MEASUREMENT AND CONCERNS ABOUT EVALUATION OF OCCUPATIONAL ULTRAVIOLET RADIATION

Antonio Francisco Gentil Ferreira Jr. [1], Raul Leone Filho[2]

[1] Instituto de Pesquisas Tecnológicas do Estado de São Paulo, São Paulo, Brazil, agentil@ipt.br
[2] Instituto de Pesquisas Tecnológicas do Estado de São Paulo, São Paulo, Brazil, rleone@ipt.br

Abstract: This works presents an arrangement for measuring the occupational ultraviolet radiation in field at workers place and its calibration and characterization procedure. Additionally, cinema headlight measurement results are presented with restriction of use according WHO UVA exposures limits.

Key words: ultraviolet, radiation, occupational limits, exposure.

1. INTRODUCTION

The ultraviolet (UV) exposure is a public health concern around the world [1]. It is a general knowledge that some products should present ultraviolet protection and the majority of them have specific standardization, as it is observed for sun glasses [2].

The occupational UV exposures limits revised in 2004 and stated by World Health Organization (WHO) are defined for skin and for the eyes, regarding UVA and effective UV radiation [3]. The effective UV radiation is the UV radiation perceived by human biological response known as the ultraviolet action spectra. This action spectrum gives how better is the capability of a determined UV wavelength to produce an erythema. The WHO effective UV limit is applied to skin and eyes exposure and UVA limit is applied only to the eyes.

On the other hand, Brazilian occupational UV exposure limits which date from 1978 considers that UVA exposure is not a risk for workers health [4].

Regarding the need of occupational UV evaluation, IPT established an arrangement for its measurement at field and followed the WHO/ICNIRP recommendation [3]. The measurement arrangement, its calibration and the UV measurement results for a cinema headlight are presented.

2. METHODS

The UV radiation is measured using 2 broadband radiometer one with the action spectra response and the other with UVA response. Both detectors are temperature stabilized. The detectors calibration and UV measurement procedure are presented as follow.

2.1. Detector calibration

The detectors are calibrated against a deuterium irradiance standard lamp calibrated by NPL, England National Institute of Metrology. The detector reference planes are positioned and aligned to the deuterium lamp and its irradiance are measured.

The UVA irradiance or effective UV irradiance are calculated from reference lamp irradiance ($E_{std}(\lambda)$) according to equation 1 and 2, respectively. The wavelength limits are determined according to effective UV and UVA range and the function $S(\lambda)$ is equal to ultraviolet action spectra for effective UV measurement [3].

$$E_{UVA} = \int_{315}^{400} E_{std}(\lambda) \qquad (1)$$

$$E_{eff} = \int_{180}^{400} E_{std}(\lambda)\, S(\lambda) \qquad (2)$$

Due to NPL traceability limitation the reference lamp irradiance data is supplied from 200 nm to 400 nm, so that spectral output from the lamp in the range of 180 nm to 199 nm is interpolated from the calibrated irradiance data.

2.2. Occupational UV measurement

The occupational UV measurements are made in field at the worker position, according to the figure 1. At a specified position the detectors are aligned to the light source and its irradiance is measured. Both detectors are temperature controlled and are shuttered when measurement are not taken to avoid irradiance drifts. The out-of-band radiation is evaluated using a long pass filter that blocks the UV radiation and allow the measurement of visible and infrared radiation. This out-of-band radiation is then subtracted from the UV irradiance measurement.

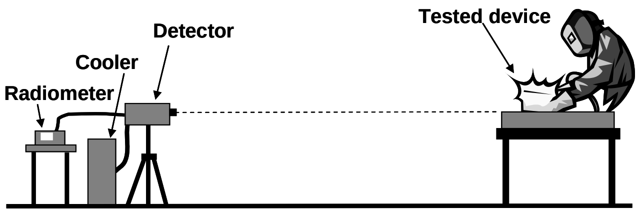

Fig. 1. UV measurement set.

