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COMPARISON OF UVA RADIATION AND ILLUMINANCE EMITTED FROM HYDROGEN (H_2) AND WATER VAPOR (H_2O) DISCHARGE LAMPS

Manal A. Haridy

Photometry and Radiometry Division
National Institute of Standards (NIS)
Tersa Street, Alharam, Giza 12211, Egypt
manal_haridi@yahoo.com

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Abstract. *Hydrogen and Water vapor discharge lamps emit light and a portion of ultraviolet radiation (UV) which can affect human health. The present research aimed to measure ultraviolet radiation and illuminance levels. The parameters such as ultraviolet irradiance quantity, the ratio of UVA irradiance to electrical power (η) and the safe parameter of UVA power to luminous flux (K) are calculated and compared for the two types of lamps to dedicate their performance. The measurement system is based on UVA/B silicon detector for measuring the irradiance in UVA region and Luxmeter for measuring illuminance. The data were analyzed, performed and calculated to determine the uncertainty model which has all parameters affects the measurements and the final results. The results show the Hydrogen discharge lamps are safer than the Water vapor discharge lamps. The study demonstrates that using Hydrogen discharge lamps in physics laboratories are safer than using water vapor discharge lamps.*
Keywords: UVA radiation, Illumination levels, Hydrogen discharge lamps, Water vapor discharge lamps, Uncertainty analysis

1. **Introduction.** To use energy safer discharge lamps makes it necessary to analyze the effect of radiation especially ultraviolet radiation on human health. The study demonstrates that the use of these types of lamps might be detrimental to human health if they are used at a shorter distance like in table lamps [1-4]. All gas discharge lamps give out their forms of radiation in ultraviolet. Ultraviolet radiation (UV) is non-ionizing part of electromagnetic spectrum. It produced either by heating a body to incandescent temperature or by passing an electric current through a gas which produces ultraviolet radiation (UV). Ultraviolet radiation (UV) is divided into three regions of wavelengths: UVA from 315 nm to 400 nm, UVB from 280 nm to 315 nm, and UVC from 100 nm to 280 nm [2,5,6]. Ultraviolet radiation (UV) is the most potentially damaging form of energy and the damage it causes is cumulative. So when lighting an area where important or valuable works are housed, it is essential to minimize the potential for damage. We must also provide a safe and comfortable working and viewing environment for people [7].

In physics laboratories, we use these lamps for different purposes involving light generation such as spectrometry, spectroscopy, and laser pumping. Hydrogen (H_2) and Water vapor discharge (H_2O) consist of a tube with two metallic electrodes (anode and cathode) at the ends and a gas filled the tube as shown in Figure 1. The voltage is applied across the two metallic electrodes in a vacuum tube and the gas will break down into electrons and positive ions. This process leads to exciting and ionizing the gas which creates themselves new ions and increases the ionization process. This results in the generation of light either usually visible or ultraviolet (UV) [1,8]. Light is essentially in all activities in our

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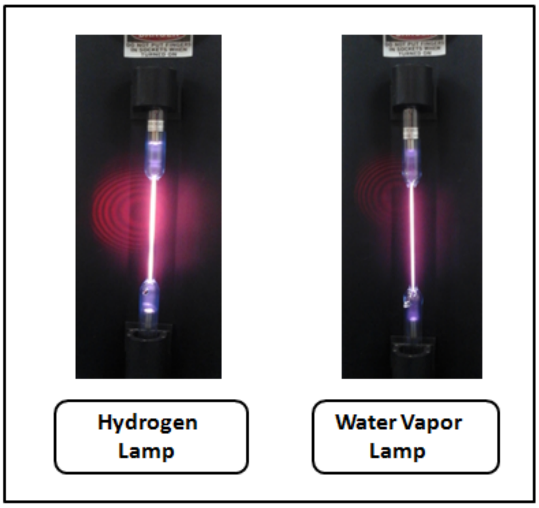

FIGURE 1. Hydrogen and Water vapor discharge lamps

life. Some characteristics of light sources and ultraviolet radiation have significant roles on visual and non-visual health effects of lighting [9]. In relation to the illuminance and ultraviolet radiation from compact fluorescent lamps and general lighting service (GLS) a study by Khazova and O'Hagan carried out that the results show in equal illuminance 500 lux for both lamps UVA for CFL and GLS was 0.05 W/m^2 and 0.03 W/m^2, for U-VB in CFL and GLS was 0.004 W/m^2 and 0.001 W/m^2, respectively [2,10]. In typical practical conditions, the illuminance under CFLs is 500 lux and 10,000 lux outdoors in natural daylight. In this condition UVA for CFL and natural daylight was 0.05 W/m^2 and 5.4 W/m^2, for UVB in CFL and natural daylight was 0.004 W/m^2 and 0.08 W/m^2, respectively. Here the illuminance increases and the amount of UV radiations also increases [2,10]. The present study aimed to evaluate the relationships between UV emissions radiated and illuminance from compact fluorescent lamps.

