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Considerations regarding the impact of artificial lighting on health

Considerații privind impactul iluminatului artificial asupra sănătății

Iasmina-Daiana Holecică[1], Andreea-Miruna Tokar[2]
Coordinator: Dănuț Tokar[3]

[1] University Politehnica Timisoara
2, Victoriei Square, Timisoara, Romania
E-mail: iasmina.vig@upt.ro

[2] Faculty of Medicine and Pharmacy-University of Oradea
1, Universitatii Street, Oradea, Romania
E-mail: tokar.andreeamiruna@student.uoradea.ro

[3]University Politehnica Timisoara
2, Victoriei Square, Timisoara, Romania
E-mail: danut.tokar@upt.ro

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Abstract. *The article presents quantitative and qualitative aspects of lighting, its influence on activities carried out in educational and health spaces, and the impact of artificial lighting through its effects, especially blue light, on health.*

Key words: artificial lighting, blue light, LED, health

1. Introduction

The role of lighting in buildings is to ensure the quantity and quality of light, natural or artificial, so that activities can be carried out in hygienic and healthy conditions throughout the day. Although, from the point of view of the positive effect on the mental state of the occupants, but also on the properties of the rooms, natural lighting is preferred, due to the multitude of uncontrollable factors (seasonal and daily variation of brightness, limitation of glazed surfaces, etc.) artificial lighting is the one that replaces daylight. In this context, artificial lighting, depending on the purpose of the buildings, must allow the occupants to easily perceive the visual task, improve precision for a better performance of the activities carried out, not to have a risk of accident (too weak light), not to damage the vision through glare or generate visual

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fatigue. Thus, optimal lighting levels are defined for a wide range of spaces, activities/areas or visual tasks.

Table 1 presents the level of illumination, and Table 2 presents a selection of recommended values for the design of general lighting systems that refer to buildings intended for educational and public health institutions (hospitals and clinics) [1].

Table 1

Lighting level [1]

Lightings level (lx)	**Type of activity/Visual perception**	**Examples of destinations**
20-30-50	Areas intended for circulation, storage	Secondary corridors, dryers in industry **)
50-100-150	Areas for circulation, simple orientation or temporary visits	Corridors, halls, warehouses, storerooms
100-150-200	Rooms where work activity is not continuous	Main halls, stairs, escalators
200-300-500	Simple visual perception	Theater, concert halls, canteens, industrial machine rooms, general factory lighting
300-500-750	Medium visual perception	Gymnasiums, classrooms, on library shelves, assembly areas
500-750-1000	Imposed visual perception	Offices (writing, reading, with computers), laboratories (where precise measurements are made)
750-1000-1500	Difficult visual perception	Fine assembly (mechanics, electronics), sewing, knitting rooms, final inspection
1000-1500-2000	Special visual perception	Precision work (electronics), color control, jewelry workshop
Peste 2000	Very accurate visual perception where high performance is required	Boxing rings, medical operating tables

**) Where color identification is not required

Table 2

Recommended values for the design of general lighting systems [1]

Types of destinations, activities or visual perception	**E_m**		**UGR_L**	**R_a**	**H_u**	**U_0**	**Remarks**
	minimum	**compensation**					
Educational institutions							
Playrooms	300	500	22	80	0.00	0.40	
Nursery and kindergarten classrooms	300	500	22	80	0.00	0.40	
Consultation rooms	300	500	19	80	0.70	0.60	
Classrooms	500	1000	19	80	0.70	0.60	For classrooms intended for young children, the minimum lighting level can be reduced to 300 lx.

