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OPERATING CONTROL OF PHOTOBIOLOGICAL SAFETY OF LED LUMINAIRES

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ABSTRACT

Photobiological safety has become an integral part of safety requirements to general use luminaires including during certification. In that context, the necessity to control this parameter in the course of designing and manufacturing of lighting devices (luminaires) as well as sales of imported devices in the Russian market has increased dramatically. In the meantime, experimental assessment of this indicator in accordance with requirements of IEC62471–2013 standard is rather hard requiring application of special equipment and certified personnel. This circumstance makes operating control of photobiological safety by manufacturers almost impossible.

The foreign practice of application photobiological safety-related standards confirms this problem. In 2014, International Electrotechnical Commission has published a handbook for application of the standard provisions, which significantly simplifies the procedure of such assessments: IEC/TR62778:2014.

The article describes the method of application of provisions of this handbook as an operating tool in the course of development of general use LED luminaires with white light LED. The provisions consist of assessment of hazard level in terms of illuminance in the area of the most possible location of a spectator and colour characteristics of a light source.

A calculation method of risk level assessment on the basis of spatial light distribution and correlated colour temperature of LED luminaires is proposed, the results of calculations are compared with the results of laboratory testing.

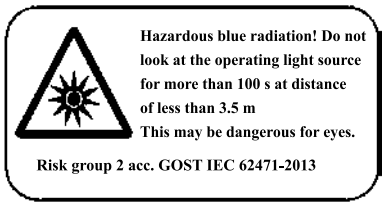
Keywords: technical regulation, photobiological safety, light emitting diodes (LED), blue light hazard, public health, quality control, performance test, testing techniques, risk groups, information for consumers

RELEVANCE

On the end of 2016, the decision of the Board of the Eurasian Economic Commission on supplementing the technical regulation of the Customs Union "On Safety of Low-Voltage Equipment" (TR CU004/2011) with new requirements to lamps and lamp systems photobiological safety, namely the requirements of standard IEC62471–2013 ("Photobiological Safety of Lamps and Lamp Systems"), has come into effect as the GOST R in Russian Federation. Therefore, in the course of analysis of safety of application of contemporary lighting devices (LD) and installations, participants of professional lighting engineering market, supervision authorities, public organisations and consumers of products should assess, take into consideration and warn about availability or non-availability of any risks in the area of photobiology.

Wide use of LED light sources in LD makes this issue especially relevant. In 2010, the report by *ANSES* (*French Agency for Food, Environmental and Occupational Health & Safety*) [1] expressed concerns on possible consequences of application of LED for illumination. By now, the global experience and scientific and applied studies by various

Table 1

Risk group	Risk level	Exposure	Additional labelling of product
0	None	No photobiological hazard, since there is no retina-hazardous blue radiation for more than 10,000 s (about 2.8 h).	Not required
1	Low	No photobiological hazard with normal behavioural limitations, since there is no retina-hazardous blue radiation for 100–10,000 s.	Not required
2	Medium	LD does not cause hazard of discomfort since there is no retina-hazardous blue light for 0.25–100 s.	 Information to be included in the documentation: WARNING! This product may emit hazardous optical radiation. Do not look at operating light source. This may be dangerous for eyes.

specialists have allowed in a more systematic and balanced manner to assess the risks of LED application. In June 2018, *SCHEER* (Scientific Committee on Health, Environment and Emerging Risks) approved the report [2]. On the basis of its analysis, which appears to be deep, the Committee made a conclusion on non-availability of evidences of adverse impact of LED on public health during normal use. Russian researchers draw similar conclusions [3].

In the meantime, in accordance with the standard IEC60598–1:2014 ("Luminaires – Part 1: General requirements and tests"), since 2014, the international practice of general use luminaires safety assessment includes requirements for assessment of *the blue light hazard* level, radiation within the region of λ in range (400–500) nm. The radiation of this region may cause photodamage to eye retina [4, 5]. In accordance with this standard, in the course of assessment of hazard degree (HD) of LED-based LD, it is necessary to follow the provisions of the regulation IEC/TR62778:2014 ("Application of IEC62471 for the assessment of blue light hazard to light sources and luminaires"), including those related to the proposed simplified method of assessment of hazard on the basis of illuminance level in a control point.

