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# Research and Practical Recommendations on the Lighting System Use with LED Light Sources.

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**ABSTRACT**

This paper is devoted to the practical results of experimental studies concerning the hygienic efficiency of LED lighting. The experiments used a complex technique of psycho-physiological and hygienic evaluation of lighting systems efficiency with LEDs, developed by the authors. The practical significance of the obtained experimental data concerning the implementation LED light source lighting.

**Keywords**: LED, lighting, complex methods, experimental studies, visual functions, fatigue, efficiency, psychophysiological profile, application fields, recommendations.

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## INTRODUCTION

An important task of lighting is the development of a favorable light and color medium which assumes the use of light to meet the complex needs of a person - ergonomic, psycho-physiological, psychological, environmental. On the other hand, the issues of electricity saving consumed for lighting are the relevant ones. The solution of these problems is possible by using light emitting diodes (LEDs), which are undoubtedly the most effective and promising light sources (LS) nowadays.

However, if the energy savings in lighting facilities (LF) during the operation of LEDs taking into account their high luminous efficacy is obvious [1, 2], the possibility of using them to create favorable conditions for lighting requires serious evidence that may be obtained through a comprehensive study of the LED radiation impact on functional parameters of a human body performance. The works of Russian and foreign scientists show some results on the effect of LED lighting on some of the eyesight features and the visual performance. The results of these studies are inconsistent and ambiguous [3 - 6]. This suggests that the performed experimental studies of LED lighting hygienic efficiency and the practical recommendations developed on the basis are the relevant ones.

## METHODS

On the basis of theoretical and experimental data analysis concerning the effects on visual performance and fatigue factors related to lighting conditions, we developed a complex method of psycho-physiological and hygienic evaluation of LED lighting facility efficiency [7]. The following factors were evaluated during the experimental studies:

- The functional state of a visual organ;
- The functional indicators of a human body state;
- The integrated values LED lighting performance;
- The expert lighting conditions.

At that the study of the most responsive indicators for a visual organ functional state, such as:

- The volume of absolute accommodation and the period of achromatic asthenopia;
- The visual acuity for distance, a blind spot projection area, the sharpness of color discrimination;
- The critical fusion frequency of light flashes (CFFLF) was the most interesting one.

The integral indicator of LED lighting efficiency is the visual capacity by the method of visual trials and the visual fatigue after work:

$$A = \left(1 - \frac{t_j}{t_i}\right) \cdot 100\ \%,$$

where *A* – is a quantitative measure of the visual fatigue;
$t_j$ – achromatic asthenopia period after work;
$t_i$ – achromatic asthenopia period before work.

The somatic status of an organism was estimated by the following methods:

- Electroencephalographic studies of the brain functional activity;
- Immune status studies;
- Hormonal profile determinations.

The group of student volunteers at the age of 20 - 25 years which had passed the preliminary clinical examination was involved in the experiment.

An experimental research facility for general lighting, implementing LED and fluorescent lamp (FL) lighting options was designed and installed for studies [8]. FL variants were taken as the basic ones at comparison. The studies were carried out at the light levels of 200, 400 and 1,000 lux and the values of

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correlated color temperature (TC) IS 3000, 4000 and 5000 K.

**Main part**

During experimental studies it was found out that LED lighting does not cause harmful effects on a visual organ and a human body as a whole. The changes which occur in the course of the experiment with the functional parameters of a visual organ and the condition of a body are included in the appropriate limits of physiological fluctuations and are reversible ones.

The studies performed under different lighting conditions (LED, fluorescent) revealed a strong relationship with the compensatory-adaptive response of a body and the stability of adaptive systems, responsible for the regulation of the visual organ sensitivity and the body as a whole.

In order to compare the efficacy of LED and fluorescent lighting options the fatigue psychophysiological profile method was used, which allowed to visualize the dynamics of a visual organ functional state and the state of a human body as a whole after the visual work performance [9].

On the basis on the obtained experimental data, we developed a list of LED application areas for the premises of different functional purpose - social, administrative, educational, residential and industrial ones. The scope LED use was determined on the basis of visual tasks character and the rated values of quantitative and qualitative lighting values. The developed proposals relate to the types of works carried out during a laboratory experiment or during similar works according to visual tasks - the mental and correctional work of Class A-2 type [10].

