International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

OP30

EVALUATION OF BLUE LIGHT HAZARD

Denan Konjhodzic

DOI 10.25039/x46.2019.OP30

from

CIE x046:2019

Proceedings
of the
29th CIE SESSION
Washington D.C., USA, June 14 – 22, 2019

(DOI 10.25039/x46.2019)

The paper has been presented at the 29th CIE Session, Washington D.C., USA, June 14-22, 2019. It has not been peer-reviewed by CIE.

CIE Central Bureau
Babenbergerstrasse 9
A-1010 Vienna
Austria
Tel.: +43 1 714 3187
e-mail: ciecb@cie.co.at
www.cie.co.at

EVALUATION OF BLUE LIGHT HAZARD

Konjhodzic, Denan
Instrument Systems GmbH, Munich, GERMANY
konjhodzic@instrumentsystems.com

DOI 10.25039/x46.2019.OP30

Abstract

Since the previous International Standard IEC 62471 (IEC, 2006) for the photobiological safety is rather theoretical, the IEC Technical Report 62778 (IEC, 2014) explains how to apply the IEC 62741 for simple assessment of the blue light hazard (BLH) of lamps and luminaires with visible radiation. Currently, worldwide efforts are underway to elevate this report to a new standard and add more detailed measurement procedures for BLH assessment that are accessible to a broader community.

In this paper we will evaluate and compare the methods for BLH assessment with some practical measurements, and emphasize the advantages and disadvantages of each method. An outlook for further developments with the consequences will be given as well. As every manufacturer should perform BLH assessment for the approval of new SSL products, some more simpler methods will be soon available and understandable for more users.

Keywords: Photobiological safety, Blue light hazard, Risk assessment, Spectroradiometer

1 Introduction

The rapidly growing significance of modern solid state lighting (SSL) technology in our daily working and living environment raises important safety issues, such as the photobiological safety and the blue light hazard (BLH) in particular. The previous International Standard IEC 62471 (IEC, 2006) was prepared as a Standard CIE S 009 and gives guidance for evaluating the photobiological safety of lamps and lamp systems including luminaires. It assigns high demands to measurement equipment and procedures to ensure a reliable evaluation of photobiological hazards and in particular the assessment of the BLH risk classes of light sources. This Standard actually identifies two health hazards which can be caused by visible light. Intense light may lead to retinal burns, a hazard which is easily avoided by normal aversive behaviour. However, blue light between 400 nm and 500 nm causes photochemical damages of the retina, a hazard which is much more difficult to assess by normal users. This so-called blue light hazard possibly leads to a degeneration of the macula. The corresponding weighting function covers the wavelength region between 300 nm and 700 nm and has its maximum around 435-440 nm. Considering the distinctive blue peak of white LEDs, the question of the hazardousness of SSL sources arises. Depending on the radiance levels, the BLH sensitivity, and the exposure times the IEC 62471 assigns light sources to four risk groups from 0 (exempt) to 3 (high risk), as shown in Table 1.

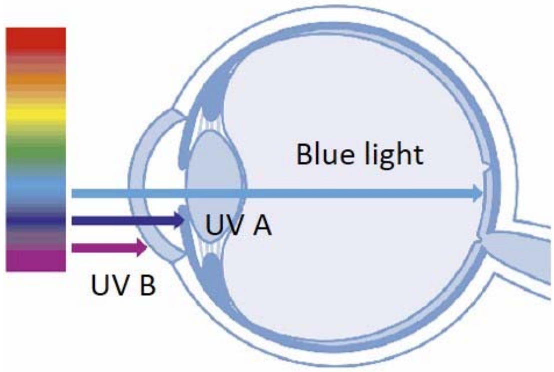

Figure 1 – Whereas UV radiation is absorbed by cornea, blue light enters the eye to the retina.

Mathematically expressed, the blue light weighted radiance, L_B, shall not exceed the level:

$$L_B \cdot t = \sum_{300}^{700} \sum_{t} L_{\lambda}(\lambda, t) \cdot B(\lambda) \cdot \Delta t \cdot \Delta\lambda \leq 10^6 \ J \cdot m^{-2} \cdot sr^{-1} \qquad (\text{for } t \leq \ 10^4 \ s) \qquad (1)$$

where

$L_\lambda(\lambda,t)$ is the spectral radiance in W m^{-2} sr^{-1} nm^{-1};
$B(\lambda)$ is the blue light hazard weighting function;
t is the exposure duration and $\Delta\lambda$ is the bandwidth in nm.

