RISK ASSESSMENT PRACTICE IN THE HYGIENIC AND EPIDEMIOLOGICAL STUDIES

UDC 616.036

HEALTH EFFECTS OF LED SCREENS FOR OPERATORS

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Front light on LED screens create an additional load on the operator by increasing the suppression of melatonin. The light spectrum emitted by an LED screen impacts the circadian rhythms, sleep schedule, and cognitive levels of work performance. The studies of potential use of LED-based lighting in professions related to road safety, in particular, train operators, drivers and dispatchers showed decreased functional stability in perceiving perception green and red, increased time of performing complex hand-eye reactions, and significant increase in preparedness for emergency actions.

Keywords*. LED screen, health risk, functional stability.*

Operators play an important role in managing today's information management systems that control complex energy and transport systems. Human efficiency has become the topic of several scientific publications [2, 4, 8]; however, those papers do not touch upon the health effects, including the impact on the visual sensory system, of the light spectrum emitted by the information display devices and lighting devices. In fact, the ability of an operator to perceive information, his/her psychophysical condition, and medical condition significantly influence the decision speed and adequacy in an emergency situation.

According to a research agency specializing in emergency planning, up to 10% of information system failures at the IMF banks happen due to a human error. Other American sources state that the impact of human factor on information system is even higher – up to 30%; including 18% due to a negligent and careless attitude to entering and processing information. A survey held in Russia in 2005 revealed that unintentional operator errors are considered the most serious threat [1].

Today information system operators work with LED devices that use LED screens. Since high-energy light-emitting diodes are widely used in various screens and illumination devices, impact of the light spectrum on vision and health of operators is becoming an issue of high importance [3,11,12].

The light spectrum of white light-emitting diodes has the following health effects for operators' health (provided that they work in shifts – day/night): operators' eyes, particularly at night, are impacted by the light from a flat screen that has RGB lighting as well as by the light from flat LED units (panels).

White light-emitting diodes use blue light-emitting diodes with a wave length of 455-465 nm, and transforming amber phosphors.

A basic wave length of a white light-emitting diode (460 nm) has a specific impact on vision and health of operators and serves as one of the main frequencies. At this electromagnetic pulse, human

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biorhythms are synchronized with the sun (a day/night cycle). Light hitting human eyes can cause various biological and behavioral effects: secretion of melatonin and cortisone, and daily variations, A research by the Department of Neurology at Thomas Jefferson University (USA) showed that in addition to cones and rods, human eyes have one more type of photoreceptors that do not influence the visual process. These cells are located in the lower part of the retina and contain a photolabile pigment – melanopsin, which modifies the light radiation of 460 nm into electric signals that are sent to the epiphyse which then synthesizes a certain amount of melatonin. The following physiological functions of melatonin are known today:

- biorythmological function;
- thermoregulation and sleep induction;
- antioxidant effect;
- immunomodulating action;
- antistress effect;
- regulation of sexual development.

It was determined that 70% of the daily amount of melatonin – a hormone that protects us from stress and early aging, cold-related diseases and even oncological diseases – are produced at night. A melatonin accumulation curve varies depending on a person's age and is unique, like fingerprints; it shows the amount of melatonin accumulated overnight that serves to prevent the formation of free radicals. Free radicals are considered to be deficient molecules that lack one electron and are trying to 'take it away' from the 'full-bodied' molecules. Melatonin's pronounced ability to connect free radicals lays in the nature of the antioxidant process. Melatonin deficiency in this process results in postponed clinical health effects. It was found that illumination of 1.3-4.0 lx of monochrome blue light or 100 lx of white light suppresses the production of melatonin. Melatonin suppression in the evening, when the artificial light is on, may shift the biological clock.

