

Ultraviolet Radiation from Some Types of Outdoor Lighting Lamps

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ABSTRACT:

Illumination using artificial light sources is common in these days. Many manufactures are paying for the design of lamps depending on high efficacy and low UV hazards. This research is focusing on the most useable lamps in the Egyptian markets; High Pressure Mercury (HPM), Metal Halide (MH), and High Pressure Sodium (HPS). A set up for relative spectral power distribution based on single monochromator and UVA silicon detector for absolute irradiance measurements are used. The absolute irradiance in (W/m²) in UVA region of the lamps and their accompanied standard uncertainty are evaluated.

INTRODUCTION

Pressure Sodium (HPS) and Metal Halide (MH) lamps mainly designed for outdoor lighting where we need high efficacy and high luminous flux.^{1,2}

High pressure mercury lamps (see Fig. 1) have a short quartz glass discharge tube that contains a mixture of argon and mercury. The discharge produces ultraviolet radiation specially the near ultraviolet. As a light source, they are relatively compact, which allows their light to be controlled via optical equipment.^{1,3}



Figure 1: High Pressure Mercury Lamp



Figure 2: High Pressure Sodium Lamp



Figure 3: Metal Halide Lamp

The High Intensity Discharge (HID) lamps such as High Pressure Mercury (HPM), High

On the other hand, high pressure sodium lamps (see Fig. 2) were developed and introduced as energy efficient sources in road lighting, industrial lighting, and security application. Nowadays, HPS lamps are also appropriate for many interior applications, particularly where color rendering is not essential concern due to their high efficiency and long life. In the lamp design, the exterior bulb protects the arc tube from changes and drafts in temperature, prevents oxidation of the internal parts. This makes HPS lamps especially easy to use in many fixture types.^{1,3}

Metal halide lamps (see Fig. 3) are a further development of mercury lamps. Apart from mercury, they also contain a mixture of metal halides to improve luminous efficacy and to enhance color rendering. They have excellent luminous efficacy and good color rendering qualities; their nominal lamp life is high. They are extremely compact light sources, whose light can be easily controlled.^{1,3,4}

This research present the study of three types of HID lamps from OSRAM in terms of their irradiance and spectral power distribution for ultraviolet radiation present in their emitted radiation. Lamps HPM 125 Watt, HPS 150 Watt and MH 150 Watt are used as they are safe use in the outdoor lighting. ⁵

In general, UV light has three wavelength regions UVA (315 nm - 400 nm), UVB (280 nm - 315 nm) and UVC (200 nm - 280 nm). Glass stop the UVB and UVC, while transpire portion of UVA ^{1, 6} so we will concern only with the UVA portion. Different parameters are measured such as UVA absolute irradiance and relative spectral power distribution. Spectral irradiance in UVA region is defined as the power of electromagnetic radiation per unit area in (W/m²/nm) hence,

$$E_{\lambda}(\lambda) = \int_{\lambda_1}^{\lambda_2} E(\lambda) d\lambda \quad (1)$$

where, $E_{\lambda}(\lambda)$ is spectral irradiance in (W/m²/nm). On the other hand, Spectral Power Distribution (SPD) measurement describes the power per unit area per unit wavelength of an illumination (radiant exitance). More specifically, the concentration is a function of wavelength to any radiometric quantity or photometric quantity. ^{2, 7}

MATERIALS AND METHODS

The setup and monochromator function illustrated at (Fig. 4) is to measure the radiation from the three spectral lamps produces narrow and intense lines. This radiation is introduced into an integrating sphere to build a uniform, monochromatic, and nearly Lambertian source of high spectral radiant flux. The integrating sphere of the entrance optics is needed in order to uniformly irradiate the entrance slit of the monochromator as a function of the irradiance of the source independent from source geometry.

