American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-4, pp-328-337
www.ajer.org
Research Paper Open Access

Visible and Ultra-Violet Radiations Emitted from Helium (He) and Mercury Vapor (Hg) Discharge Lamps Used in Spectrometer

Manal A. Haridy [1,2,*]

1 Photometry and Radiometry Division, National Institute of Standards (NIS), Giza, Egypt.
2 Physics Department, College of Science, University of Hail (UOH), Hail, Kingdom of Saudi Arabia (KSA).

ABSTRACT: *Helium and Mercury vapor discharge lamps emit light and a portion of ultraviolet radiation (UV) which can affect on human health. The present research aimed to measure Illuminance and Ultraviolet Radiation Helium (He) and Mercury vapor discharge lamps. Also, determining some important lighting parameters such as the safe parameter of UVA power to illuminance values (K) of Helium (He) and Mercury vapor discharge lamps which evaluate the relationships between UVA radiation and illumination levels. The parameters such as ultra violet irradiance quantity, 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. A set up based on UVA/B silicon detector for irradiance measurements in UVA region. Another set up based on Luxmeter is used for measuring illuminance. The Data were analyzed, performed and calculated to determine the uncertainty model which have all parameters affect on the measurements and the final results. This study demonstrates that using Helium discharge lamps in physics laboratories are safer than using Mercury vapor discharge lamps. According to this study, I recommended using Helium discharge lamps when it used for physics laboratories when using spectrometer.*

KEYWORDS: *UVA Radiation, Irradiance, Illumination Levels, Human Health, Helium discharge lamps, Mercury vapor discharge lamps, Uncertainty Analysis.*

Date of Submission: 04-04-2019 Date of acceptance: 23-04-2019

I. INTRODUCTION

Nowadays, there are a lot of uses of gas discharge lamps. In physics laboratories, we use these lamps in different purposes involving light generation such as spectrometry, spectroscopy, and laser pumping. As a results of unusual appearance of light produced from these kind of lamps such as quacks and con artists, the gas discharge lamps used in essence all area of recent lighting technology [1]. To use 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 [2-6]. 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). Helium and Mercury vapor discharge lamps consists of tube with two metallic electrodes (anode and cathode) at the ends and a gas filled the tube (Helium gas for Helium lamps and Mercury vapor gas for Mercury lamps) as seen in Figure 1. When a voltage is applied across the two metallic electrodes in a vacuum tube in some cases less than the pressure of the atmosphere, the gas will break down into electrons and positive ions. These electrons accelerated by the potential difference entering the tube and collide the gas atoms or molecules depends on the gas in the tube pure gas or mixture gas. This process leads to exciting and ionizing the gas which create themselves new ions and increases the ionization process. At this stage, the self sustaining plasma produced. This results in the generation of light either usually visible or ultraviolet (uv) [7].

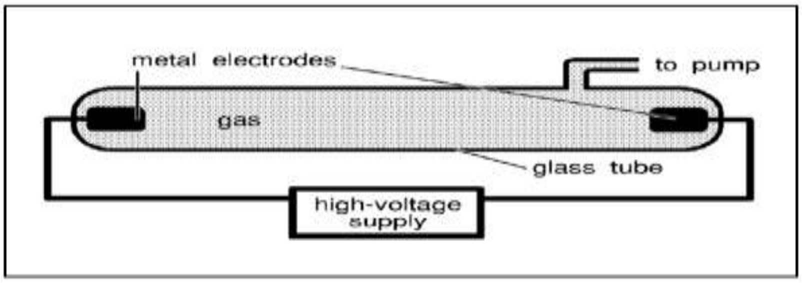

Figure 1 . Construction of Gas Discharge Lamps.

Gas discharge lamps emits their own wavelengths and their own spectrum depending on the atomic structure of the gas filled in the tube as seen in Figure 2. The spectrum of the gas discharge lamp determines the color of the light emit from this lamp. The International Commission on Illumination (CIE) introduced the color rendering index (CRI) to evaluate the ability of a light source to reproduce the colors of various objects being lit by the source [8].