It is particularly dangerous to be sleeping in front of an LED monitor when the general LED light is on: it can suppress the production of melatonin even through closed eyes. Researchers from the Harvard Medical School in Boston were able to prove this theory through a survey. They invited 116 volunteers aged 18-30 to take part in the survey: 8 hours a day, five nights in a row, the volunteers were exposed to the light of various intensity – right before sleep and while sleeping. With the help of an intravenous cannula, the researchers drew blood from the respondents to measure the level of melatonin. It was determined that the higher the light intensity, the lower the hormone level, thought melatonin was supposed to reach its peak level in the period between 12 am and 4 am. Moreover, the presence of light during sleep lowered the level of melatonin in blood even more. "A seemingly innocent habit to sleep with a light on may easily result in hypertension and type 2 diabetes", - warns Professor Joshua Gooley, the head of the experiment.

It is noteworthy that many monitors or screens use LED light ('cold' white light-emitting diodes or RGB) which also suppress the production of melatonin. This fact is proved by a Sleep in America 2011 study conducted in the United States by the National Sleep Foundation (NSF). According to the agency, nearly all (95%) respondents admitted to using some sort of communication device (a smartphone, laptop, desktop, or tablet) for about an hour before going to bed. Using social networks, watching movies on a tablet with an artificial light in the room, surfing the net and other similar activities that prevent the brain from relaxing (the impact of the blue light from the screen illumination) and suppress the production of melatonin – a hormone that 'tells' the body it is time to rest (sleep). This impairs the internal biological clock and leads to sleep disorders.

LED light impacts not only human hormones and vision, but also the psychophysiological condition, work performance, and fatigability.

After the new sanitary rules and regulations for passenger transportation allowed for the use of light diodes in railroad transport, researchers from the Laboratory of professional Selection, Psychophysiology and Rehabilitation at the All-Russian Research Institute of Railway Hygiene, Rospotrebnadzor, conducted a study that focused on the possibility of the application of LED light in the work of employees involved in traffic safety, primarily, train operators, drivers, and dispatchers. The study involved volunteers of older age (old people have a lower level of melatonin as compared to young people). By the age of 45, human blood contains only half of the amount of hormones produced in the youth. Additionally, older people have a different amplitude and dynamics of the daily production of melatonin. The metrological assessment of the light units and workplaces was conducted by the Railway Research Institute that has a program on introducing LED lights at the Russian Railways sites. The study included four parts and used various traditional (lens-end lamp, luminescent) and new (light diodes) sources of light.

At the first stage, the researchers assessed the general state of health and, separately, the condition of the visual analyzer. At the second stage, they simulated the mental workload typical of operators.

At the third stage, they repeated the assessment conducted at the first stage.

To simulate an operator's workload, the researchers used the method of preparedness for an emergency action (PEA) which is widely used in similar situations and approved for use in railway transport.

The results of the study showed a lower level of functional stability in the perception of green and red colors, increased time of performing complex hand-eye reactions, and significant increase in preparedness for emergency actions in the respondents.

The comprehensive assessments of the psycho-physiological condition performed in the course of the experiment (plus - positive changes or trends, negative - negative changes or trends) were as follows:

- Incandescent lamp with a white canopy - plus 5
- Luminaire - minus 2
- LED flashlight with microlens diffuser - minus 5
- LED panel with a microlens diffuser - minus 9

The analysis of the above and earlier results [3] suggests the following:

- The white diode light spectrum and the used optics (light diode and light unit) determine the level of impact of the light on one's psycho-physiological condition. Direct exposure to LED light (LED luminaire raster made by the recommendation of the Research Institute of the Federal Council (open lens of white LEDs)) reduces work performance by more than a factor of 2, and increases fatigue test more than 2 times. Uneven illumination of LED lamp causes discomfort; its assessment using the generally accepted formula is incorrect and unacceptable;
- In terms of the level of melatonin, it is mostly dangerous to use cold LED (6000- 10000K) or even neutral (4000-5000K) white light in the evening or at night.The amount of produced melatonin is 2-3 times higher as compared to the lens-end lamp.
- The studies carried out by Poluprovodnikovaya Technika showed that it is not smart to replace the traditional light sources with LED without giving a good thought to it. Since LED luminous density is higher as compared to the traditional luminescent lamps, LED then have a stronger dazzling impact on people which leads to weaker work performance and higher fatigue.