Table 1 – Retinal blue light hazard risk groups

Risk group number	Risk group name	L_B limit [W/m²sr]	Corresponding t_{max}
RG 0	Exempt	≤ 100	> 10 000 s
RG 1	Low risk	100 - 10 000	100 - 10 000 s
RG 2	Moderate risk	10 000 - 4 000 000	0.25 - 100 s
RG 3	High risk	> 4 000 000	< 0.25 s

Additionally, the IEC Technical Report 62778 (IEC, 2014) explains how to apply the IEC 62741 for simple assessment of the BLH of lamps and luminaires with visible radiation. However, this has not yet become a standard. Worldwide efforts are currently underway to elevate this report to a new standard and add more detailed measurement procedures for BLH assessment that are accessible to a broader community.

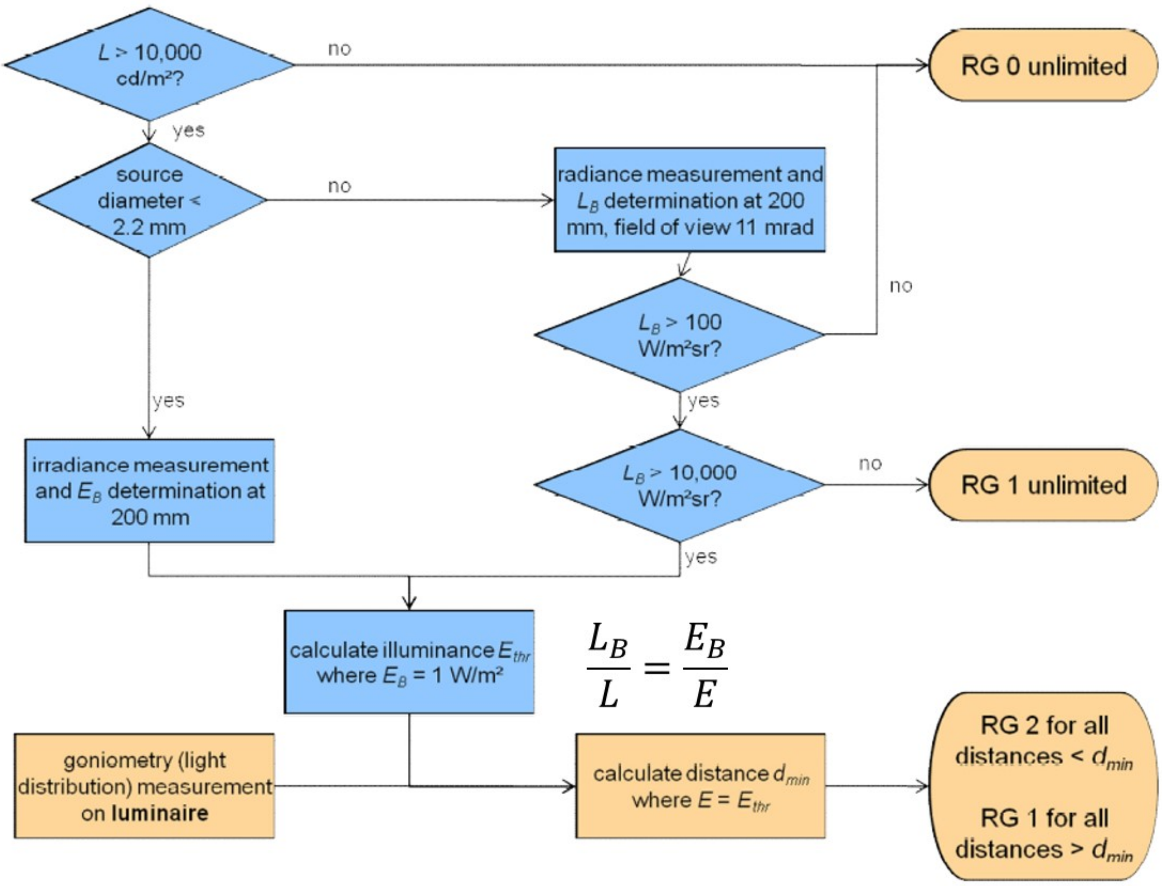

Figure 2 – Evaluation guide for blue light hazard as a flow chart from (IEC, 2014).