3. RESULTS AND DISCUSSION

The results of calibration of radiometer from International Light concerning the UVA and effective UV irradiance probes are presented. After calibration this equipments are used to measure a cinema headlight equipment.

3.1. Detector calibration

The figure 2 presents the irradiance from the standard lamp calibrated by NPL as well as the interpolated irradiance data. The interpolation was performed using a cubic polynomial fit and the correlation coefficient (R^2) of 0,999 indicated a good fit agreement.

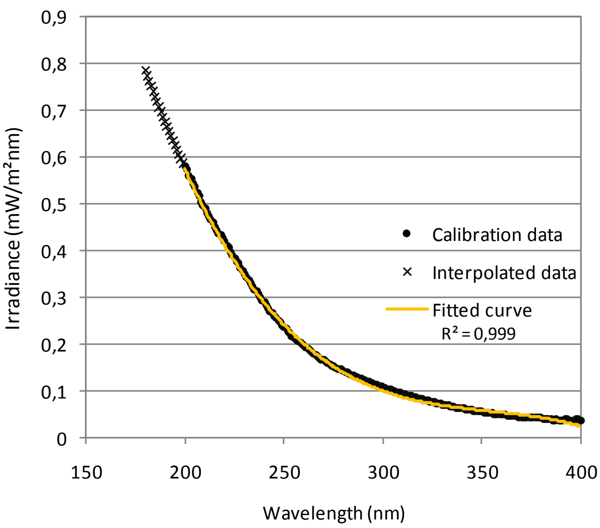

Fig. 2. Calibrated deuterium lamp irradiance data.

Table 1. Calibration results.

Quantity	Measured Equipment	
	Standard lamp (μW/cm²)	Radiometer (μW/cm²)
UVA irradiance	0,462±0,025	0,259
Effective UV irradiance	0,903±0,062	1,01

The calibration results are presented in Table 1. The UVA irradiance presented an error which is almost 80% of radiometer measured value. The effective UV irradiance presented an error of approximately 10%. The high error in the UVA irradiance is associated to a limited responsivity wavelength band of the UVA radiometer probe compared to the UVA range stated in the equation 1.

The UVA probe responsivity stated by the manufacture is presented in the figure 3. Regarding the nonideal radiometer responsivity and its Gaussian shape similarity, it is possible to define the equivalent to ideal responsivity band pass [5], which defines the equivalent wavelength range take into account during the measurement. For this case, the measured range corresponds to the full width at half maximum (FWHM).

Using this approach the equivalent wavelength range to be used in the equation 1 shall be 340 nm to 390 nm. The results for the UVA irradiance calibration using these new integration limits are presented in Table 2.

Table 2. UVA calibration results according FWHM .

Quantity	Measured Equipment	
	Standard lamp (μW/cm²)	Radiometer (μW/cm²)
UVA irradiance $_{(340\ a\ 390\ nm)}$	0,243±0,013	0,259

The UVA irradiance result with the FWHM band pass integration limits has an error of 6% which agree with the stated uncertainty from manufacture for UV range of 10%. It should be note that using this radiometer probe for UVA measurements the obtained measures will be underestimated when compared with the full UVA wavelength range.

Although the error for effective UV irradiance is within the manufactures limits, it is important to note that further attention should be considered for this measurement. The first point is the interpolation of the deuterium lamp irradiance data in the far UV, which is not bad assumption comparing to results that indicated an almost constant irradiance for deuterium lamp in the range of 180 nm to 200 nm [6]. The second, it should be mentioned that according to BIPM calibration and measurement capabilities, none National Metrology Institute (NMI) can perform irradiance calibration in the wavelength range of 180 nm to 200 nm [7].

