PREVENTIVE MEDICINE: URGENT ASPECTS OF RISK ANALYSIS

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TRANSPORT LIGHTING TECHNOLOGY: HEALTH RISK FOR STAFF AND PASSENGERS

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We have studied hygienic aspects of transport lighting technology and risks of negative influence exerted by LED lighting on operators, drivers and passengers' health. Transport lighting technology has long been examined, the focus of studies being influence of head-lights and signal lights on a driver's reactions and blinding. But we couldn't find any studies dedicated to influence of vehicles lighting on passengers' health; it may be due to the fact that incandescent lamps were usually used to light passenger saloons, and their characteristics were well-known. But as trips get longer, their intensity increases, and incandescent lamps are replaced with LEDs, an examination of influence exerted by lighting on passengers using all kinds of transport becomes quite relevant.

We should pay special attention to the fact that transport is used by millions of people including children who are regularly exposed to excess dozes of blue light. Exposure to this light can amount to more than an hour over one trip around a city and more than 5 hours for interurban trips. Specialists of "Biochemical physics institute named after N.M. Emmanuel" of Russian Academy of Science noted in their research works that up-to-date white LED have an apparent radiation fringe in blue-light-blue fringe 440-460 nm; this fringe is completely within action spectrum of photochemical damage to eye retina and its pigmentary epithelium. Such radiation is especially dangerous for children' and teenagers' eyes as their lenses are two times more transparent in blue-light-blue area, than adults' eyes. Photochemical damage to eye retina develops with time and it can lead to gradual irreversible visual impairment.

Negative influence risks become especially high when blue LEDs are used as lighting sources for motor transport passengers cabins. We have shown that when eye retina cells are damaged by an excess doze of blue light negative consequences are usually postponed. We have described the results of accelerated retina damage assessment made on Japanese quails (Coturniz japonica). These birds' eyes are totally analogous to human eyes. We have shown that moderate daily exposure to blue LED lighting leads to 1.5 times higher load on retina cellular metabolism in young birds which causes retina accelerated ageing and lower functional activity of hemoretinal barrier structure.

Key words: *excess doze of blue light, blue danger, transport lighting technology, blue LEDs, hemoretinal barrier, eye retina damage.*

Contemporary economy, defense capacity, national and food safety of a country are to a great extent provided by an up-to-date transport complex. As per Federal Law N 16-FL of February 9, 2007 "On transport safety" transport infrastructure includes usable transport networks or communication lines (roads, railways, air corridors, canals, pipelines, bridges, tunnels, and waterways) as well as traffic centers or terminals where cargos and passengers are transshipped from one kind of transport onto another (for example, airports, railway stations, bus stops, sea ports etc.). Passenger transport vehicles usually include ships, elevators, cars, buses, trams, trolleybuses, trains, subway, and planes.

This complicated system requires optimal control; here we mean control over traffic signals, railway points, flight control, as well as overall traffic control. Transport system control can be

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described as a set of activities aimed at efficient functioning via coordination, organization, ordering system elements, both between each other and between them and external environment.

Integrated transportation system scheme is shown in Figure 1.

This article deals with a problem common for practically all kinds of transport, namely efforts aimed at eliminating negative influence on passengers and transport companies staff exerted by widely spread up-to-date innovative light sources. The issue is pressing also due to the fact that within the frameworks of conventional transport lighting technology the main attention is paid to the influence exerted on visual analyzers by signaling devices light and heads lights [14,15,17,22], to accidents risks and professional risks [16,18,20,21], to staff health (air hostesses' health in particular) [19].

Transport lighting technology includes passenger carriages and saloons lighting systems, as well as head lights, signaling devices and traffic signals. Nowadays transport lighting technology is created under following conditions:

- applying LED lighting sources of high intensity [10];
- lower ceilings of passenger carriages and saloons (light sources are placed next to passengers' heads and in close proximity to eyes' retina);
- longer trips for passengers in a space with artificial light (longer period of negative influence);
- greater labor intensity (for transport drivers, transport system control operators and maintenance staff);
- necessity to conform to stricter safety requirements (signals identification in LED lighting environment).