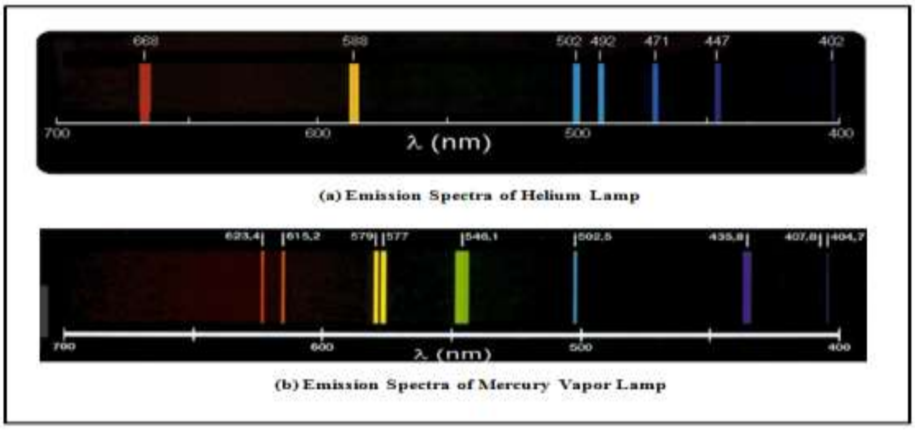

Figure 2 . Emission Spectra of Helium and Mercury Vapor discharge lamps [9].

Some gas-discharge lamps have a relatively low CRI, which means colors they illuminate appear strongly different from how they do under sunlight or other high-CRI illumination [8]. In physics laboratories, we use these lamps for different purposes involving light generation such as spectrometry, spectroscopy, and laser pumping. Helium and Mercury vapor discharge consist of a tube with two metallic electrodes (anode and cathode) at the ends and a gas filled the tube as shown in Figure 3. 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) [3,10]. Light is essentially in all activities in our life. Some characteristics of light sources and ultraviolet radiation have significant roles on visual and non- visual health effects of lighting [11]. 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 $0.03w/m^2$, for UVB in CFL and GLS was $0.004w/m^2$ and $0.001w/m^2$, respectively [4, 12]. 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 $5.4w/m^2$, for UVB in CFL and natural daylight was $0.004w/m^2$ and $0.08w/m^2$, respectively. Here the illuminance increases and the amount of UV radiations also increases [4, 12]. The present study aimed to evaluate the relationships between UV emissions radiated and illuminance from compact fluorescent lamps.

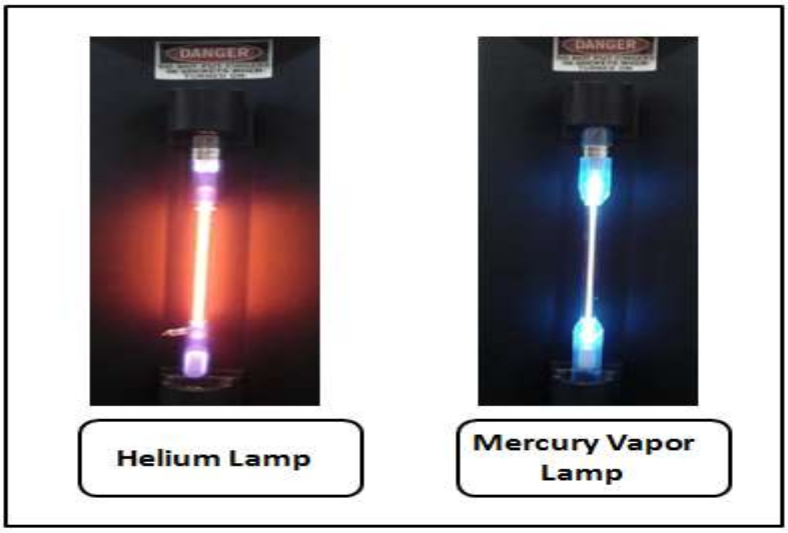

Figure 3 . Helium and Mercury Vapor discharge lamps.

Light is essentially in all activities in our life. Some characteristics of light sources and ultraviolet radiation have significant roles on visual and non- visual health effects of lighting [11]. All gas discharge lamps give out their forms of radiation in ultraviolet. 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 [13]. Ultra violet 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 Ultra violet radiation (UV). Ultra violet radiation (UV) has three regions of wavelengths as shown in Figure 4. Which divided to: UVA from 315 nm to 400 nm, UVB from 280 nm to 315 nm, and UVC from 100 nm to 280 nm [3, 14]. The UVC has the greatest health effects of UV radiation. According to occupational exposure limited (OEL), occupational UVB and UVA exposure should be limited to an effective irradiance of $3\mu W/m^2$ and $1.04166\ W/m^2$ in an 8 hrs. period, respectively [15].