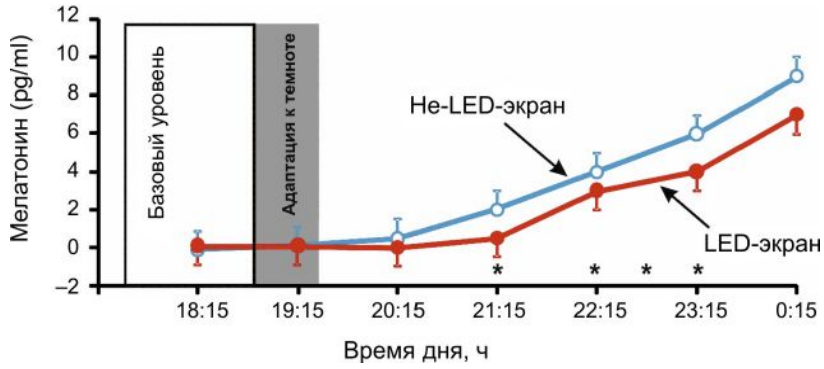
- LED light causes inadequate contraction of the pupil resulting in a higher dose of blue light reaching the retina as compared to the sun light of the same light intensity. The researchers called it "the melanopsin cross effect" for energy-saving lights [6].

An article by American researchers "Evening exposure to a light emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance" [10] suggests that in the evening and at night more and more people are spending a lot of time in front of LED-backlit screens. To study the effects of evening exposure to LED, the levels of melatonine (the marker of circadian physiology) and cognitive performance were assessed in 13 young male volunteers; the study was conducted in controlled laboratory conditions. The quality of PC screens (with a fluorescent lamp and light diodes) and visual comfort were assessed as being at the same level; however, it was noted that the screens with no fluorescent lamp LED light are brighter). LED-backlit screens emitted 3.32 times more light in the blue range between 440 and 470 nm as compared to fluorescent lamp screens,

The results of the study are presented below in figures 1-3.

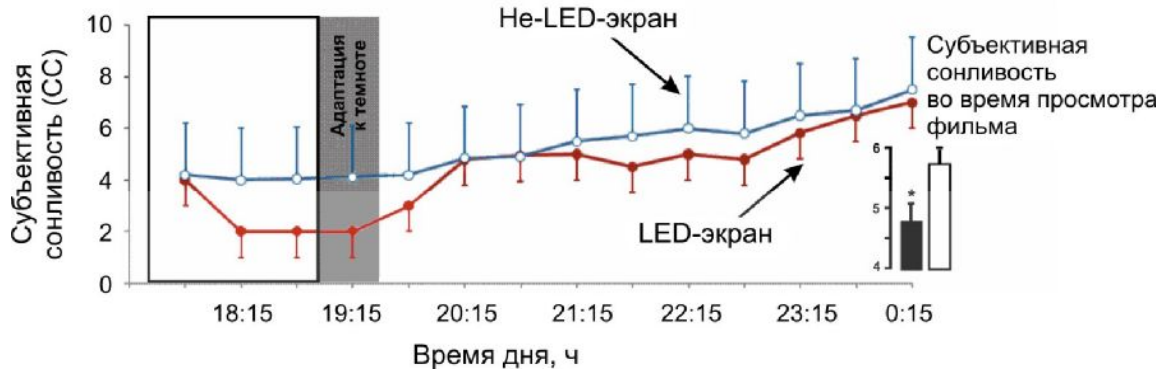
The figures show that the light spectrum emitted by the LED-screens affects the circadian rhythms, the cognitive performance levels, and drowsiness. The data above show that decreased drowsiness leads in a short-term increase of performance in a healthy person. Based on these results, the researchers emphasize the necessity to develop a program that will manage the spectrum of an LED-backlit screen with the account for the information about individual characteristics of a person's circadian rhythms. It is necessary to take into account the fact that RGB light parameters can affect the physical condition of a person.