Traffic control service is a very important part of transport system; its workers control moving objects' flows round –the –clock (in shifts). There are studies dedicated to influence exerted on operators' working capacity by LED lighting and

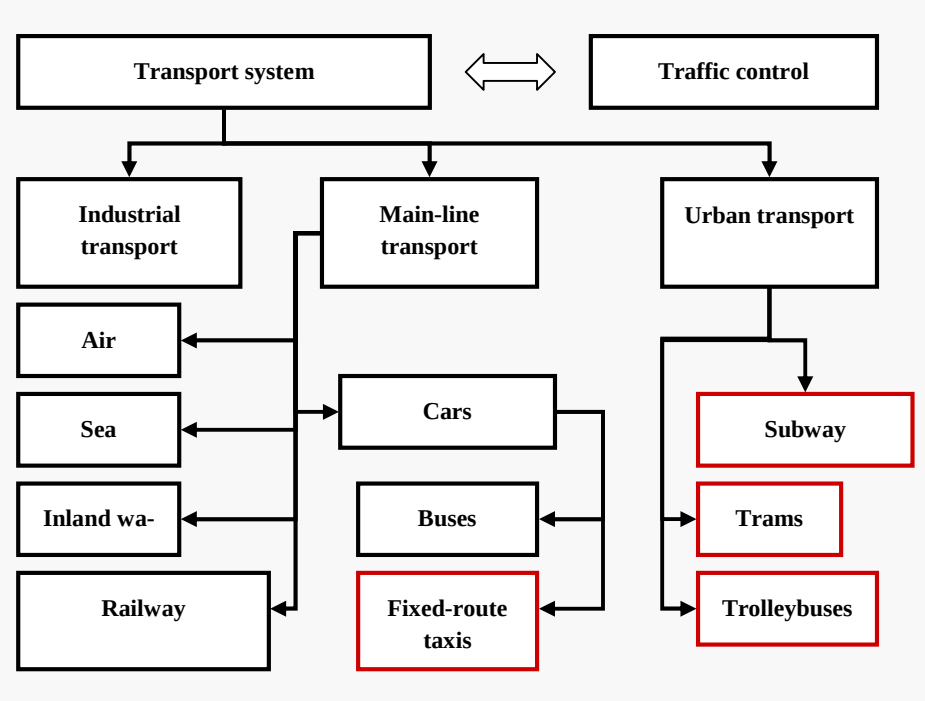


Figure 1. Integrated transportation system scheme

LED display light of PCs [8].

Subway is one of the most significant parts among urban transport.

Certain set of ideas on subway lighting technology was created as far back as in 30ties last century by S.M. Kravets, an architect who designed the first subway station. He wrote in his article [9], "when we work out the **interior layout** of a passenger carriage we should remember not only about strict requirements to it, resulting from static character of passengers' staying in it, but also about the fact that a subway passenger doesn't have any landscape to look at out of windows. His complete attention … is inevitably

concentrated on estimation of this interior layout. It leads to greater responsibility for engineers to create composite parts of all details, to use only qualitative materials, to do all the work properly. We do not need "luxury" of restaurant carriages and 'international" carriages, but at the same time we must not allow *shabby approach to interior layout similar to that which can be found in usual electric train carriages*. What we need is architectural details of junctions made from **polished wood**, all metal parts should be **nickel-plated**, glass should be **mirror-like**, and seats if they are going to be stiff are to be made of **oak** as it helps to avoid an impulse to paint them (it always makes any interior look cheap) and to achieve better amortization. Carriage lighting is to be abundant and should be made for sitting and standing places in a different way. Seats are to be equipped with a line of brackets above the windows and on side walls; as for standing places they are to be lit by 2 rows of lams on carriage ceiling. All lighting sources are to be devoid of direct *blinding effect*; and while other variants are unavailable, use old VEO lamps, later on all lighting devices for subway carriages will be made according to *special subway models design*" [9].

But time went by and professional subway designers were replaced by engineers with professional experience in the sphere of railways. And subway lighting concept changed as well.

An issue of contemporary requirements to subway objects' lighting has been studied quite profoundly [2–5].