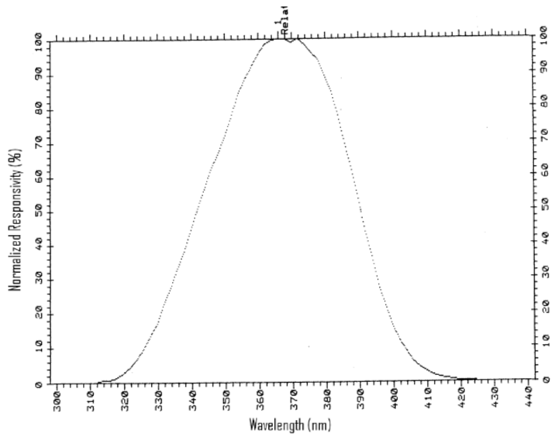

Fig. 3. UVA sensor responsivity from International Light documentation.

The UV irradiance measurement using radiometer should be performed carefully, once it could be affect by the source spectral distribution used in the equipment calibration, source spectral distribution measured, out-of-band radiation and the environment conditions [8]. It is very important to verify during the measurements if the visible or infrared parts of source spectrum are not accounted by the radiometer probe.

3.2. Occupational UV measurements

The measurements of occupational UVA exposure limit of a cinema headlight are presented concerning the effective UV irradiance and the UVA irradiance in Table 3. The cinema headlight is a commercial version with 200W metal halide lamp. The measurement is performed with close focus with the UV protection filter.

Table 3. Headlight UV measurements.

Equipment	**Distance (m)**	**Irradiance** (μW/cm²)	
		$UV_{effective}$	**UVA**
Cinema Headlight	4	0,110±0,015	340±45

These results indicate according to Brazilian Law [4] that the equipment does not cause damage during occupational use. However, according to WHO occupational limits [3] the maximum exposure time of worker´s eyes during a work day shall be less than 1 hour, regarding the UVA criterion, and could be more than 8 hours regarding effective UV radiation. So using WHO criterion if the workers are exposed for more than one hour it exceeds the safety limits.

This situation represents one case among many other possible in the work environment. Attention should be directed regarding the update results in the safety working limits and the law up-to-date claims. Not only the law safety concerns should be subject to a revision, but also the training of safety engineering and correlated workers.

4. CONCLUSIONS

A calibration procedure for broadband radiometer with UVA and effective UV irradiance probes was presented. The results showed an agreement of 10%, but for UVA there were limitation in the spectral range of measurement.

A practical UV occupational radiation measurement on a cinema headlight was performed and indicated 1 hour of exposure limit time for worker´s eye, concerning the WHO occupational limits. However, this restriction does not appear when the Brazilian´s occupational limits were applied. It is recommended a review of Brazilian´s occupational limits and the training of safety technicians.

REFERENCES

[1] WORLD HEALTH ORGANIZATION. *Environmental Health Criteria 14.* Geneva, 1979

[2] ABNT. *NBR 15111 Proteção pessoal dos olhos – Óculos de Sol e filtros de proteção contra raios solares para uso geral.* Rio de Janeiro/Brazil, 2004.

[3] ICNIRP. *Guidelines on limits of exposure to ultraviolet radiation from 180 to 400 nm.* Health Phys 87:171–86; 2004

[4] MTE. *Nr-15 Atividades e Operações Insalubres*. Brasília/Brazil, 1978.

[5] Wyatt, C. L. *Chaper XII Spectral Purity* In: Radiometrics Calibration: Theory and Methods. Academic Press, London, 1978.

[6] Saunders, R.D.; Ott. W.R.; Bridges, J.M. *Spectral irradiance standard for the ultraviolet: the deuterium lamp.* Appl. Opt., v17, n4, 1978, pp. 593-600.

[7] Bureau International des Poids et Mesures. Apresenta as informações gerais sobre intercomparação. Avaible at < http://kcdb.bipm.org/appendixC/country_list_search.asp?CountSelected=FR,DE,HU,MX,GB,US&iservice=PR/Detector.3.1.2/> Accessed: 01/jul/2011.

[8] Larason, T.C.; Cromer, C.L. *Sources of error in UV radiation measurements.* J. Res. Natl. Inst. Stand. Technol., v106, n4, 2001, pp. 649-56.