Due to a short period of the study, it was impossible to identify all the consequences and health hazards of blue light. Major American epidemiological studies show that daily additional exposure to blue light during teenage years can result in the development of AMD by the age of 30 – 10 years before it normally develops under natural light; this increases the chance of blindness by 2.



a) Melatonin in saliva

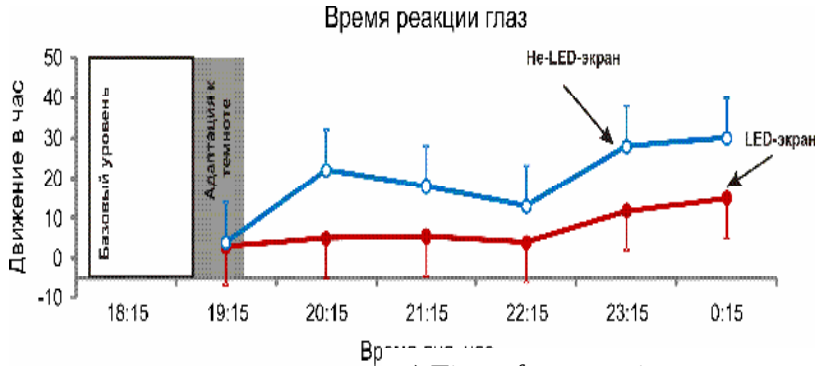
Melatonin (pg/ml)
Baseline level
Dark adaptation
He-LED screen
LED screen
Time of day, hour



b)Subjective drowsiness

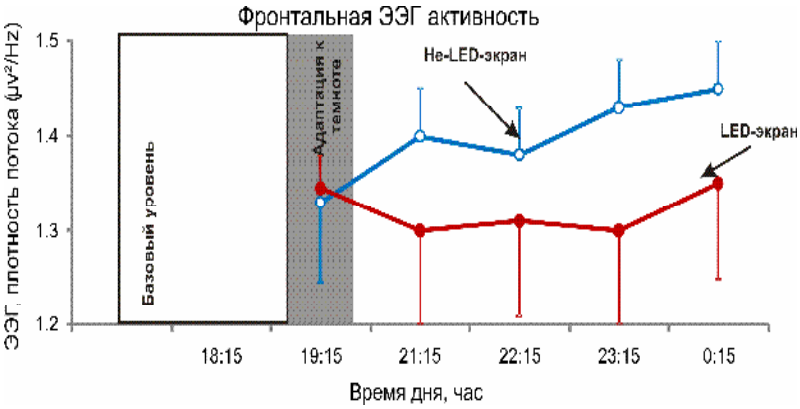
Subjective drowsiness (SD)
Baseline level
Dark adaptation
He-LED screen
LED screen
Subjective drowsiness while watching a movie
Time of day, ho

Figure 1. Decreased melatonin in blood (a) and drowsiness (b) when using different types of computer screens



a) Time of eye reaction

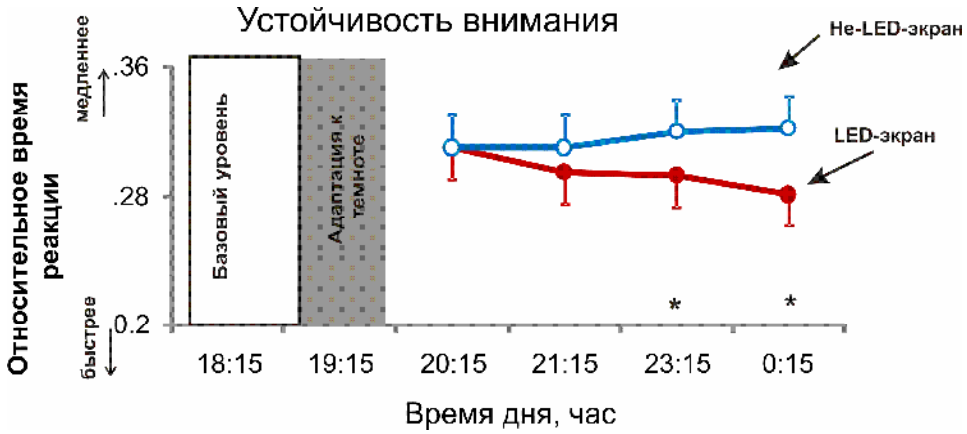
Movements per hour
Baseline level
Dark adaptation
He-LED screen
LED screen
Time of day, hour