We can't imagine contemporary motor transport without LEDs. If previously they were placed in brake signals and back lights only, nowadays they are used practically everywhere, including turn indicators, dashboard lighting, radio light, internal lighting of a car, and in head lights. LEDs market for car-making industry grows by 16.2% annually, having increased from $542 million in 2008 to $1.2 billion in 2013 (fig. 2).

Nowadays white LEDs are becoming more widely used for car saloons lighting [10]. Market of car saloon LEDs lighting is rather small but it has a great influence on drivers' and passengers' health.

This influence is well-known, but it becomes even greater in motor transport saloons, especially in modern fixed-route taxis, as a distance to light sources and their spectrum is very small. In particular, blue LEDs are used for interior lighting [Fig.3–6].

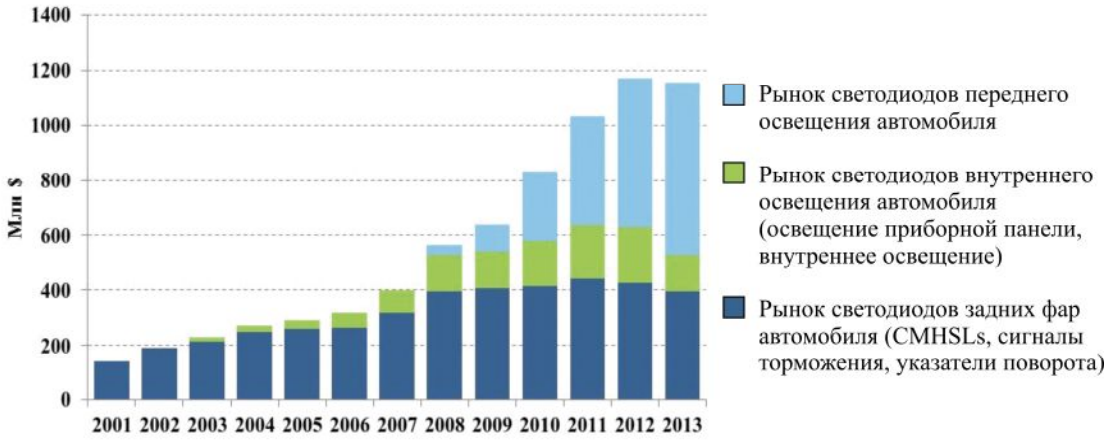
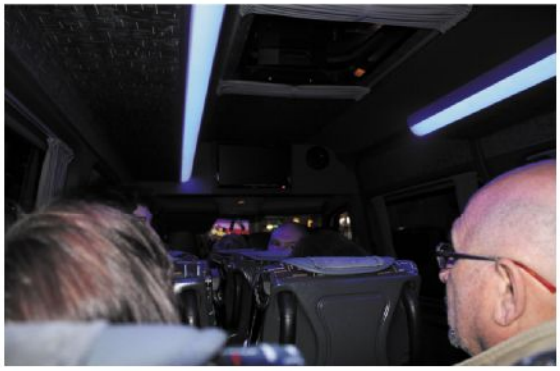


Figure 2. Use of LEDs in automobile electronics [10]

Legend: head lights LEDs market; internal LEDs lights (dashboards lighting, internal lighting); back lights LEDs market (CMHSLs, brake signals, turn indicators)

a

b



c

d

Figure. 3. Options for the interior lighting of passenger transport: *a* – fixed-route taxi saloon lighting in Minsk[1]; *b* – LED lighting in a bus saloon[2]; *c* – Moscow excursion bus with blue LED lighting[3]; *d* – Mercedes-Benz Sprinter excursion bus with blue LED lighting[4]

[1] Onliner. – URL:http://contener.bynt.onliner.by/news/2015/02/default/8b9caf8a259bee9b3a999296410bbfdf.jpg.
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It results from fixed-route taxis drivers and heads of transport companies not knowing about blue danger for children's eyes; and sanitary inspectors when certifying vehicles don't recommend transport companies management to replace blue light inside fixed-route taxis with another one.

Buses with blue LED lighting run on every road in Russia; particularly, in Moscow, Crimea resort zones (Sevastopol and Yalta) and Krasnodar region.