Types of destinations, activities or visual perception	**E_m**		**UGR_L**	**R_a**	**H_u**	**U_0**	**Remarks**
	minimum	**compensation**					
Classrooms for evening classes or for adults	500	750	19	80	0.70	0.60	
Reading rooms	500	750	19	80	0.70	0.60	
Blackboard	500	750	19	80		0.70	On the board. To be avoid veiling reflections
Demonstration board in lecture halls Workshops	500	750	19	80		0.70	On the board. To be avoid veiling reflections
Workshops	500	750	19	80	1.0	0.60	
Art workshops in art schools	750	1000	19	90	0.7	0.70	4000 K $\leq T_{cp} \leq$ 6500 K
Technical drawing rooms	750	1000	19	80	0.7	0.60	Pe planșetă
Laboratories	500	750	19	80	0.7	0.60	
Amphitheaters	500	750	19	80	0.7	0.60	
Music rooms	300	500	19	80	0.7	0.60	
Computer rooms	300	500	19	80	0.7	0.60	
Language laboratories	300	500	19	80	0.7	0.60	
Study Rooms Sports	500	750	22	80	0.7	0.60	
Student Common Rooms and Meeting Rooms	200	300	22	80	0.7	0.40	
Teacher's room	300	500	19	80	0.7	0.60	
Halls and Swimming Pools	300	500	22	80	0.0	0.60	For public access areas, the values are correlated with the SR EN 12193:2019 standard.
Entrance halls	200	300	22	80	0.00	0.40	
Corridors, circulation areas	150	200	25	80	0.00	0.40	
Stairs	150	200	25	80	-	0.40	Lighting is done at the level of the stairs.
Teaching material warehouses	100	150	25	80		0.40	On the shelves.
Hospitals and clinics							
Waiting rooms	200	300	22	80	0.00	0.40	-
Corridors, day	-8î	200	22	80	0.00	0.40	-
Corridors, night	50	-	22	80	0.00	0.40	-
Staff offices	500	1000	19	80	0.7	0.60	-
Staff rooms	300	500	19	80	0.7	0.60	-
General lighting in the rooms	100	200	19	80	0.00	0.40	Floor-level lighting. By local lighting on the
- reading in the rooms	300	750	19	80		0.70	

Types of destinations, activities or visual perception	E_m		UGR_L	R_a	H_u	U_0	Remarks
	minimum	compensation					
- simple examination in the rooms	300	500	19	80		0.60	usable surface.
- examinations and treatments	1000	1500	19	90		0.70	
- nighttime/observation lighting	5		-	80		-	
Patient bathrooms and toilets	200	300	22	90		0.40	At the mirror
General lighting in consulting rooms	500	750	19	90	0.70	0.60	4000 K ≤ T_{cp} ≤ 6500 K
Eye and ear examinations	1000	1500	-	90	-	-	4000 K ≤ T_{cp} ≤ 6500 K
Vision tests (reading and color)	500	750	16	90		0.70	On the test surface 4000 K ≤ T_{cp} ≤ 6500 K
Dialysis rooms	500	750	19	80	0.70	0.60	-
Dermatology rooms	500	750	19	90	0.70	0.60	-
Endoscopy rooms	300	500	19	80	0.70	0.60	-
Dressing rooms	500	750	19	80	0.70	0.60	-
Massage and radiotherapy rooms	300	500	19	80	0.70	0.60	-
Saloane preoperator și de reanimare	500	750	19	90	0.70	0.60	-
Operating rooms: - general lighting;							
- general lighting;	500		19	90	0.70		3 x 3 m^2 around the table
- general lighting around the operating table;	1000		19	90	0.70		
Local lighting operating table.	10000-100000		16	90			On the operating field
Intensive care:							
- general lighting;	300	500	19	90	0.00	0.60	At floor level
- simple examinations;	500	750	19	90	0.00	0.60	
- examinations and treatments;	1000	1500	19	90	0.00	0.70	At bed level
- nighttime surveillance.	20	-	19	90	0.00	-	On examination surface
Dentistry:							Lighting must not present a risk of blinding the patient
- general lighting	500	750	19	90	0.70	0.60	
- local patient lighting	1000	1500	-	90		0.70	Local examination lighting
- local lighting operation	5000			90			On the operator

Types of destinations, activities or visual perception	E_m		UGR_L	R_a	H_u	U_0	Remarks
	minimum	compensation					
							field. Values higher than 5000 lx may be required
- jointing, adjustment white teeth	5000			90			T_{cp} at least 6000 K
Laboratories and pharmacies	500	750	19	80	0.7	0.60	-
Color control (laboratories)	1000	1500	19	90	0.7	0.60	4000 K ≤ T_{cp} ≤ 6500 K
Sterilized/disinfected rooms	500	750	22	80	0.7	0.60	-
Autopsy rooms and morgues	500	750	19	90	0.7	0.60	-
Autopsy and dissection table	5000	7500	-	90	0.7	0.60	Values higher than 5000 lx may be required