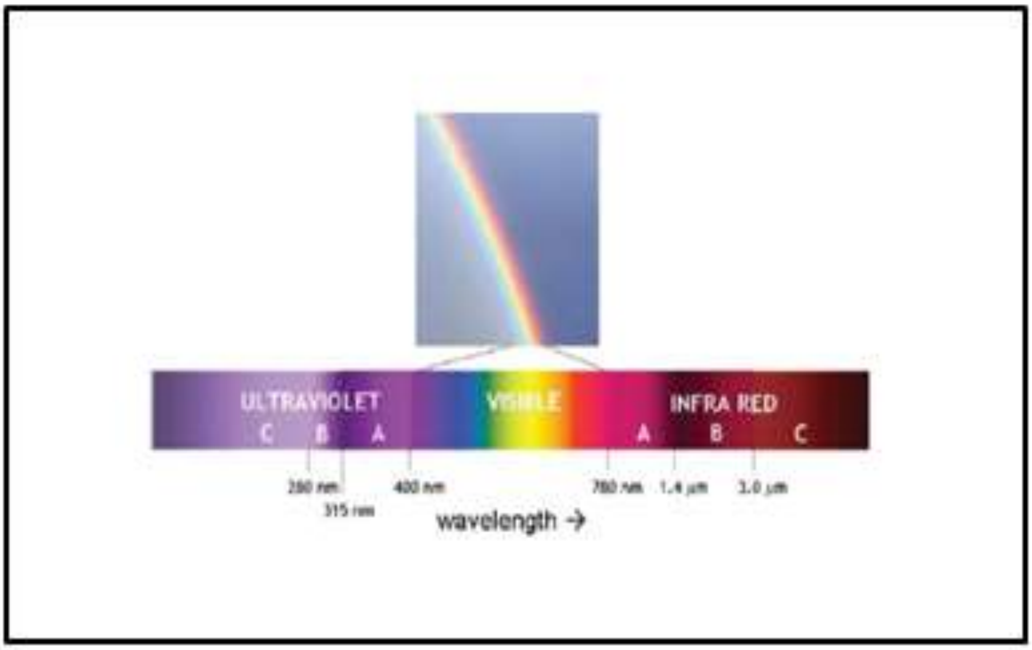

Figure 4. Types of UV radiation [16]

II. THEORETICAL PRINCIPLES:

The following equation describe the relation between intensity of tested lamp and the illuminance quantity:

$$E = \frac{I \cos\theta}{d^2} \qquad (1)$$

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 the normal of the receiving surface and the direction of emission [17].

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,

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

where,
$I_\lambda(\lambda)$: is the spectral irradiance in ($W/m^2/nm$).
$I_i(\lambda)$: 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 [18].
To determine and calculate the ultraviolet radiation in class A (UVA) it will be helpful to use the following equation [3]:

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

Where,
$E_{irr}(\lambda)$: is the ultraviolet irradiance.
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).

$$K = \frac{\int_{\lambda_1}^{\lambda_2} E_{irr}(\lambda)\,d\lambda}{k_m \int_{400nm}^{800nm} E_{irr}(\lambda)\,d\lambda V(\lambda)\,d\lambda} \qquad (4)$$

$E_{irr}(\lambda)$: 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:

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

This parameter can help to determine which type of these artificial light source emit less ultraviolet radiation to the lumen. The following equation can calculate the safe parameter. It is depending on the distance between the lamp and the area exposure [3].

III. METHOD:

In the present work, a comparative ultraviolet irradiance and illuminance study made it to two different gas discharge lamps, Helium and Mercury vapor discharge lamps. The comparative study was to dedicate their performance and also to analyze and calculate the uncertainty budgets for the measurements [2-6]. All lamps were measured in the vertical position [17]. Different parameters determined for the types of lamps such as ultra violet 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 [19] and the temperature was maintained at $(25 \pm 2)^{o}C$. The photometric bench consists of Sper Scientific UVA/B Light Meter (Model 850009C) is calibrated at National Institute of Standard and Technology (NIST), USA as shown in Figure 5. The UVA detector was mounted on a translation stage and positioned at the same height as the light source (Helium and Mercury vapor discharge lamps) on the optical bench as shown in Figure 5. 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.