In general, the method of assessment of compliance of LD (luminaire) with the requirements of IEC/TR62778:2014 includes the following stages:

- Determination of the risk group (RG) of LED radiation (usually by means of a series of illuminance and/or radiance measurements in accordance with testing methods described by the regulation);
- Confirmation of the fact that the product has relevant RG confirming signs on the body, information of the same in the specification and user's manual;
- Elaboration of testing report documenting compliance of LD with requirements of IEC/TR62778:2014 and IEC60598.

The method is of huge practical importance. The manufacturers (sellers) of LD have obtained an instrument for operating control of compliance of products with photobiological safety requirements and capability to use a report for declaring of general safety of a product. According to data of developers, the accuracy of obtained estimations is 15 %, which may be considered acceptable.

Table 2

Range of T_{cc} values of the light source, K	Threshold illuminance in the point of spectator's eyes location, lx, not more
< 2350	4000
$2350 \le T_{cc} < 2850$	1850
$2850 \le T_{cc} < 3250$	1450
$3250 \le T_{cc} < 3750$	1100
$3750 \le T_{cc} < 4500$	850
$4500 \le T_{cc} < 5750$	650
$5750 \le T_{cc} < 8000$	500

IEC/TR62778 PROVISIONS PRACTICAL APPLICATION METHOD

Testing engineers of the Central Plant Laboratory of MGK Light Technologies, confirming compliance of the products with the photobiological safety requirements, alongside with testing of LD (luminaires) in specialised testing centres, entered the IEC/TR62778 method into everyday practice.

According to IEC62471–2013, IEC62031–2011 standards and IEC/TR62778:2014 technical requirements LED-based LD are categorised into 4 RG on the basis of photobiological hazard of their radiation (upon the "blue light hazard" criterion) (Table 1)[1].

The goal of photobiological safety check of general use LED-based LD is categorising it as one of the safe RG: RG0 or RG1.

In case the RG2 hazard level is reached, the condition of the most probable installation of LD in a facility in relation to possible spectators with which the condition of safe RG1, the border of RG1/RG2, is defined. This information should be placed on the body of LD in a form of a special sign as well as in supporting documentation.

In Table 2, the thresholds of illuminance in the point of location of spectator's eye in a plane normal to the direction to light source depending on the value of T_{cc} (IEC/TR62778:2014) defining the upper border of RG1 are listed.

According to provisions of IEC/TR62778:2014, the manufacturer (seller) of a specific LD defines the most probable position of a spectator where occasional irradiation of eyes by the light from LD is possible provided the LD is located in its designed location. This method was included in the industry standard of the Association of Manufacturers of LED and LED-Based Systems (APSS) as a method of evaluation of photobiological hazard of LED-based LD [6].

THE RESULTS OF CALCULATION AND EXPERIMENTAL EVALUATIONS

We reviewed the most possible spectator position scenarios and gave an example of assessment of hazard of LED-based LD blue light impact

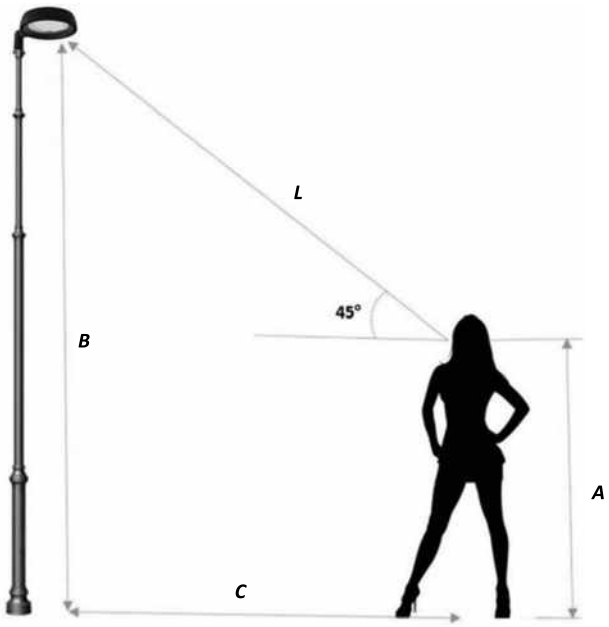


Fig. 1. Scene of the most probable position of a spectator in the illumination area of external LD

[1] Photobiological hazard of general use LD compliant with RG 3 is of low practical probability and is not considered in this case.