Note: E_m represents the recommended illumination level on the reference surface, in lx; UGR_L – the limit value of the UGR index (unified glare index) corresponding to the type of destination, activity or visual load; R_a – the general color rendering index; H_u – the height of the reference surface when it is parallel to the floor/useful plane, in m; U_0 - the minimum value of the illumination uniformity coefficient on the surface of the useful plane.

In the specialized literature, it is estimated that insufficient lighting creates a series of consequences, including [2]:
- visual fatigue;
- decreased work capacity;
- sensations of stinging or foreign bodies in the eyes;
- the appearance of vision disorders or even conditions such as myopia;
- increased waste;
- risk of trauma.

On the other hand, excessive lighting can produce a series of negative phenomena that refer to photophobia, tearing, pain in the eyeballs, headaches, etc. [2].

Hygienic requirements for room lighting refer to the following aspects [2]:
- to ensure a satisfactory level in the entire field of view;
- to ensure an optimal level for various activities;
- to be relatively uniform; to protect the eyes from radiation coming from the source or the reflection of surfaces;
- to ensure adequate radiation to avoid shadows;
- the light from artificial sources should have a spectrum as close as possible to that of natural light.

Even though the European Commission's SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks) committee states that it is very unlikely that artificial lighting is the cause of eye discomfort or even eye damage [3], there are still sources that express some concerns and emphasize the importance of choosing the type of lighting, the quality of light sources, and changing lighting levels [4, 5]. However, in 2012, the same document [3] states that there is still a lack of relevant data regarding the effects of lighting on some medical conditions and that blue light and ultraviolet radiation are a potential risk factor for worsening symptoms in some patients with diseases such as chronic actinic dermatitis (a chronic papulopustular and eczematous facial dermatitis) and solar urticaria (Solar urticaria is a rare form of chronic inducible urticaria in which the skin swells within minutes of exposure to natural sunlight or an artificial light source that emits ultraviolet radiation.).

For this reason, it is very important that the choice of artificial light sources in healthcare buildings (hospitals, medical clinics, etc.) is well regulated. From the point of view of lighting installations for hospitals, in Romania, the regulatory framework is regulated by NP 015-2022 [6], which, however, does not address these aspects by referring to NP 061-2002 with the amendments and additions of 2023 [1], to the I7-2011 standard with subsequent amendments and additions [7] and to a series of standards, including SR EN 12464-1 [8], SR EN 12665:2024 [9], etc. On the other hand, various international institutions have established regulations for hospital lighting that take into account the safety and comfort of the patient, as well as of the hospital staff, namely: ANSI/IES RP-29-16 which recommends two different levels of lighting, one for the day and the other for the night correlated with the natural ability of the eye to adapt to the lighting conditions [10]. For example, the ANSI/IES RP-29-16 standard provides for a hospital lobby lighting of 800 lux during the day and 400 lux at night, taking into account the recommended lighting level for patients over 65 years old [10, 11], compared to the Romanian standard [1], which provides, according to Table 2, the values of 200 lux during the day and 50 lux at night. It can be seen that there is a difference in approach regarding the safety and comfort of patients and medicated staff, in favor of energy saving.

In general, in artificial lighting, certain types of lamps (including incandescent bulbs) can emit low-level UV radiation, which may increase the incidence of squamous cell carcinoma. The SCENIHR Committee [3] states that blue light from LED lamps and generally from improperly used lamps could theoretically induce retinal diseases, but other eye damage from chronic exposure to artificial light under normal lighting conditions is unlikely [3].

2. The main concepts addressed in lighting technology

Luminous flux represents the radiant flux emitted in the visible spectrum, evaluated by the intensity of the visual sensation. The radiation is emitted in the entire space around the light source. The unit of measurement is the Lumen (lm) and this measurement provides the best comparison between two sources that do not have directional light (>120°) (Figure 1). Between two lighting fixtures with directional light, the appropriate basis for comparison is the luminous flux emitted in an infinitely small solid angle. The unit of measurement is the Candela (cd) (Figure 1).