According to occupational exposure limited (OEL), occupational UVB and UVA exposure should be limited to an effective irradiance of 3 μW/m^2 and 1.04166 W/m^2 in an 8 hr period, respectively [11,12].

2. **Theoretical Principles.** The relation between intensity of tested lamp and the illuminance quantity is described by:

$$E = \frac{I \cos\theta}{d^2} \tag{1}$$

where E is the quantity of illuminance. I is the intensity of the tested lamps. d is the distance from the tested lamp to the surface of the detector. θ is the angle between normal of the receiving surface and the direction of emission [13].

The spectral irradiance in the part of ultraviolet radiation in class A (UVA) is defined as the electromagnetic radiation power divided by area in (W/m^2/nm) hence,

$$I_\lambda(\lambda) = \int_{\lambda_1}^{\lambda_2} I_i(\lambda) d\lambda \tag{2}$$

where $I_\lambda(\lambda)$ is the spectral irradiance in (W/m^2/nm) and $I_i(\lambda)$ is the intensity.

It is obvious that the spectral power distribution of any light source describes the power divided by area per unit of wavelength of illumination. In other words, the concentration is a function of wavelength to any radiometric and photometric quantities.

To determine and calculate the ultraviolet radiation in class A (UVA) it will be helpful to use the following equation [1]:

$$\eta = \frac{\int_{\lambda_1}^{\lambda_2} E_{irr}(\lambda)d\lambda}{P} \tag{3}$$

where $E_{irr}(\lambda)$ is the ultraviolet irradiance and P is the electrical lamp power.

To make a better comparative study between two different artificial light sources, it is necessary to determine the safe parameter (K).

$$K = \frac{\int_{\lambda_1}^{\lambda_2} E_{irr}(\lambda)d\lambda}{k_m \int_{380nm}^{780nm} E_{irr}(\lambda)d\lambda V(\lambda)d\lambda} \tag{4}$$

where,

$E_{irr}(\lambda)$: is the spectral distribution of the radiant flux (W/nm).

$V(\lambda)$: is the spectral human eye response (CIE response curve).

k_m: is photometric radiation constant and equal (683 lm/W).

From Equation (1) K is also defined as:

$$K = \frac{\int_{\lambda_1}^{\lambda_2} I_\lambda(\lambda)d\lambda}{k_m \int_{380nm}^{780nm} I_\lambda(\lambda)d\lambda V(\lambda)d\lambda} \tag{5}$$

This parameter can help to determine which type of these artificial light sources emits less ultraviolet radiation to the lumen and the value of this parameter depends on the distance between the lamp and the area exposure [1].

3. **Method.** In the present work, a comparative ultraviolet irradiance and illuminance study made it to two different gas discharge lamps, Hydrogen and Water vapor discharge lamps. The comparative study was to dedicate their performance and also to analyze and calculate the uncertainty budgets for the measurements [1-4,14]. All lamps were measured in the vertical position [11]. Different parameters were determined for the types of lamps such as ultraviolet irradiance (UVA), ratio of UVA irradiance to electrical power (η) and ratio of UVA power to luminous flux (K) at different distances. Measurements were performed in a conditioned black box around the set up of the measurements according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommendations [15] and the temperature was maintained at (25 ± 2)°C. The photometric bench consisting of Sper Scientific UVA/B Light Meter (Model 850009C) is calibrated at National Institute of Standard and Technology (NIST), the USA as shown in Figure 2. The UVA detector was mounted on a translation stage and positioned at the same height as the light source (Hydrogen and Water vapor discharge lamps) on the optical bench. Before taking measurements, each lamp was warmed up to 15 minutes. Measurements were repeated for each lamp and were finally averaged out and the uncertainty in irradiance measurements is calculated.