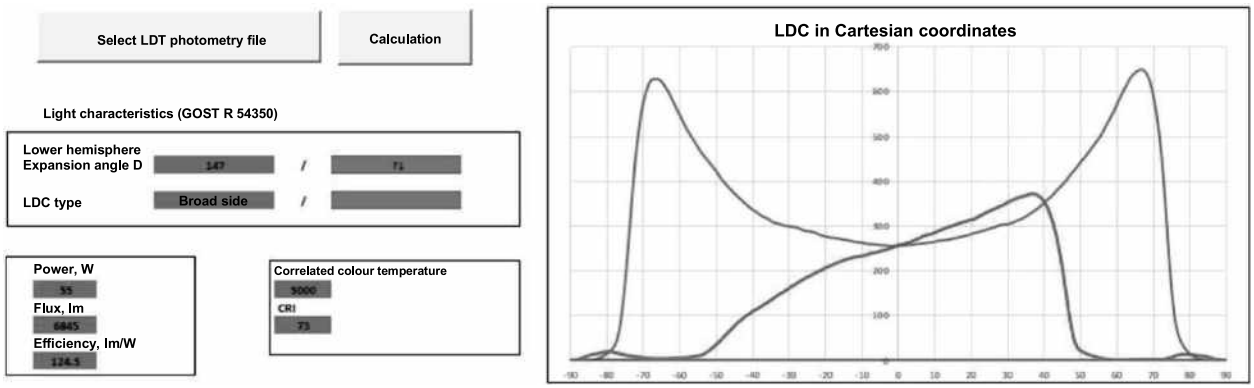


Fig. 2. Interface of the software for estimation of the level of photobiological hazard and light intensity distribution of LD (luminaire) in Cartesian coordinates (CCT – correlated colour temperature, *CRI* – general colour rendering index, R_a)

on human organ of sight on the basis of the IEC/TR62778:2014 method.

Let's review an example with a console LD for lighting of gardens and parks (Fig. 1):

- The LD is placed on a support at height of $B = 4$ m;
- The LD is based on a LED with T_{cc} equal to 4000 K in the first case and to 5000 K in the second case.

Intrinsic error of illuminance meter is within the range of ±10 %. The values of chromaticity of the reviewed light sources for general use LD are similar and the light of both LD is white. In that respect, possible error of white light illumination measurement with different values of T_{cc} does not significantly affect the intrinsic error of the illuminance meter.

In terms of light effect on the spectator, the most probable position of the latter is at some distance C from the support of LD (in the reviewed example, $C = 2.5$ m). The spectator's head is located at height of 1.6 m from the ground and the spectator's sight is directed to the LD at angle of about 45° to the horizon line. Therefore, the distance between the LD and the spectator's head $L = 3.5$ m (Fig. 1). It is worth noting that the possible range of LD view an-

