction. The DNA molecule is damaged when the UV-C light is absorbed by the microorganism, so the maximal value of the optical absorption coefficient of the DNA is at 260 nm. The absorption value is referred to a specific wavelength (λ) and is related with the ultraviolet transmittance (UVT) through the Lambert-Beer Law. Prior to the appearance of (deep ultraviolet light emitting diodes) UV-C LEDs, all UV disinfection devices were calibrated and characterized for a λ of 253,7 nm, which is a property of mercury gas spectrum. However, the use of mercury in the industrial processes is quickly decreasing in our days. New methodologies have been proposed by different researchers to determine the germicidal UV dose (*Fluence*) with LED technology, considering a series of four key parameters, all strongly depending on the wavelength: UVT, Photodiode responsivity, kinetic inactivation constant of microorganisms (*k*) and wall plug efficiency (WPE).

Previous research has considered these physical parameters, nevertheless not referring to the same wavelength [1]–[6], e.g. for water disinfection devices, the fluence is determined using transmittance measurements referred to 253.7 nm (Hg lamps) but the device is using UV LED at 285 nm, additionally the intensity monitoring is performed applying photodiodes commonly calibrated at 253,7 nm, as opposed to working with 285 nm. On the other hand, all kinetic inactivation constants of microorganisms have been tabulated at 253.7 nm. The main issue is the question: are we searching for energy consumption efficiency in the process or effective microbiological inactivation? The next table has been made considering the Rattanakul ´s results [7].

Table 1

	Wavelenght nm	*WPE* %	*k* cm^2/mJ	E_3 kWh/m^2
Hg Lamp	253,7	33	8,11	0,009
LED	265	0,6	8,05	0,41
LED	280	1,9	5,61	0,17

Is more convenient to work at 280 nm as shown by Hull [3] since according to a table quoted value the *WPE* is three times larger than 265 nm, the kinetic inactivation constant *k* is only 30% lower than the one at 265 nm which yields an energy consumption one half lower compared to the use of an LED at 265 nm. Addition it has been shown that the LED at 285 nm has better lifetime.

The next equation shows all parameters to take account when the *Fluence* is determine.

$$Fluence = I\left[TUV(\lambda), WPE(\lambda)\right] \times (Vol / Q) = k(\lambda)^{-1} \log\left(N / N_0\right) \quad (1)$$

The fluence is defined commonly as a product between intensity (*I*) with mW/cm^2 units, and exposure time (seconds). In water treatment, the time exposure can be expressed by active volume *Vol* divided for flow rate *Q* (cm^3/s). In kinetic inactivation equations [7], the *Fluence* appear related with *k* and with N_0 and *N*, that represents the number of initial microorganism concentration and final concentration respectively.

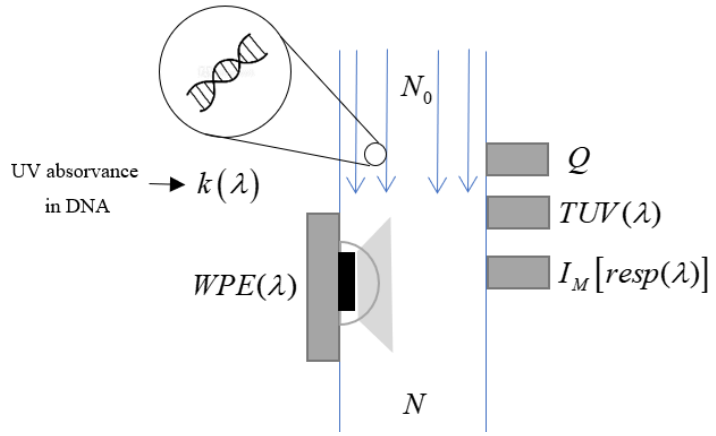

Figure 1. Key parameters for fluence determination in water disinfection process. *WPE* is a UV LED property, I_M represent the instant intensity measured, in the same way *TUV* and *Q* are measured values. The values for N_0, *N* and *k* are a found after bioassays analysis.

Conclusions

All parameters must be referred to the same wavelength λ to determine a Fluence value closer to real expected one.

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