The illuminance of each lamp is measured using a Luxmeter TM-201Lux. The Luxmeter was mounted on a translation stage and positioned at the same height as the artificial Helium and Mercury vapor discharge lamps on the optical bench. Measurements were repeated for each lamp and were finally averaged out and the uncertainty in irradiance measurements.

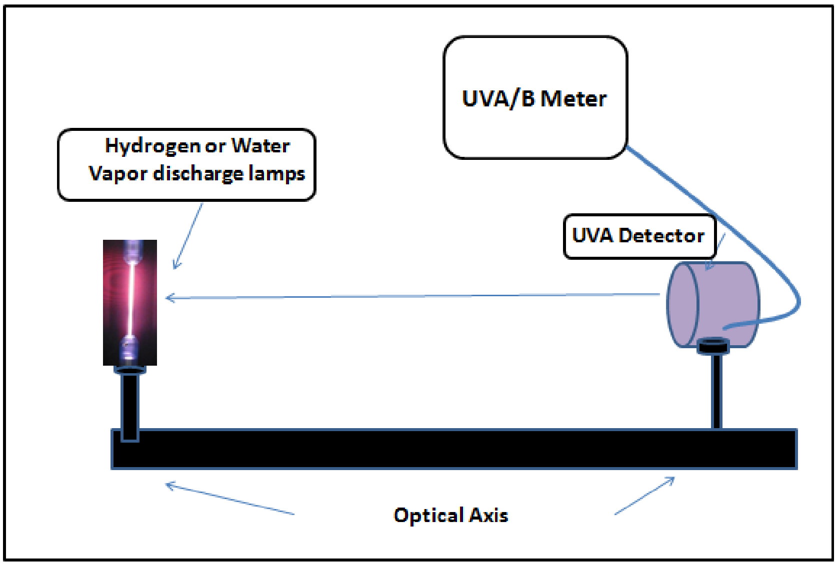

FIGURE 2. A setup diagram for measuring UVA irradiance

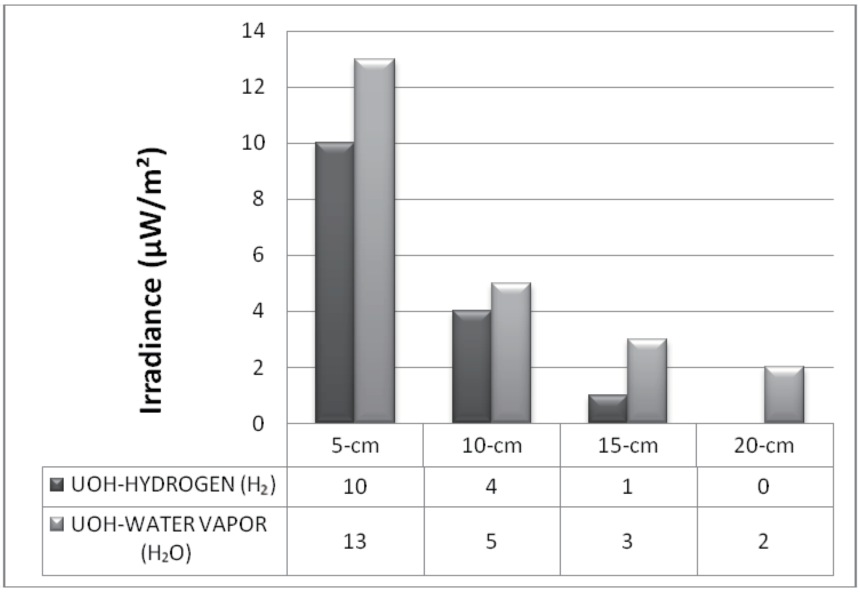

FIGURE 3. Comparison measurements of UVA absolute irradiance levels between Hydrogen and Water vapor discharge lamps at different distances

4. **Results and Discussions.** UVA irradiance and illuminance were measured for Hydrogen and Water vapor discharge lamps at different distances. The discharge lamps were measured for the UV content at 5 cm distance. It is the closest distance for students and instructors exposed to the lamp in spectrometer experiment. The description of these lamps is as the following: UOH-Hydrogen lamp and UOH-Water vapor lamp. These lamps are designed to emit their power in the visible region. In fact, they emit most of their energy in the visible region but part of their energy is emitted in the UV region. Negligible amounts of UVA were detected at 20 cm from Hydrogen lamp. Also, negligible amounts of UVA and UVB were detected at 30 cm from Mercury vapor discharge lamp. Therefore, only data related to the UVA irradiance measured at 5 up to 20 cm were analyzed in this study.