White LEDs and blue LEDs have an apparent radiation fringe in blue-light-blue fringe 440-470 nm which is completely within spectrum of action doing photochemical damage to eye retina and its pigmentary epithelium. Such radiation is especially dangerous for children' s and teenagers' eyes as their lenses are two times more transparent in blue-light-blue area than adults' eyes. A yellow spot which should protect retina cells from negative influence exerted by blue light (460 nm) is not always developed completely. Photochemical damage to retina developes with time and can result in gradual irreversible visual impairment. Using LED light sources may have unpredictable negative and irerversible consequences for child eyesight and requires serious professional ophtalmologic and physiological justification [6]. Newborns have yellow spot of light-yellow colour with fuzzy contours. When a child is 3 months old, a macula reflex develops in his or her eyes, and yellow colour intensity reduces. By the end of the first year a foveolar reflex develops, yellow spot center becomes darker. In 3-5 years old children yellow colour of macula area almost mingles with rose or red colour of retina central zone.

Yellow spot area in 7-10 years old children and in elder ones is defined by avascular retina central zone and light reflexes.

To get an accelerated assessment of influence exerted by blue light on human eyes, scientists in photochemistry and photobiology department of Biochemical Physics Institute named after N.M. Emmanuel, Russian Academy of Science, carried out research dedicated to blue light influence on Japanese quails' (*Coturnix japonica)* eyes. These birds' eyes are biologically similar to human eyes and have a yellow spot to protect retina [7,12]. During the research *Coturnix japonica* quails were placed into cages lit by incandescent lamps, blue LEDs and yellow light (figure 7).

The research results showed that blue LEDs light exerts the following influence:

- it causes changes in choroid [12];
- it leads to photo-induced changes in subcellular structures of retina pigmentary epithelium [7].

It was detected that moderate daily blue LED lighting of young animals caused 1.5 times greater load on retina cellular metabolism than normal which led to its accelerated ageing and to lower functional activity of hemoretinal barrier. Hemoretinal barrier is a part of blood-ocular barrier which protects retina tissue from large molecules which can penetrate into it from blood vessels. There are two hemoretinal barriers, an external and internal one:

– internal hemoretinal barrier is formed by close contacts of retina blood vessels endotheliocytes, like hematoencephalic barrier (for retina internal layers);

– external hemoretinal barrier is sustained mostly by retina pigmentary epithelium (for retina external layers). Retina pigmentary epithelium serves as a mediator between choriocapillars of choroid and photoreceptors.

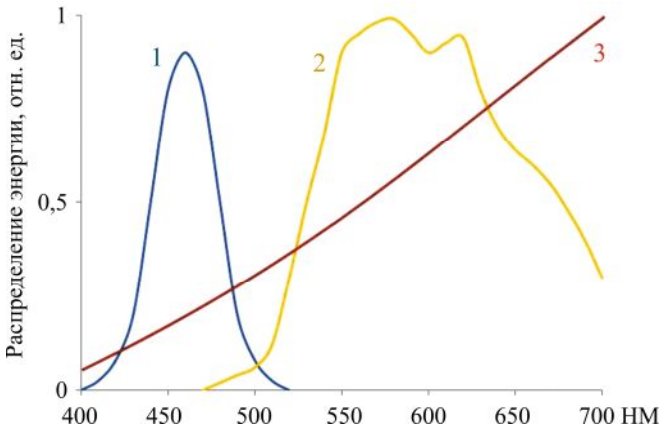
Figure 8 shows integrated results of light effect (incandescent lamps and blue LEDs) on functional activity of hemoretinal barrier structures.

As we can see form the graph, changes in functional activity of hemoretinal barriers structure in remote future can develop in quails which were placed in cages lit by blue light; on the contrary, light environment of incandescent lamps doesn't have similar effects. Such changes in functional activity of hemoretinal barrier can lead to rapid development of eye diseases.

American epidemiologic research showed that daily additional influence exerted by blue light on eyes of a young man in teenage years results in retinopathy (AMD) by 30 years of age which is generally 10 years earlier than in case of natural light.