In the used spectral range, two 1200 lines/mm gratings (blaze wavelengths 250 nm and 750 nm) were used to analyze the input spectrum of the lamps to their spectral power distribution while the data was collected through the exit slit. At the exit slit of the monochromator, a silicon (Si) detector is used to detect the output signal. The lamps was aged according to IES publication⁸ then each lamp aligned at 50 cm in front of the integrating sphere entrance slit of a system based on MS257 single monochromator from Newport Corporation. The system was adjusted to acquire readings at the range from 200 nm to 800 nm with step 2 nm, also this monochromator band pass was adjusted nominally at 4 nm resulting slit function uncertainty $\pm 0.34\%$ at $k = 2$. ⁹

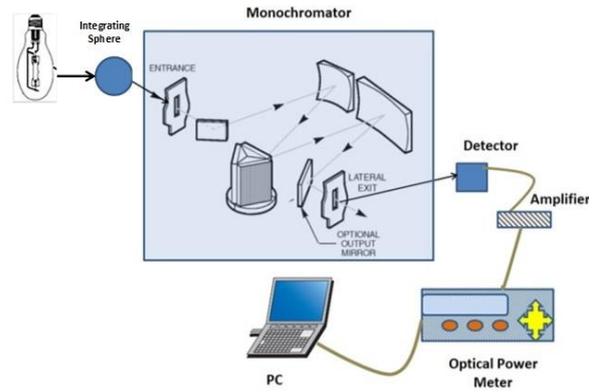


Figure 4: Schematic Diagram of NIS Facility for Measuring Spectral Power Distribution.

According to CIE ⁵, UVA irradiance can be calculated spectrally and the total radiant exposure to the eye shall not exceed 10000 J/m² for exposure times less than 1000 sec.

The equation of the total radiant exposure is:

$$E_{UVA} t = \sum_{315}^{400} \sum_t E_{\lambda}(\lambda, t) \cdot \Delta t \cdot \Delta \lambda \leq 10000 \quad (2)$$

hence, $E_{UVA} \leq 10$ W/m², where $E_{\lambda}(\lambda, t)$ is the spectral irradiance in W/m²/nm; $\Delta \lambda$ is the bandwidth in nm; and t is the exposure duration in seconds.

Irradiance levels hazard for E_{UVA} in W/m² according to CIE ⁵ are classified into Exempt = 10, Low risk = 33, and Mod risk = 100.

The absolute spectral irradiance level of each lamp in the UVA range at 50 cm is measured using a calibrated radiometer model 268 UVA from UDT Company (see Fig. 5).

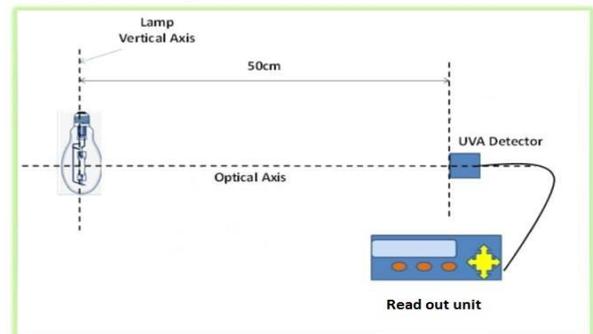


Figure 5: Schematic Diagram of NIS Facility for Measuring UVA Irradiance Using Calibrated Radiometer.

RESULTS:

The acquired relative spectral power distribution was normalized for each lamp so we can compare the lamps (see Fig. 6). Results show that HPM emits the largest amount of UVA compared with MH and HPS lamps. While HPS emits the lowest amount with moderate amount was from MH lamp. The amount of UVA irradiance is measured absolutely at distance 50 cm and the quantities illustrated in (Fig. 7).