Figure 3 shows the comparison of UVA irradiance level between Hydrogen and Water vapor discharge lamps at a distance of 5 up to 20 cm. Each lamp was measured at distances of 5 up to 20 cm from its central vertical axis respectively using Sper Scientific

UVA/B Light Meter (Model 850009C) calibrated at National Institute of Standard and Technology (NIST), USA. The UVA irradiance for two types of lamps at different distances varies from 1 μW/m^2 to 13 μW/m^2. The results showed that the Water vapor discharge lamp has higher values of the UVA irradiance than Hydrogen discharge lamp.

Figure 4 shows the comparison of the illuminance level between Hydrogen and Water vapor discharge lamps at different distances. Each lamp was measured at distances of 5 up to 20 cm from its central vertical axis using a Luxmeter TM-201Lux. The illuminance level at distances of 5 up to 20 cm for all lamps varies from 5 lux to 20 lux. The results showed that Hydrogen discharge lamps have higher values of the illuminance level than the Water vapor discharge lamps.

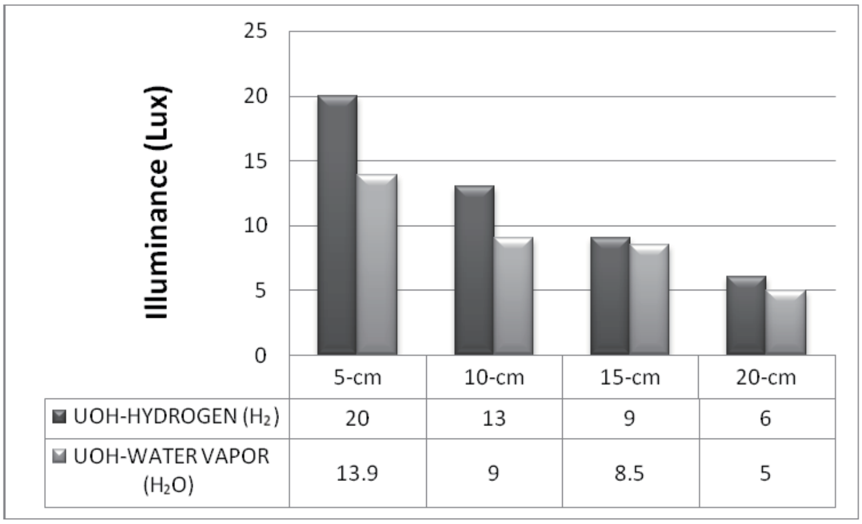

FIGURE 4. Comparison measurements of illuminance levels (Lux) between Hydrogen and Water vapor discharge lamps at different distances

It would be more appropriate to analyze UVA irradiance per electrical wattages (η). Figure 5 shows the histogram for comparison of UVA absolute irradiance levels per electrical power of (η) between Hydrogen and Water vapor discharge lamps at different distances from 5 cm up to 25 cm which varies from 0.00909 m^{-2} to 0.059 m^{-2}.

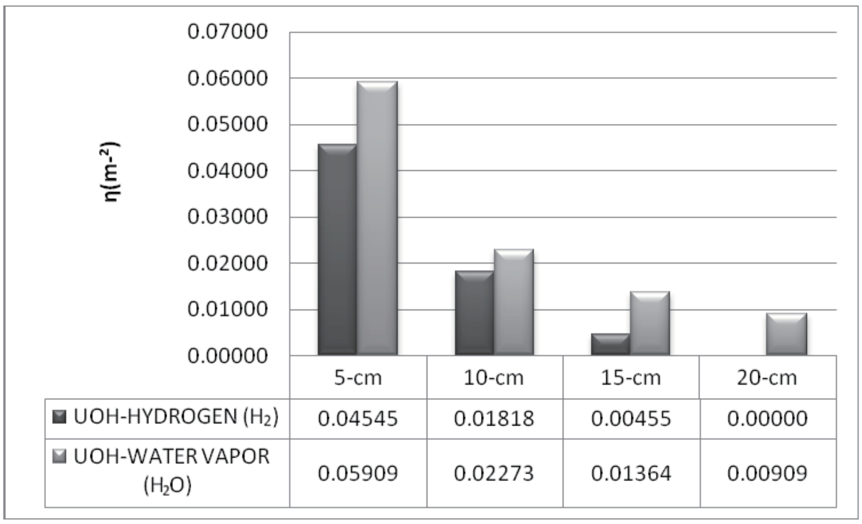

FIGURE 5. Comparison measurements of UVA absolute irradiance levels per to electrical power (η) between Hydrogen and Water vapor discharge lamps at different distances