Unfortunately, the specifications only provide for the specification of the flux of the light sources, which in the case of light sources with a narrower angle distorts the comparison. The illumination of a surface is characterized by the density of the luminous flux on the surface whose unit of measurement is Lux (lx) [12] (Figure 1).

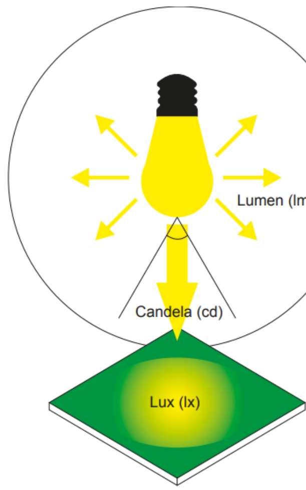


Fig. 1. Illumination of a surface [12]

Color rendering index

To express the color rendering index, worldwide, there are several expressions:
- general color rendering index (Ra) – used in Europe and Asia;
- special color rendering index (R9) – which measures the transmission of red tones;
- color rendering index CRI – used worldwide.

However, the CRI score is the most widely used measurement in North America and is internationally recognized as the standard measure of color rendering. The color rendering index (CRI) is a ratio that shows how accurately an object illuminated by artificial light reproduces its colors compared to natural light. The CRI ranges from 0 to 100, with a score of 100 representing perfect color rendering, meaning that the colors of objects illuminated by the light source appear exactly as they do in natural sunlight. Sunlight is considered to be 100, the minimum prescribed index for indoor lighting is 80, and for outdoor and industrial lighting it is a minimum of 70 [12,13]. The color rendering index is a critical factor in the design of lighting systems for applications where accurate color rendering is essential (laboratories, work areas for medical or care activities with high risk potential, etc.). The lower the index, the more inaccurately the colors are rendered, which can cause color distortion and affect the perception of the subject's appearance. An example of this is shown in Figure 2 [12,13].

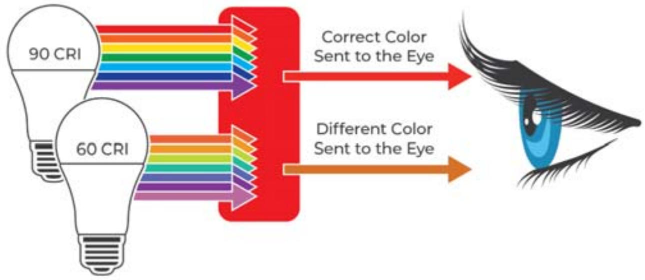


Fig. 2. Color perception by the human eye according to the CRI index [13]

Color rendering index has a significant impact on the ability to accurately assess organ anatomy during surgery. High CRI illumination ensures accurate color rendering of tissues and anatomical structures, helping to differentiate healthy from diseased tissues. Many anatomical structures present similar coloring and vastly complex anatomical particularities such as shape and positioning, as seen in Figure 3. Intra-operatory, the ability to accurately differentiate between anatomical structures is crucial. Thus the CRI standard is highly important in operating rooms.

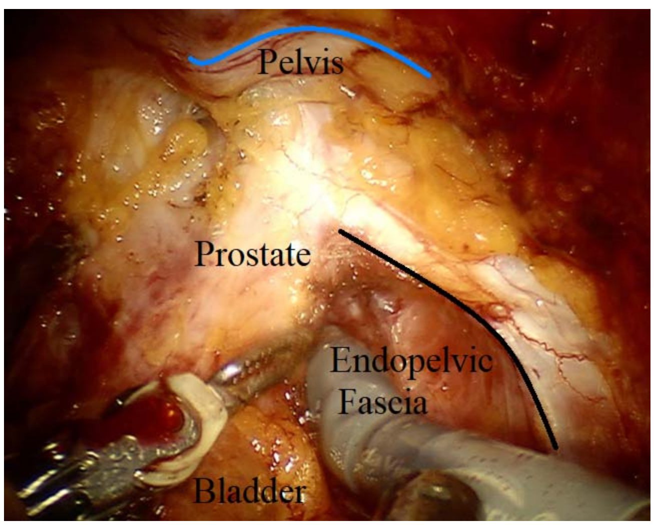


Fig. 3. Differentiating between various tissues[14]

The CRI index is calculated by comparing the color rendering of the light source to that of a reference light source for a set of eight color samples representing different hues, saturation levels, and skin tones, and assigned a value based on how accurately they are rendered by the tested light source. The results are then averaged to determine the color rendering index for the tested light source [13].