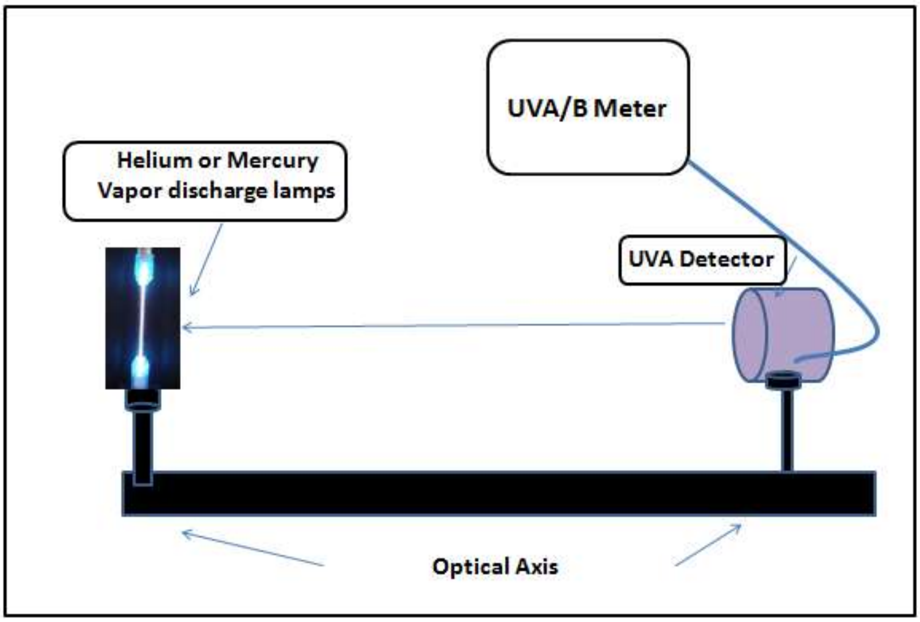

Figure. 5. A Set up diagram for measuring UVA irradiance.

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 as shown in Figure 6. Measurements were repeated for each lamp and were finally averaged out and the uncertainty in irradiance measurements.

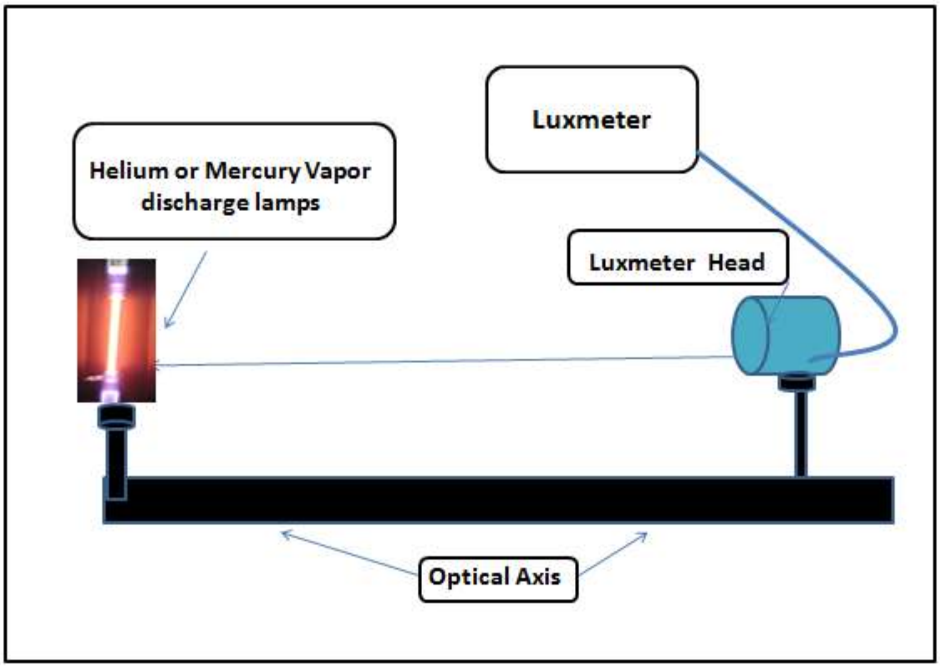

Figure. 6. A Set up diagram for measuring illuminance.

IV. RESULTS AND DISCUSSIONS

UVA irradiance and illuminance were measured at the different distance for Helium and Mercury vapor discharge lamps. At the distance of 5 cm that was considered to be the closest distance that students and instructors would be exposed to the lamp especially in physics laboratories when using this lamps in spectrometer experiment. For analyzing the UV content at the short distance, the measurements were conducted at the distance of 5 cm. The description of these lamps as the following: UOH-Helium lamp and UOH- Mercury vapor lamp. These lamps are designed to emit their power in the visible region. In fact, they emit almost 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 25 cm from Helium lamp. Therefore, only data relating to the UVA irradiance measured at 5 up to 25 cm were analyzed in this study. Also, Negligible amounts of UVA and UVB were detected at 30 cm from Mercury vapor discharge lamp. Therefore, only data relating to the UVA irradiance measured at 5 up to 25 cm were analyzed in this study.