To make a better comparison in UVA concentration to illuminance ratio (K), is of more interest in analyzing the lamps radiation characteristics as shown in Figure 6. It shows the histogram for comparison of UVA concentration to illuminance ratio (K) Hydrogen and Water vapor discharge lamps at different distances from 5 cm up to 20 cm for all types of studied lamps which varies from 0.111 μW/lm to 0.935 μW/lm.

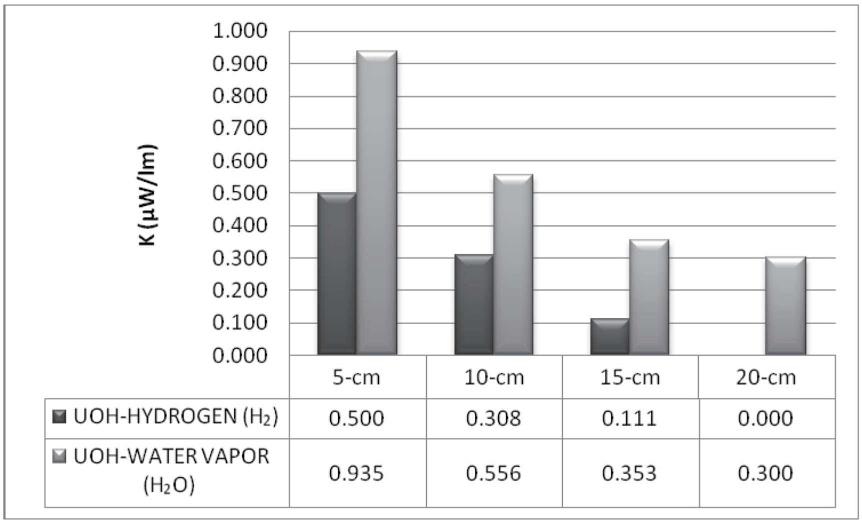

FIGURE 6. UVA absolute irradiance levels per illuminance values (K) Hydrogen and Water vapor discharge lamps at different distances

5. **Uncertainty Analysis.** When reporting the result of measurement of any quantity, it must be a quantitative indication of the quality of the result being given so that those who use it can assess its reliability. With such an indication, measurement results can be compared. The ideal method for evaluating and expressing the uncertainty of the result of a measurement should be universal which means that the method should be applicable to all types of measurements and all kinds of input data used in measurements. The combined uncertainty should be characterized by the numerical value obtained by applying the usual method for the combination of variances [16-18].

TABLE 1. Estimated uncertainty budget of UVA irradiance for lamps

Uncertainty Component	**Relative Standard Uncertainty (%)**
Irradiance responsivity calibration of standard radiometer	5.2
Distance measurements	0.016
Repeatability	0.023
Relative Expanded Uncertainty ($k = 2$)	**10.4**

TABLE 2. Estimated uncertainty budget of illuminance for lamps

Uncertainty Component	**Relative Standard Uncertainty (%)**
Irradiance responsivity calibration of standard radiometer	6
Distance measurements	0.016
Repeatability	0.024
Relative Expanded Uncertainty ($k = 2$)	**12**

6. **Conclusions.** UVA emission and illuminance were measured from Hydrogen and Water vapor discharge lamps. UVA emission was studied to assess their unwanted output in the UVA region. Various parameters such as ultraviolet irradiance (UVA), ratio of UVA irradiance to electrical power (η) and ratio of UVA power to luminous flux (K), for the two types of lamps are studied to dedicate their performance. The higher values were measured in Water vapor discharge lamps than Hydrogen discharge lamps. The Hydrogen discharge lamps appeared to be safer. Also, the smaller value of (η) is safe for a human being and then Hydrogen discharge lamps appeared to be safer at 20 cm distance. Data analysis was performed. Uncertainty model including all parameters accompanied by the measurements is studied. The accompanying uncertainties in the absolute UVA irradiance measurements (10.4%) and in the illuminance measurements (12%) are calculated respectively in Table 1 and Table 2 with confidence level 95% ($k = 2$). We recommended using Hydrogen discharge lamps in physics laboratories because they are safer.

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