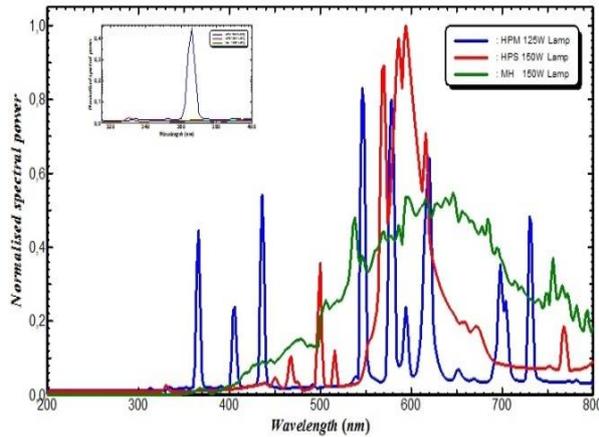


Figure 6: Normalized Spectral Power Distribution

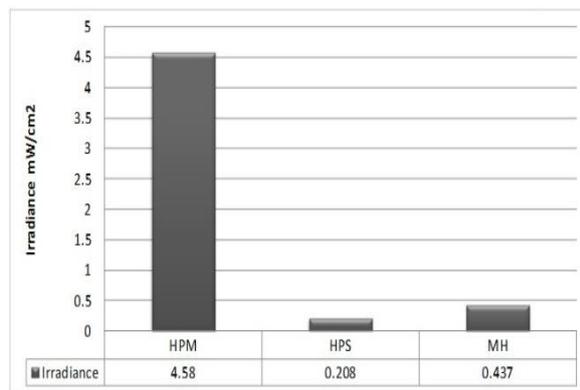


Figure 7: UVA Absolute Irradiance Levels Using UVA Radiometer at 50 Cm.

Also, according to (Eq. 2), it is highly recommended to use these lamps only in outdoor, as they may be lie in the range of the CIE hazard condition if used indoor. By using inverse square law, Table 1 shows the calculated value of the minimum distance for the three lamps to be used in the safe limit.

Table 1: Calculated Safe Limit Distance for the Three Lamps

Lamp	Safe limit
HPM	>107 cm
HPS	>33 cm
MH	>23 cm

Uncertainty Analysis

The associated uncertainty must be quoted whenever the results of a measurement are reported. This tells the user of the precision with which the measurement was made. Uncertainty analysis is thus a fundamental part of metrology.

Evaluation of the uncertainty is done by the Guide to the expression of Uncertainty in Measurement (GUM) method. This method is adopted and

described in details by International Organization for Standardization (ISO) (ISO, 1993).¹⁰

The standard uncertainty $u(x_i)$ to be associated with input quantity x_i is the estimated standard deviation of the mean.^{10, 11}

$$u(x_i) = s(\bar{X}_i) = \left(\frac{1}{n(n-1)} \sum_{k=1}^n (X_{i,k} - \bar{X}_i)^2 \right)^{1/2} \quad (3)$$

The combined standard uncertainty $u_c(y)$ is obtained by combining the individual standard uncertainties u_i , these can be evaluated as Type A and Type B.

That is,

$$u_c^2(y) = \sum_{i=1}^N \left(\frac{\partial f}{\partial x_i} \right)^2 u^2(x_i). \quad (4)$$

The uncertainty budget of the absolute irradiance measurements is shown at Table 2 with confidence level 95 % ($k = 2$).

Table 2: UVA Irradiance Uncertainty Budget:

Uncertainty component	Relative standard Uncertainty %
Irradiance responsivity Calibration of UDT radiometer	1.24
Current regulation of lamp	0.32
Distance measurements	0.01
Repeatability	0.01
Expanded uncertainty ($k = 2$)	2.56

DISCUSSION

The absolute spectral irradiance measurements of UVA region as well as the relative spectral power distribution of three outdoor lighting lamps from OSRAM are carried out. The measurements were performed under control of environmental conditions and good regulation of electrical power. Results show that HPM emits the largest amount of UVA compared with MH and HPS lamps. While HPS emit the lowest amount with moderate amount was from MH lamp. The accompanied uncertainty in the absolute irradiance measurements is ± 2.56 %. It is highly recommended to use these lamps only in outdoor, as they may be lie in the range of the CIE hazard condition if used indoor. For indoor using the minimum safe limit distance according to table 1 must be taken into consideration.

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