б)

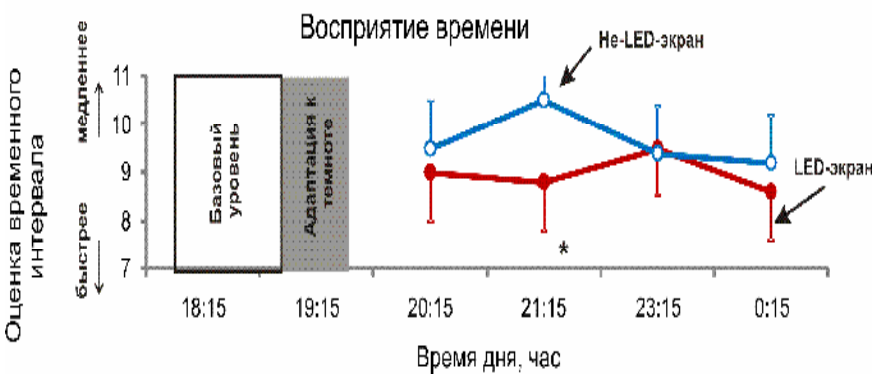
Frontal electrocortical activity
EEG, flow density
Dark adaptation
He-LED screen
LED screen
Time of day, hour

Figure 2. Time of eye(s) reaction and changes in EEG parameters (b) when using different types of computer screens



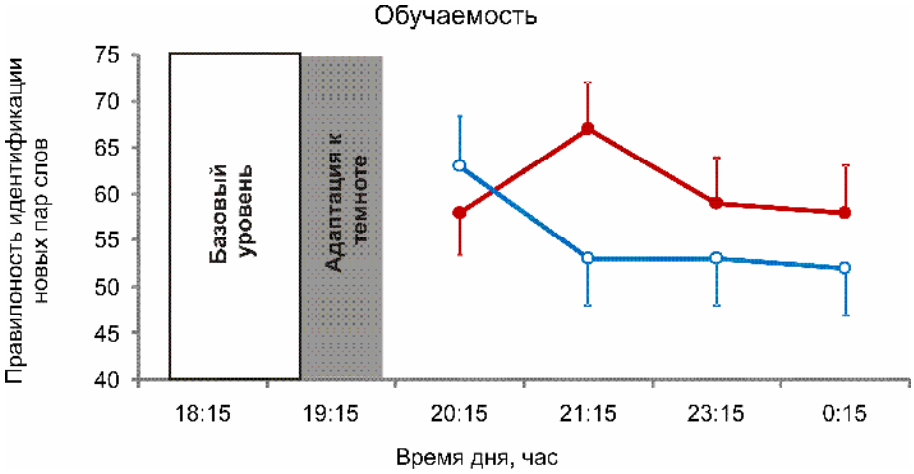
a) attention span

Relative time of reaction
Faster – slower
Dark adaptation
He-LED screen
LED screen
Time of day, hour



b) time perception

assessment of time interval
faster – slower
Dark adaptation
He-LED screen
LED screen
Time of day, hour



c) Learning ability

Correct identification of new word pairs
Dark adaptation
Time of day, hour

Figure 3. Attention span (a), change in time perception (b) and learning ability (c) under exposure to different types of computer screens