With the assumption that light sources classified as exempt or RG1 for BLH are safe, and require no safety label, and RG3 classification is extremely unlikely for SSL, the only task is to determine if the source exceeds RG1 emission limit at the distance of 200 mm and field of view of 11 mrad (Fig. 2). For “extended sources”, with sizes bigger than field of view of 11 mrad (which corresponds to a 2.2 mm diameter measuring spot), a spectral radiant measurement should be performed, otherwise a spectral irradiance measurement is recommended for “small sources”. If the blue light weighted radiance (or irradiance) exceeds the RG1 limit, the boundary between RG1 and RG2 should be determined as the threshold illuminance E_{thr}, which should be stated in the datasheet for LED components or lamps. It can be converted to the threshold distance d_{thr} for the final product, at which E_{thr} is obtained.

2 Methods

A correct risk assessment is a challenging task for the experimenter as one has to decide on the suitable test equipment. Nowadays, the measurement instrument of choice is often an array spectrometer instead of the hard-to-handle double monochromator suggested by the standard IEC 62471. But even high-end array spectrometers must have advanced stray light correction methods to achieve the required high dynamic measuring range especially in the less sensitive blue region. Carefully designed test adapters are necessary to ensure correct and reproducible test geometry. With such equipment testing labs, which should be accredited according to ISO 17025, can reliably assess the risk class of lighting products.

Two main measurement procedures for BLH assessment were proposed in the IEC 62471, the direct spectral radiance measurement with an optical system and an alternative method as an irradiance measurement performed with a well-defined field of view.

2.1 Direct spectral radiance measurement

The direct spectral radiance measurement can be realized with a telescopic optical probe in combination with an array spectrometer calibrated on spectral radiance. A telescopic optic with viewfinder camera allows easier positioning and faster determination of BLH for light sources that do not have radiation below 360 nm, since the lens is not transmissive for the UV radiation. Therefore, in order to fulfil IEC 62471, an additional measurement with other optic suitable for the UV range may be necessary to prove, if there is detectable UV radiation. On the other hand, IEC TR 62778, and an emerging standard based on it cover only visible radiation.

2.2 Alternative method

An alternative method is proposed in the standard IEC 62471 as an irradiance measurement performed with a well-defined field of view. Here, the measured irradiance value is divided by the solid angle to obtain the final radiance value. Our alternative method consists of a stray light corrected array spectrometer with a PTFE integrating sphere calibrated on irradiance and a tube which contains apertures necessary for the calculation of radiance. The 200 mm length of the tube and the two apertures with the size of 20 mm and 2.2 mm define angles of 100 mrad and 11 mrad, respectively. This system covers the entire spectral range of the weighting function for BLH from 300 to 700 nm, as proposed in (IEC, 2006).

Figure 3 – Realization of the alternative method with the PTFE integrating sphere and a tube with all necessary apertures for the BLH measurements.

3 Results

Both procedures have been realised, the measurements on some samples such as LED package and LED retrofit have been performed, and the risk groups assigned (Tab. 2). With the standard method the measured spectral radiance was weighted with the blue light hazard function and integrated in the range between 300 nm and 700 nm in order to obtain L_B, and the resulting t_{max} =10^6/ L_B. Risk assessment is done according to the Table 1. With the alternative method the measured spectral irradiance was first divided by the solid angle defined with the aperture used and then the procedure was the same.

The deviations in the results for L_B are rather low, although both methods have quite different setups and calibrations. But, the result is assessment to the proper risk group, which is not critical for the most sources, since one risk group covers several orders of magnitude. Deviations of several percent only play a role if the source crosses the border to risk group 2. But even in this case an E_{thr} and d_{thr} should be calculated, which are not critical for most applications.