Figure 7 shows the comparison of UVA irradiance level between Helium and Mercury vapor discharge lamps at distance of 5 up to 25 cm. Each lamp measured at distances of 5 up to 25 cm from its central vertical axis respectively using Sper Scientific UVA/B Light Meter (Model 850009C) which calibrated at National Institute of Standard and Technology (NIST), USA. The UVA irradiance for two types of lamps at different distances varies from $7\,\mu W/m^2$ to $14\,\mu W/m^2$. The results showed that the Mercury vapor discharge lamp has higher values of the UVA irradiance than Helium discharge lamp.

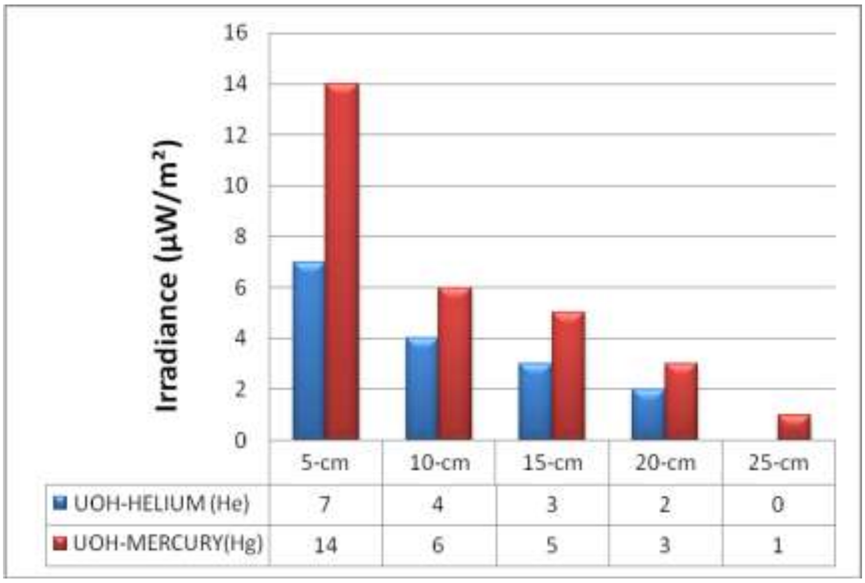

Figure. 7. Comparison measurements of UVA absolute irradiance levels between Helium and Mercury vapor discharge lamps at different distances.

Figure 8 shows the comparison of illuminance level between Helium and Mercury vapor discharge lamps at different distances. Each lamp measured at distances of 5 up to 25 cm from its central vertical axis using a Luxmeter TM-201Lux. The illuminance level at distances of 5 up to 25 cm for all lamps varies from 6 lux to 160 lux. The results showed that Helium discharge lamps has higher values of the illuminance level than the Mercury vapor discharge lamps.