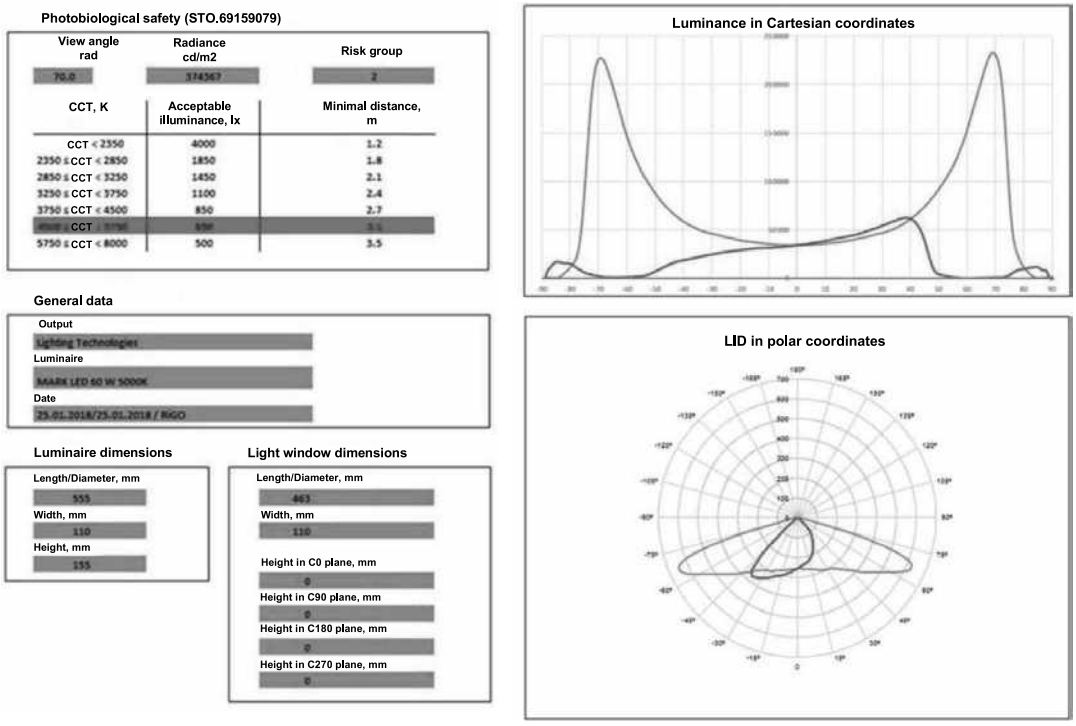


Fig. 3. Interface of the software with the results of estimation of the level of blue light photobiological hazard and overall luminance of LD (luminaire) in Cartesian coordinates

gles is (30÷60) ° and estimations of threshold distances for this type of LD may be made within this range.

At this distance, illuminance E_v on a virtual plane normal to the direction to LD is necessary to be measured. If luminous instensity in given direction I_v is known (e.g. using goniophotometer measurements), illuminance is defined as $E_v = I_v \cdot L^{-2}$.

Let's presume that the value of illuminance in the selected point is 750±75 lx. Then the condition of compliance with RG1 is met for the light source of LD with T_{cc} = 4000 K (Table 2) as 750±75 lx < 850 lx.

Therefore, 3.5 m is the distance at which the light source of LD can be seen without adverse consequences for visual apparatus. The minimal accepted threshold distance of the RG2 zone may be defined experimentally or by calculation more precisely.

After defining the value of threshold, it is necessary to place corresponding information in the technical documentation and a warning sign on RG2 classification in case of viewing from specific distance on the body of a general use LED-based LD.

Now let's presume that T_{cc} of the light source of LD is 5000 K. In this case, the RG1 compliance condition is not met. In accordance with IEC62778:2014, illuminance should not exceed 650 lx in this case. For defining of minimal accepted distance, it is necessary to place the virtual point of the spectator's head location at a higher distance in order to get the value of illuminance not exceeding 650 lx. In this case, the new value of this distance at which the light source of LD can be viewed without adverse consequences for visual apparatus (e.g. 4.5 m) will be defined. In this case, it will be necessary to place a warning sign indicating the minimal distance of 4.5 m on the body of the LED-based LD with RG2 radiation.

Classification of LD as RG0 is conducted using determination of overall luminance of the lighting body in the direction of spectator's eyes. Luminance is determined using a relevant measurement device in accordance with GOST R54350–2015. The position of the virtual spectator is selected on the basis of the above descripted example. If the measured (calculated) value of overall luminance is less than 10,000 cd/m^2, the LD is classified as RG0.

The described approach to estimation of RG of LD on the basis of photobiological safety allows us to use the data of spatial distribution of luminous intensity acquired by goniophotometer in the form of *LDT* files.

We have developed software allowing to estimate the said characteristics of LD. Apart from the luminous intensity distribution data, the *LDT* files contain information about electric and colour characteristics as well as dimensions of LD. Some parameters are input manually for calculation. First of all, it is the most probable angle of view of LD.

For convenience of the users, the information of LD luminous intensity and radiance distribution is output in the form of graphs (Figs. 2, 3). Such information is useful for analysis of the space around LD and determination of the most hazardous areas in terms of photobiology. Then the software checks all meridian planes at the above said angle and indicates the maximum one.

Comparison of the results acquired and the results of tests conducted in certified laboratories allowed to ascertain that the simplified method estimations in accordance with IEC/TR62778:2014 are estimations of hazard from above. This allows to determine the distance to safe areas of spectator position, i.e. the areas where the photobiological safety RG1 conditions for white light LD are met, and to place such information in a warning sign on the body of LD if necessary.

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