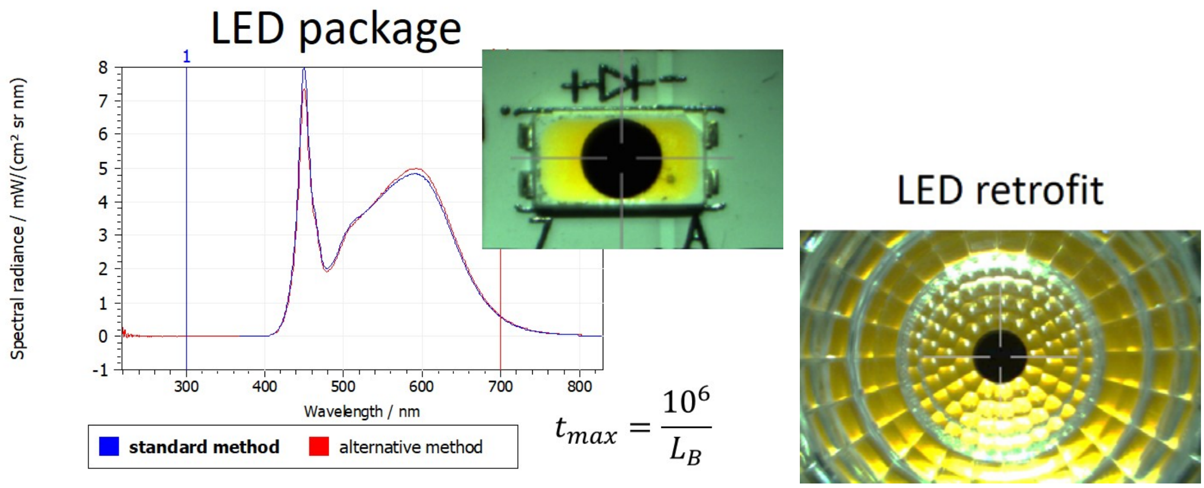

Figure 4 – Measuring spot with 2.2 mm size on the LED package and on the LED retrofit with spectra of LED package measured with the standard and the alternative method.

Table 2 – Measurement results of standard and alternative method for the samples in Fig. 2.

LED package	L_B [W/m²sr]	t_{max} [s]	Assessment
standard method	1989.8	503	RG 1
alternative method	1949.9	513	RG 1
deviation	-2.0%		
LED retrofit	L_B [W/m²sr]	t_{max} [s]	Assessment
standard method	5829.9	172	RG 1
alternative method	5497.9	182	RG 1
deviation	-5.7%		

4 Outlook – More methods with the emerging Standard

In addition to the measurements of radiance or irradiance, some considerations about the risk group classification based on CCT (correlated colour temperature) and luminance or illuminance of the source, are proposed in IEC TR 62778 and further developed in the emerging Standard. Simplified expressed, the more a source emits light in the blue region, the higher the

CCT and the greater the blue light hazard posed. The measurement of luminance and CCT, for example, can be performed with a filter based imaging colorimeter, for example.

Another method as a proposal for the emerging Standard requires luminance distribution and any relative spectrum for the calculation of L_B and therefore risk assessment. In the case of required luminance distribution an imaging colorimeter gives the fastest overview. Additional relative spectrum can be obtained with a spectrometer and any coupling optics.

In the simplest way, only data sheet specifications for CCT and maybe luminance can be used for the exclusion of a risk group greater than RG1 or very rough estimation of E_{thr}. But, the simpler method used, the higher over estimation of the hazard expected, since higher safety factors must be added for the estimation in order not to oversee any risk.

5 Conclusions

Measurement of blue light hazard is a difficult task, as the radiance measurement itself is demanding and highly dependent on the geometry of the setup. The direct spectral radiance measurement is limited for the source without radiation below 360 nm, due to no suitable lenses. However, the positioning of the measuring spot is very convenient and the measurement itself extremely fast. The major challenge for the alternative method is to reproducibly and precisely position a small aperture of 2.2 mm defining an angle of 11 mrad in 200 mm distance for most measurements. However, the PTFE sphere it is more sensitive in the UV range and entire spectral range for BLH from 300 to 700 nm is covered.

In the emerging Standard based on IEC TR 62778 even more methods are allowed, which are available for broader community. But these simpler methods must add additional safety factors to avoid under estimation of the BLH risk.

Therefore, results can vary more or less depending on the measured source and the method used. However, the result of BLH assessment is not the exact absolute value but the correct risk group, each covering few orders of magnitude. Only in the case that the measurement result is on the border between the two risk classes, it is important to perform the most exact and reproducible measurement. If possible, the results from the direct spectral radiance measurements or the alternative method as proposed in (IEC, 2006) should be taken for assessment, rather than some simplified measurements and approximations discussed in the emerging Standard based on (IEC, 2014).

Several studies, e.g. (SCHIERZ, 2018), have evaluated the risk classes for various kinds of displays and SSL sources, lamps and luminaires. In general, consumer displays and SSL sources were not found to impose any larger risks to the user than conventional sources. Most luminaires with not directly visible LEDs were assigned to risk group 0. Only luminaires with directly visible LEDs ended up in RG 1 or in some cases in RG 2, which are still safe under normal use and aversion behaviour - just like conventional sources. The high risk group 3, which is dangerous even for short exposure times below 0.25 s, is extremely unlikely for sources in general lighting and consumer displays.

References

IEC 2006. IEC 62471:2006. *Photobiological safety of lamps and lamp systems.* Geneva: IEC.

IEC 2014. IEC TR 62778:2014. *Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires.* Geneva: IEC.

SCHIERZ C. 2018. Proceedings of the conference Licht 2018 in Davos, Ch. Olten: SLG.