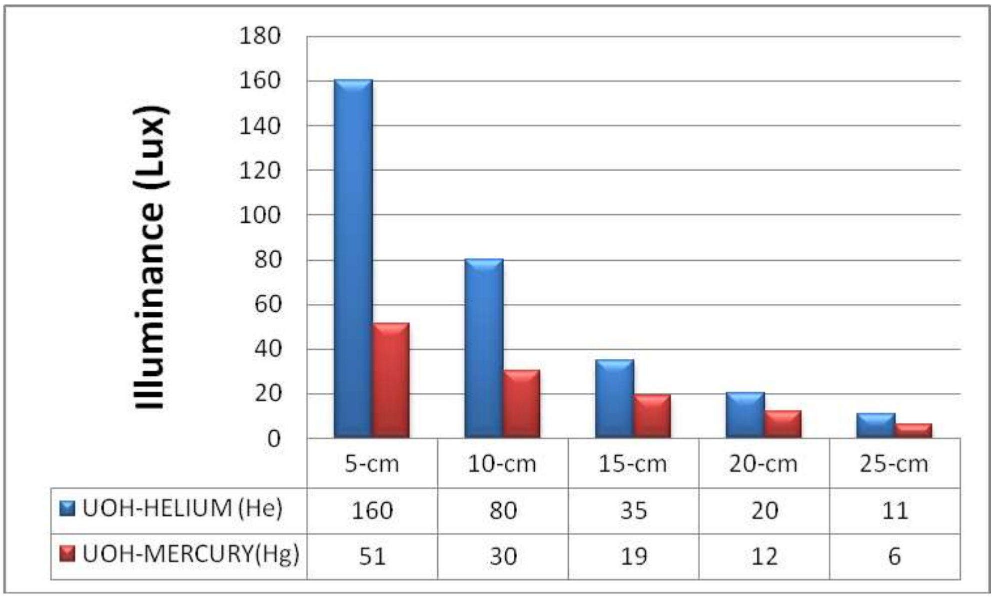

Figure. 8 Comparison measurements of Illuminance levels (Lux) between Helium and Mercury vapor discharge lamps at different distances.

It would be more appropriate to analyze UVA irradiance per electrical wattages (η). Figure 9 show the histogram for comparison of UVA absolute irradiance levels per electrical power of (η) between Helium and Mercury vapor discharge lamps at different distances from 5 cm up to 25 cm which varies from $0.0045\, m^{-2}$ to $0.06\, m^{-2}$.

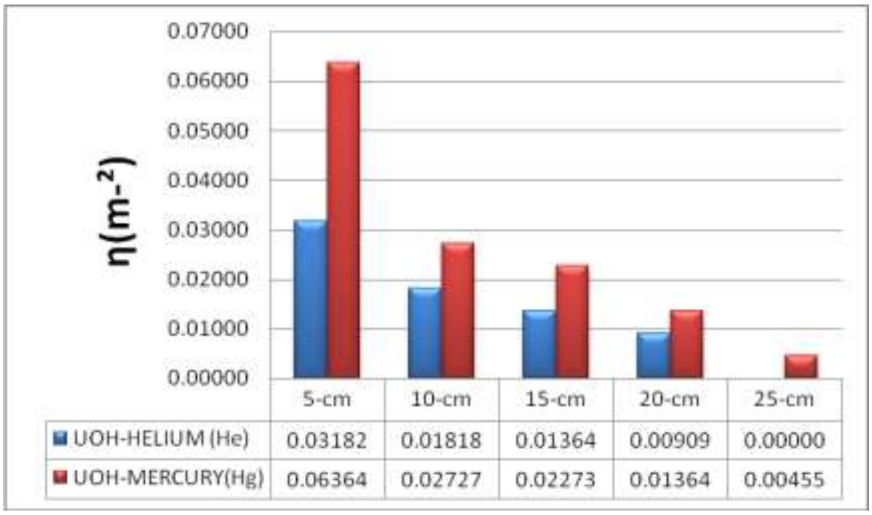

Figure 9. Comparison measurements of UVA absolute irradiance levels per to electrical power (η) between Helium and Mercury vapor discharge lamps at different distances.

To make a better comparison in UVA concentration to illuminance ratio (K), is of more interest for analyzing the lamps radiation characteristics as shown in Figure 10. It shows the histogram for comparison of UVA concentration to illuminance ratio (K) Helium and Mercury vapor discharge lamps at different distances from 5 cm up to 25 cm for all types of studied lamps which varies from $0.044\,\mu W/lm$ to $0.275\,\mu W/lm$.

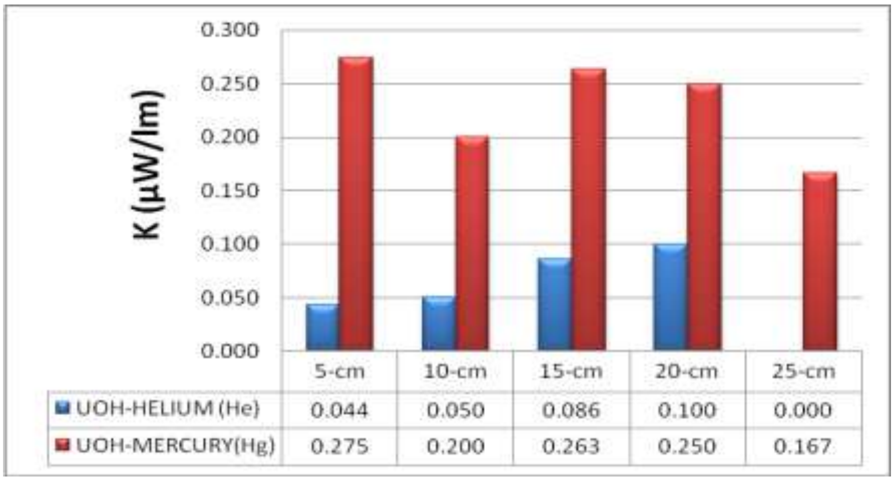

Figure 10. UVA absolute irradiance levels per illuminance values (K) Helium and Mercury vapor discharge lamps at different distances.