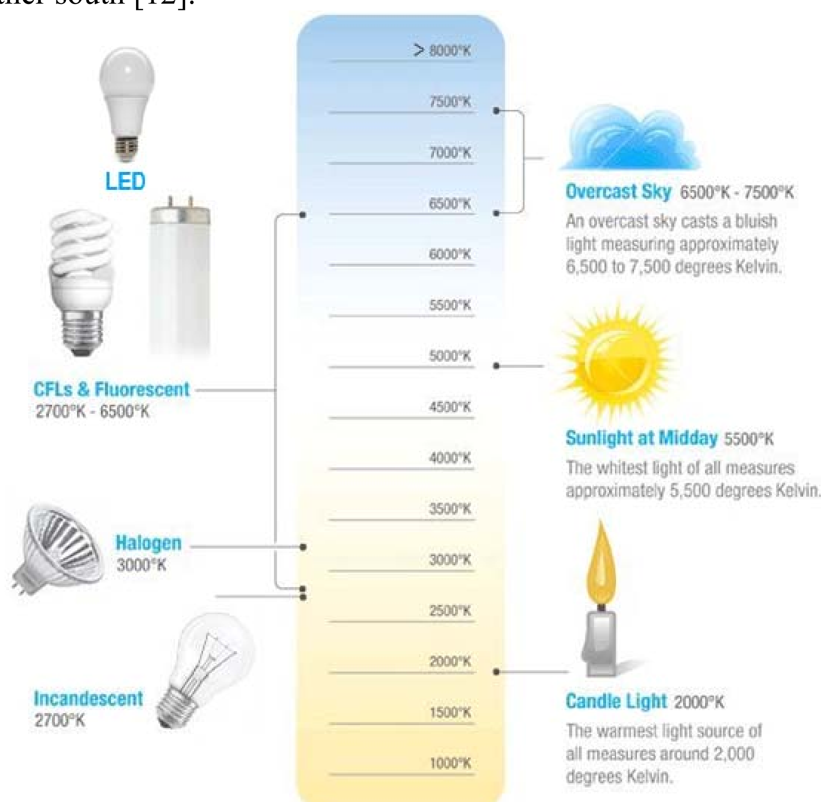
The CRI index is used to select suitable light sources for specific applications. LED lighting has become increasingly popular in recent years due to its energy efficiency and long lifespan. However, the CRI of LED lights can vary greatly, with some models scoring as high as 60 or 70. The general rule is: the higher the color rendering index, the better the color rendering ability. However, the CRI is not dependent on the color temperature. LED lights with lower CRIs can distort colors and make it difficult to distinguish them accurately. In contrast, LED lights with higher CRIs, typically above 90, can provide excellent color rendering, making them ideal for applications where accuracy is important.

But, CRI index is not the only factor to consider when choosing a light source, as it does not take into account other aspects of light quality, such as temperature, brightness, and color consistency. However, it is an essential measure of color rendering and can provide valuable information when selecting a light source for specific applications.

In conclusion, CRI plays a vital role in lighting design, as it determines how well a light source can illuminate colors compared to natural sunlight.

Color temperature

Artificial lighting is correlated with the color temperature which is given in degrees Kelvin (K), essentially determining the ambient lighting. The higher color temperature is cooler, and the lower one designates the warmer light. Sunlight has an average value of 5500 K, which at sunset and sunrise warms up to around 4800 K. In general, in the range of 2700-3500 K of the color temperature we call it warm light (yellow-red range), in the range of 3500-5000 K neutral light and 5000 -6500 K cool light (green-blue range), aspects highlighted in Figure 3 [16, 17]. Geographically, warm light is more popular towards the north, while neutral and cool light are more popular further south [12].