If a man stays in light environment created by LED lighting for a long time it may lead to higher risks related to identification of objects' colours, colour of signals in particular. Specialists of the laboratory for professional selection,

a



1 – «blue lighting, 2 x 10^{-3} Wt/cm^2.
2 – yellow lighting, 2 x 10^{-3} Wt/cm^2.
3 – Incandescent lamps, 2 x 10^{-3} Wt/cm^2 200 meter-candela.

b

Figure. 7. Integrated data on conditions of research accomlished in Biochemical Physics Institute named after N.M. Emmanuel, Russian Academy of Science: a – quails' cages lighting by incandescent lamps, yellow light and blue LEDs; *b* – light spectrums for cages' lighting colour and energy parameters of lighting

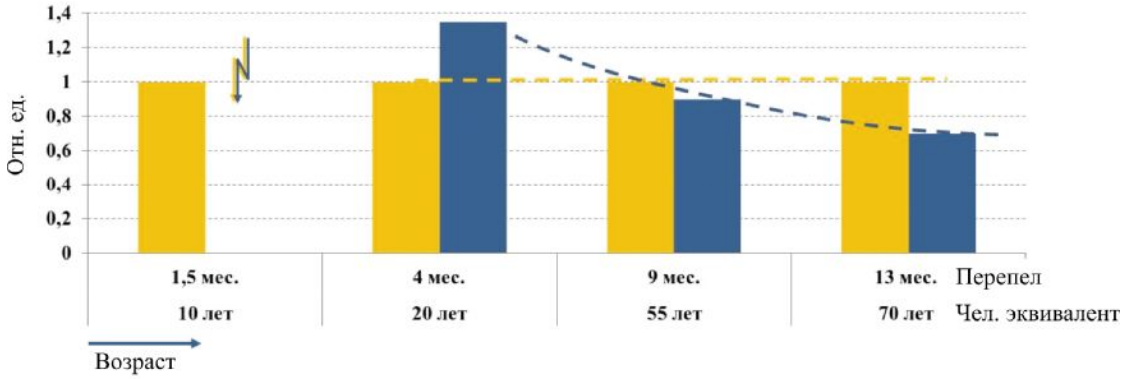


Fig. 8. Functional activity of hemoretinal barrier structures (Report by Zack P.P. Biochemical Physics Institute named after N.M. Emmanuel, Russian Academy of Science). X-axis – age, Y-axis – relative units

psychophysiology and rehabilitation in Rospotrebnadzor Russian Scientific Research Institute for Railway Hygiene accomplished some research devoted to influence exerted by LED light and light from conventional lamps on a man's psychophysiological state (driver of a railway rolling stock at Russian Railways - RZD). Metrologic assessment of lamps and working places was made by leading experts in the labor protection sphere from Russian Scientific Research Institute for Railway Hygiene; they are responsible for implementing LED lighting schemes on the company's objects.

Integrated results are presented in the table.

[5]Report of the PP Zach FGBUN "Institute of Biochemical Physics. NM Emmanuel "RAS

Table

Integrated results of the research carried out by
Russian Scientific Research Institute for Railway Hygiene (20)

Parameters	Psychophysiological assessment (points)			
	Incandescent lamp with white bowl	Fluorescent lamp	LED torch with microlense diffusers	LED board with microlense diffuser
Assessment accomplished as per certified technique parameters	Plus 5	Minus 2	Minus 5	Minus 9

NB. Plus means positive trends (changes); minus is negative trends (changes)

During research there were some situations when examined staff mixed signal colours up in LED lighting environment [1,5].

So, an excess doze of blue light in LED lighting devices in vehicles and transportation systems leads to higher risks of its negative influence on passengers' eyes, especially children [11].

American Medical Association (AMA) in its report dated June 2016 informs about LED lighting danger [13], and in some European countries one can already see a sign "Danger, LEDs" (Danger ampoules a LEDs).

Conclusions:

1. Systematic influence exerted by blue light on human eyes (especially children) can have negative consequences in the nearest and remore future.

2. It is advisable to exclude blue lighting application from passenger saloons' lighting schemes in order to prevent risks of eyes damage.

3. To secure safety in trasnportation systems and prevent visual and non-visual negative effects, it is necessary to use certified lighting sources with biologically adequate light spectrum.

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