V. UNCERTAINTY ANALYSIS

When reporting the result of measurement of a any quantity, it must be quantitative indication of the quality of the result be 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 uncertainty in the result of a measurement consists of several components which may be grouped into two categories. According to the way in which their numerical value is estimated. Type A those which are evaluated by statistical method and type B those which are evaluated by other means. The components in type A are characterized by the estimated variances s_i^2 (or the estimated "standard deviation" s_i) and the number of degree of freedom v_i . The components in type B should be characterized by u_j^2, which may be considered as approximations to the corresponding variances, the existence of which is assumed. The quantities u_j^2 may be treated like variances and the quantities u_j like standard deviations. The combined uncertainty should be characterized by the numerical value obtained by applying the usual method for the combination of variances. The combined uncertainty and its components should be expressed in the form of "standard deviations". Expanded uncertainty is termed overall uncertainty. It is quantity of an interval about the results of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand. Coverage factor is numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty [20].

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) [20]. The standard uncertainty $u(x_i)$ to be associated with input quantity is the estimated standard deviation of the mean [21, 22]

$$u(x_i) = s(\bar{X}) = \left(\frac{1}{n(n-1)} \sum_{k=1}^{n} (X_{i,k} - \bar{X})^2 \right)^{1/2} \quad (6)$$

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

$$u_c^2(y) = \sum_{i=1}^{N} (\frac{\partial f}{\partial x_i})^2 u^2(x_i) \quad (7)$$

Uncertainty model used for the determination of the UVA irradiance $E_{UVA}(\lambda)$ is [14]

$$E_{UVA}(\lambda) = E_S(\lambda) + \delta E_l + \delta E_r \quad (8)$$

where, $E_S(\lambda)$ = uncertainty due to reference spectral irradiance UVA standard radiometer (obtained from the calibration certificate).

δE_l = uncertainty due to distance effect on the irradiance measurements (calculated by using the inverse square law).

δE_r = uncertainty due to repeatability of the measurements (standard deviation of repeated 5 times).

The uncertainty must be quoted whenever the results of a measurement are reported, it tells us about the precision with which the measurements were made. The uncertainty budget of the absolute irradiance and illuminance measurements are shown respectively in Table 1 and Table 2 with expanded uncertainty with confidence level 95% (coverage factor **k**=2). Finally, UVA irradiance, and illuminance measurements are calculated.

Uncertainty Component	**Relative Standard Uncertainty (%)**
Irradiance responsivity calibration of standard radiometer	5.2
Distance measurements	0.019
Repeatability	0.022
Relative Expanded Uncertainty (k=2)	**10.4**

Table (1). Estimated Uncertainty budget of UVA irradiance for Lamps.

Uncertainty Component	**Relative Standard Uncertainty (%)**
Illuminance responsivity calibration of standard photometer	6
Distance measurements	0.018
Repeatability	0.02
Relative Expanded Uncertainty (k=2)	**12**

Table (2). Estimated Uncertainty budget of illuminance for lamps.

VI. CONCLUSION

UVA emission and illuminance were measured from Helium and Mercury vapor discharge lamps. UVA emission were studied to assess their unwanted output in the UVA region. Various parameters such as ultra violet 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 Mercury vapor discharge lamps than Helium discharge lamps. The Helium discharge lamps appeared to be the safer. Also, the smaller value of (η) is safe for human being then Helium discharge lamps appeared to be the safer at 25 cm distance. Data analysis was performed. Uncertainty model includes all parameters accompanied with the measurements are studied. The accompanied uncertainty 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). According to the results of this research, I recommended using Helium discharge lamps when it used for physics laboratories specially with spectrometer experiment and more safe for students and instructors at the universities and schools.

REFERENCES

[1]. . Samuel M. Goldwasser Donald L. Klipstein, “Gas discharge lamps, ballasts, and fixtures”. Online [https:// www.repairfaq.org/sam/dlamp.htm].

[2]. Manal A. Haridy,” Comparison of UVA Radiation and Illuminance Emitted from Hydrogen (H2) and Water Vapor (H2O) Discharge Lamps”, ICIC Express Letters, Part B: Applications, Volume 10, Number 4, April 2019.