Table 1 shows the recommended areas of LED application for public, administrative, residential and industrial premises.

The choice of illumination level during the visual tasks performance listed in Table 1 is carried out in accordance with [10 - 12]. It is premature to Talk about the reduction of illumination level in LF with LED, since the unreliable changes of this value are obtained during the study of visual capacity in a number of fluorescent and LED lighting options. Besides, the differences in the quality of work (accuracy factor according to correction sample method) with different spectral composition of radiation in all investigated illumination options were also insignificant. The results obtained in the course of research allow to formulate the requirements for LED lighting devices and to develop the practical recommendations for the implementation of illumination systems with LED LS (LED lights). The recommendations are aimed at the optimization of the working conditions when intense mental and visual works are performed.

The need for LED lighting is justified when visual works are carried out requiring the luminous flux (light) ripple factor restrictions (illumination) during works involving color discrimination at low requirements. The use of LED lamps in LF may be recommended when a sufficiently high level of illumination is necessary on working surfaces (A-2, III r rate works).

The use of LED for a comfortable and safe light environment creation is effective in the systems of mixed lighting, for example, in conjunction with FL.

The mixed LED and FL lighting DM may be recommended for the LF, where mental and visual works are performed with achromatic objects or the works without high requirements for color discrimination.

The lower limit of a working surface brightness range should be 100 - 150 cd/m2. At these levels of surface brightness one should use an object negative contrast with the background to prevent irradiation with the brightness ratio of about 1:3 (a dark object with a light background).

In order to ensure the focus on objects the surrounding brightness should be below the work surface brightness and brightness difference between them, providing a favorable distribution in the field of view, should be less than the maximum difference (i.e. $L_{\phi}$ / $L_{o}$ = 3 - the ratio of a background and an object brightness). The distribution of brightness on a work surface should be optimized, as most uneven brightness (more than 3 - 5) calls for a constant eye readaptation during work.

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**Table 1: Recommended application areas of LED for public, administrative, residential and industrial buildings**

| Premises | The working surface and illumination rate plane (H - horizontal, V - vertical) and the height of the plane above the floor, m | Illumination of work surfaces at general lighting, lux |
|---|---|---|
| *Administrative buildings (ministries, departments, committees, research institutions, etc.)* | | |
| Project facilities and design room, drawing offices | Г-0,8 | 500 |
| Typing pools, reading rooms | Г-0,8 | 400 |
| Facilities for visitors, expeditions; recording rooms and registration of readers, thematic exhibitions | Г-0,8 | 300 |
| Public catalogues | В-1,0 | 200 |
| Bookbinding premises; repair shops | Г-0,8 | 300 |
| Premises for display and video terminal operation, computer rooms | Г-0,8<br>Display screen:<br>В-1,2 | 400<br><br>200 |
| Research and technology laboratories (except for medical institutions): | Г-0,8 | 400 |
| *Banks and insurance institutions* | | |
| Operating room, credit group, bank hall, money re-calculation room; server room, encryption hardware facilities; | Г-0,8 | 400 |
| Cash Collection Division premises; premises for retail banking | Г-0,8 | 300 |
| *Institutions of higher education* | | |
| Lecture halls, classrooms, laboratories | Г-0,8 | 400 |
| Computer science classrooms | Г-0,8<br>Display screen:<br>В-1 | 400<br>200 |
| Offices and rooms of teachers | Г-0,8 | 300 |
| *Hotels* | | |
| Service bureau, lounge, premises for attendant staff | Г-0,8 | 200 |
| Rooms | Г-0,0 | 150 |
| *Stations* | | |
| Operation rooms, ticket halls, ticket and baggage offices, postal telegraph offices, operator room, dispatch room | Г-0,8 | 300 |
| Computing Center | Г-0,8 | 400 |
| *Residential buildings* | | |
| Living rooms, lounges | Г-0,0 | 150[1)] |
| Living rooms of dormitories | Г-0,0 | 150 |
| Offices, work rooms, offices, representative offices | Г-0,8 | 300 |
| Note<br>[1)] the listed illumination values at residential houses and apartments are recommended ones; | | |

An uneven brightness (luminance) on a work surface during LED illumination is recommended at the ratio of 1:3.