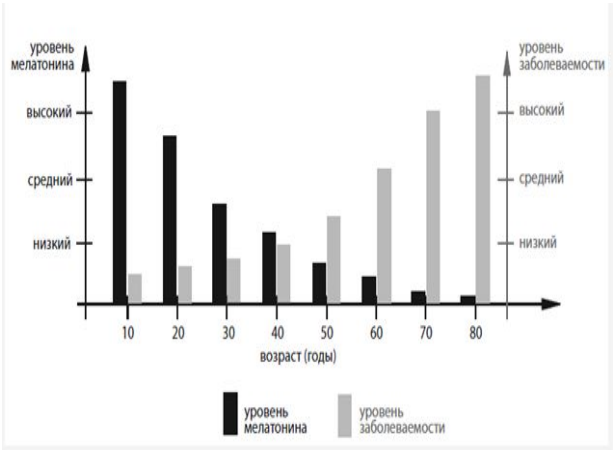
It is noteworthy, that modern screens are not normally in compliance with recommendations for protection from blue light effects on the hormonal system. However, there are some exceptions.

For example, AOS, a display manufacturer, has introduced a new technology that protects users' eyes from the negative impact of the LED screen's blue light. The developers have already submitted a patent application for the new product which they called simply Anti-Blue Light (ABL). Due to a new technology, the peak value of the length of the waves emitted by the backlight went up from 450 to 460 nm. According to AOS, even an insignificant change allows moving the blue component out of the 'hazardous' range. The 'hazardous' range includes the wave lengths from 380 to 450 nm. They impact a user's vision during long hours in front of a computer screen. Despite de-

creased intensity of the backlight, the new technology does not impact the quality of the picture. It does not use additional filters or software, and suppression of 'hazardous' waves does not lead to color imbalance. AOS is planning on introducing the new product into the monitor 76V Series. We just need to wait and see what other characteristics of the new product are to compare it with other solutions. For example, Philips SoftBlue monitors presented at IFA 2014 also protect the users from the 'hazardous' emission, like in AOS ABL, the product is based on controlling the LED backlight.

LED-backlit screens have a negative impact on the users because they suppress melatonin synthesis due to increased level of blue light (wave length – 460 nm) in the light spectrum. Increased performance of operators is good for the management (employer), but in a long term, it increased the accumulated deficit of melatonin. When the critical dose of melatonin deficit reaches its peak, an operator's performance goes down; this is true especially for older people (Figure 4).

Problems in the circadian rhythm accelerate degenerative processes in the brain that underlie dementia, Alzheimer's and Parkinson's syndromes. Neuroscientists from the University of Oregon, USA reported that irregular biological clock increased the risk of neurodegenerative diseases. The worse the biological clock is "tuned", the more nervous tissue is destroyed, and the more it is destroyed, the more irregular hours. Scientists admit it is possible to slow down the aging of the brain with a proper functioning of the biological clock and the pineal gland [7].



Level of melatonin
High
Average
Low

Figure 4. Age dynamics of the melatonin level in a human body and morbidity[1]

Today's trends in the development of LEDs and their implementation in a display device and lighting present certain health risks to operators – information system managers. All this is of concern for doctors as well as developers of new light sources [4].

New lighting products have recently hit the market. For example, following the doctors' recommendations, ELECTROSPELL has developed an innovative "tungsten" and RGB- LEDs with a spread spectrum [9]. In terms of the white light spectrum, they imitate conventional tungsten filament light bulb thus making them ideal for replacing incandescent lamps and lighting displays. The emission spectrum of RGB-LEDs with a spread spectrum is fully harmonized with the absorption spectrum of RGB-rods of the human eye. The use of these LEDs will reduce the proportion of blue light in the spectrum, under the melanopsin cross effect [6], and reduce the negative impact of LED panel display devices and lighting.

Thus, our studies show that:

- LED panel with LED backlight are increasingly used in displays and lighting devices at operators' workplaces; they significantly affect the synthesis of melatonin and accumulated deficit;
- Accumulated deficit of melatonin generates the risks of psychophysiological dysfunctions and reduces the time of occurrence and development of diseases among information systems operators;
- It is necessary to develop a software for managing the RGB-LED backlight spectrum taking into account the individual patterns of circadian rhythms of human operators;
- It is necessary to review the regulations on occupational safety and health, taking into account the negative impact of blue light in the spectrum of lighting and display devices.

[1] The graph is based on international research on age-related predisposition to chromic diseases and changes in the level of melatonin in blood

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