[3]. Parag Sharma, V.K. Jaiswal, H.C. Kandpal, "Ultraviolet Radiation Emitted by Compact Fluorescence Lamps", J. Metrol. Soc. India (MAPAN) 24, 183–191 (2009).

[4]. Shahram Safari et al., "Ultraviolet Radiation Emissions and Illuminance in Different Brands of Compact Fluorescent Lamps ", International Journal of Photoenergy, volume 2015..

[5]. M. A. Haridy, S. M. Reda and A. N. A. Mohmed, Illuminance and ultra violet emissions radiated from white compact fluorescent lamps, Int. J. Metrol. Qual. Eng., vol.7, no.4, p.407, 2016.

[6]. M. A. Haridy, K. R. Alreshidy and G. S. Alazmi, Comparative study of UVA-radiation and illuminance of white tubular fluorescent lamps for different brands in Saudi Arabia market, International Journal of Research in Engineering and Technology, vol.6, no.6, pp.1-8, 2017..

[7]. Characterization of a Helium Gas- discharge lamp, Christian Stieger, semester thesis, September,14,2012. n.ethz.ch/~stiegerc/Sem_pres.pdf.

[8]. https://en.wikipedia.org/wiki/Gas-discharge_lamp.

[9]. https://physics.stackexchange.com/questions/284394/second-order-spectra-vs-first-order..

[10]. D. Parsons, “The environmental impact of compact fluorescent lamps and incandescent lamps for Australian conditions,” The Environmental Engineer, vol. 7, no. 2, pp. 8–14, 2006.

[11]. Azizi M, Golmohammadi R, Aliabadi M. Comparative Analysis of Lighting Characteristics and Ultraviolet Emissions from Commercial Compact Fluorescent and Incandescent Lamps. J Res Health Sci.; 16(4):200-205, 2016.

[12]. M. Khazova and J. B. O’Hagan, “Optical radiation emissions from compact fluorescent lamps,” Radiation Protection Dosimetry, vol. 131, no. 4, pp. 521–525, 2008.

[13]. Jacqueline C. VISCHER, Mariam WIFI “Handbook of Environmental Psychology and Quality of Life Research”, Chapter 20(THE EFFECT OF WORKPLACE DESIGN ON QUALITY OF LIFE AT WORK), Eds: Ghozlane Fleury-Bahi, Enric Pol, Oscar Navarro. London: Springer, (2015).

[14]. ACGIH, TLVs and BEIs Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents, and Biological Exposure Indices, ACGIH, Cincinnati, Ohio, USA, 2008. , B. L.Diffey, “Sources and measurement of ultraviolet radiation,” Methods, vol. 28, no. 1, pp. 4–13, 2002..

[15]. Occupational Exposure Limits, Requirements, Guidelines and Technical Guidance and Environmental Health Center, Institute for Environmental Research, 2011, S. Safari, M. Kazemi, H. Dehghan, H. A. Yousefi, and B. Mahaki, “Evaluation of ultraviolet radiation emitted from compact fluorescent lamps,” Journal of Health System Research, vol. 9, no. 11, pp. 1177–1183, 2013.

[16]. Manal A. Harid, Affia Aslam “Optical Radiation Metrology and Uncertainty”, “Metrology”, InTech; 2018,DOI:10.5772/intechopen.75205,http://www.intechopen.com/books/metrology/optical-radiation-metrology-and-uncertainty. ISBN: 978-1-78923-594-4.

[17]. European Standard EN13032-1:2004. Light and lighting. Measurement and presentation of photometric data of lamps and luminaires. Measurement and file format.

[18]. F. Grum, R. Becherer, Optical Radiation Measurements (Academic Press, Radiometry, 1979), Vol. 1.

[19]. International Commission on Non Ionizing Radiation Protection (ICNIRP). Guidelines on limits of exposure to ultraviolet radiation of wavelength between 180 nm and 400 nm. Health Phys.; 87(2):171-186,2004.

[20]. International Organization for Standardization (ISO), Guide to the expression of uncertainty in measurement (1995).

[21]. International Organization for Standardization (ISO), Guide to the expression of uncertainty in measurement (1993).

[22]. United Kingdom Accreditation Service (UKAS), The expression of uncertainty and confidence in measurement, 2nd edn. (2007).

Manal A. Haridy " Visible and Ultra-Violet Radiations Emitted from Helium (He) and Mercury Vapor (Hg) Discharge Lamps Used in Spectrometer" American Journal of Engineering Research (AJER), vol.8, no.04, 2019, pp.328-337