To exclude the direct and reflected glare it is necessary that the combined rate of discomfort UGR does not exceed 21, and the maximum brightness of a work surface should be limited to 500 cd/m2. In order to limit the LED lamp glare the diffusers should be used in lighting devices excluding the possibility of direct ray exposure in the visual field of workers. In order to reduce the reflected glare a matte finish of a work surface and an active surveillance surface should be used.

If the luminance contrast use is not possible a color contrast is allowed. Taking into account the good quality of color reproduction with LED lighting, the use of several color objects is not excluded.

When you choose LED lamps made by "remote phosphor" technology during the design of lighting it is necessary to carry out their input control for the presence of ultraviolet radiation. The intensity of UV radiation within the wavelength range of 320 to 400 nm should not exceed 0.03 W/m2 [10].

The minimum allowable values of LED light source unit power factor as the part of a lamp with the power up to 25 W should not be less than 0.7; if the value is more than 25 W the minimum allowable values should not less than 0.85.

When you design a LED lighting system that are safe for a man visual system, you shall:

- Choose the optimum layout of LED lighting, which provides regulated uneven distribution of brightness (luminance) on the working surface;
- Determine (calculate) the combined value of discomfort UGR, which shall not exceed the regulated values [10, 11].
- Ensure that the illumination ripple coefficient is no more than 5%. The negative effect of the ripple coefficient on a human body is sufficiently small pulsation only when the pulsation depth makes no more than 5 - 6%. The stroboscopic effect may occur (at operating conditions) at the pulsation depth of more than 5% [12];
- In order to comply with the standards adopted by the International Electrotechnical Commission CIE S009/IEC 62471, one should use the LED lights, which have values of correlated color temperature up to 5000 K, which is confirmed by the results of our studies;
- To use LED lights the general color rendering index Ra no less than 80 to illuminate the area where the visual works of A - B rates are performed [10] at high relatively high requirements for color discrimination.

At that the choice of lights must be performed in accordance with the requirements of [13]:

- Uneven brightness distribution along the LED outlet of lights must be $L_{макс}/L_{мин} \leq 5:1$;
- The LED brightness used in lamps shall not exceed 104 cd/m2, which guarantees the absolute safety of their use in accordance with IEC62471-2008;
- The capacity of individual LED (at CMD installation) for the lamps should not exceed 1 watt (in order to achieve the specified parameters of UGR limitation and meet the requirements of overall brightness limitation for the LED lamps);
- The capacity of individual LEDs of lamps manufactured according to "remote phosphor" technology, should not exceed 2 watts.

Since LED lights provide the light flux ripple no more than 2.5%, then we propose to toughen the regulation requirements for this qualitative illumination indicator. The color temperature values should be set depending on the nature of the visual tasks performed in public and administrative, residential and industrial buildings and on CIE S009 / IEC 62471 standard compliance.

## SUMMARY

During the experimental studies it was found out that LED lighting is not harmful for a visual organ and for a human body as a whole. The materials of experimental studies provide the justification for regulation amendments in terms of LED application in the LF for various purposes.

## CONCLUSIONS

The performed series of LED lighting efficiency research allows you:

- To use a developed complex (comprehensive) methods of psychophysiological and hygienic assessment concerning the impact of lighting on the state of a visual organ and a human body as a whole for the study of illumination produced by LEDs, and by any other LS, as well as during the study of the of lighting impact on different age and gender groups;
- To carry out the development of illumination projects with a reasonable use of LED lamps, as for the buildings under construction so as for LF reconstruction;
- To reduce the energy consumption for lighting by replacing at least 30% of fluorescent lamps with the LED ones;
- To achieve additional energy savings at the implementation of flexible control systems for the luminous flux of LED lamps. Depending on the level of illumination automation the possible additional illumination energy savings will make 20 - 25% when the lighting is turned on and turend off discretely depending on the zonal distribution of natural light; 30 - 40% with a smooth power control and the luminous flux of lamps depending on the natural light distribution;
- To create conditions improving the efficiency of visual work and reducing the visual fatigue when a visually-intense work is being performed.
- The obtained results are the basis for further study of the LED light efficiency in various industries, within a field experiment.

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