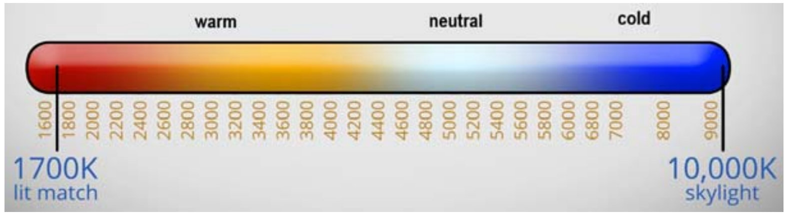


Fig. 3. Color temperature of light sources [16], [17]

LED sources are made up of several LEDs grouped in the same source to obtain higher luminous fluxes. In commercial LED sources, the color temperature can vary from 2800K to 12000K, with color rendering ranging from poor to excellent. Figure 4 shows the light spectrum obtained by 3 LED sources on the market. The difference in spectral shape is given by the execution technology of the LED source. To obtain cool and neutral color temperatures, single-chip LEDs are usually used, and for warm color temperatures, dual-chip LEDs are used.

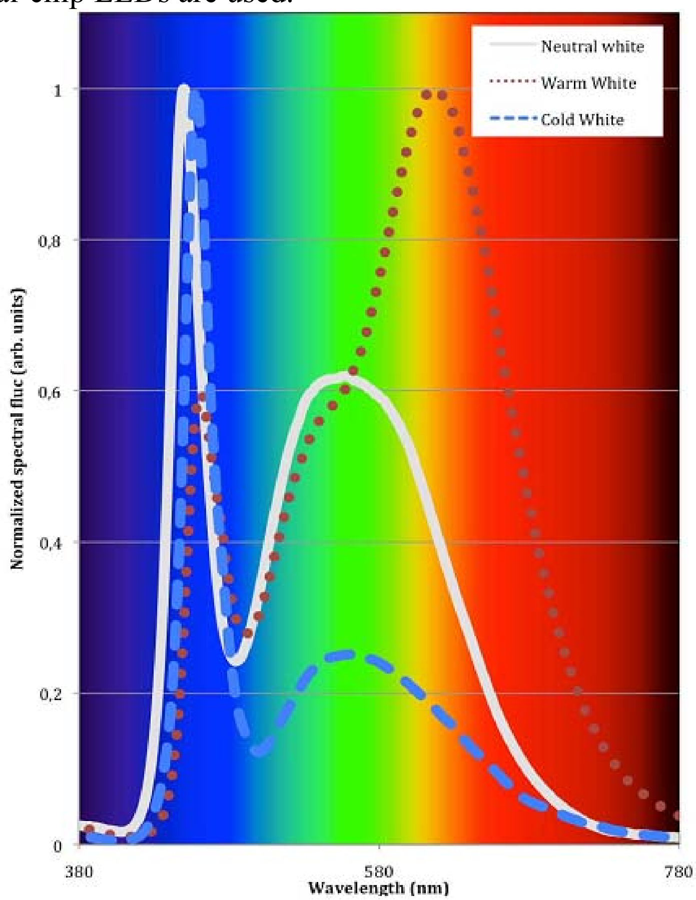


Fig. 4. The spectral flux of three different types of LEDs [3]

3. Light that affects health

With the pandemic, exposure to blue light from backlit screens and digital devices has increased. In fact, blue light, like any other visible color, is everywhere in the environment. The sun, fluorescent light sources, incandescent light sources, and light-emitting diode (LED) technology all emit blue light, so people are exposed to a lot of blue light [18].

Some eye health experts have expressed concerns about exposure to blue light from backlit digital screens and devices. A 2020 study [19] found that so far, research in humans has not shown any concern about eye damage from blue light, but some animal studies have shown that blue light can damage cells in the retina [20]. It is known that the eye has structures that protect it from certain types of light (for example, the cornea and lens protect the light-sensitive retina at the back of the eye from harmful UV rays) (Figure 5 [21]).

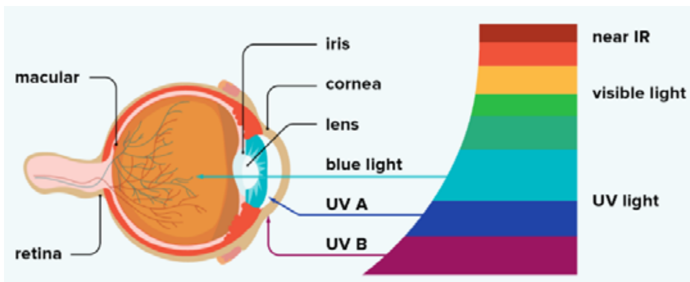


Fig. 5. The structure of the eye's protection from light [21]

Yet, there is a slow deterioration in eye health across all age groups and an awareness of eye fatigue, with degenerative changes in the structure of the retina (Figure 6) being observed due to artificial light [22].

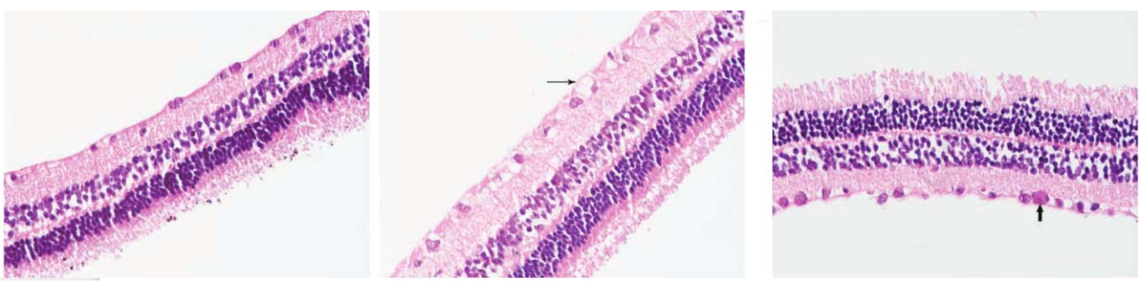


Fig. 6. Degenerative changes in the structure of the retina induced by artificial light [22]
a) natural light, b) LED lights, c) blue light

For this reason, relevant studies are needed that ultimately lead to the establishment of measures that minimize possible adverse effects. Therefore, it is difficult to conclude which of the light components (blue, red or infrared) have more pronounced negative effects on human health [19], but according to the opinion issued by SCENIHR [3] in 2008, blue and UV light represent a potential risk for the aggravation of certain diseases, such as: chronic actinic dermatitis and solar urticaria. This category includes compact fluorescent lamps (CFC), halogen lamps and even LED lamps, commonly found in educational and public health buildings due to their low electricity consumption.

Some researchers say that the information regarding LED devices is still uncertain due to the fact that they are relatively new and there are not enough long-term studies to certify the effects of blue light on health. On the other hand, papers claim that light with a strong blue component affects circadian cycles, the hormonal system and even the immune system [3].

For laparoscopy newer light sources were found that met the required CRI and safety standards. Liquid crystal and optic fiber cables most frequently used. While both are relatively safe options the lather one poses the risk of rupture. Both present burn risks especially liquid crystal cables [23]

6. Conclusions

In the context of promoting the widespread use of energy-saving lamps and the gradual elimination of incandescent lamps, the issue of verifying information according to which the symptoms of some diseases are or could be aggravated by energy-saving lamps arises.

The importance of ensuring a level of illumination, adopting lighting systems that are close to natural light, with a CRI index as close as possible to 100, is emphasized to ensure health, comfort and work efficiency. Greater attention must be paid to the design of lighting systems for healthcare spaces. Efficient lighting not only allows surgeons to perform procedures with precision but also plays a vital role in ensuring patient safety and optimal clinical outcomes.

Since the harmful effects of blue light are attributed to cardiovascular diseases, diabetes, osteoporosis and even breast cancer, it is necessary to continue research, to publish its results, putting human safety and health first. These results must also form the basis for updating lighting regulations, even at the expense of reducing electricity consumption.

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