UDK 537.563.2:72.033.5 DOI 10.7251/COMEN2401009T

MEASUREMENT AND ANALYSIS OF THE SPECTRAL EMISSION OF DIFFERENT TYPES OF DOMESTIC LAMPS IN THE BLUE LIGHT HAZARD WAVELENGTH RANGE

Plamen Tsankov*, Veselina Stefanova, Milko Yovchev, Ivaylo Stoyanov

Technical University of Gabrovo, Faculty of Electrical Engineering and Electronics, Gabrovo, Bulgaria

*Corresponding author: plamen@tugab.bg

Abstract: In recent years, research on the photobiological impact of light on humans has been expanding and deepening. A significant part of this research is aimed at harmful effects such as the blue light hazard (BLH) on the retina of the human eye, for which there are standardized indicators in international normative documents. The current research presents laboratory measurements and results for the spectral emission in blue light hazard wavelength range for several domestic lamps: conventional tungsten filament lamps, halogen and metal halide lamps, compact fluorescent lamps, and state-of-the-art LED lamps. The measurements are conducted in a specialised laboratory in the Technological Park of the Technical University - Gabrovo using a photometer with a spectroradiometer in an integrating sphere and are processed with specialised software. Graphical comparisons of the spectral distributions of lamps in the visible part of the electromagnetic spectrum with the dangerous blue light wavelength range are shown. Data on the main photometric and colour characteristics - luminous flux, light efficacy, chromaticity coordinates, colour temperature, colour rendering index, and indicators for assessing the presence of dangerous blue light - blue light (weighted power) and blue light hazard factor (weighted power/ lux), for the different types of lamps, are shown in tables. Conclusions and recommendations regarding the choice of the type of domestic lamp and its colour characteristics to limit the level of dangerous blue light are made.

Keywords: blue light hazard, domestic lamp, light-emitting diode, spectral distribution of lamp, spectroradiometer measurement.

1. INTRODUCTION

In recent years, the widespread adoption of artificial lighting in domestic settings has revolutionized our lives, enhancing productivity, safety, and comfort during nighttime hours. However, with the rapid proliferation of energy-efficient light sources, particularly light-emitting diodes (LEDs), concerns have arisen regarding their potential adverse effects on human health. Of particular interest is the blue light emitted by these lamps, which has been identified as a potential hazard due to its impact on the circadian rhythm and ocular health.

One of the significant direct potentially harmful effects of radiation from light sources is the Blue Light Hazard (BLH), which has a relatively strong photochemical effect in retinal tissues. [1,2] Specific measurement methods and BLH level control indicators are systematized and defined in international normative documents. [3,4] The relevance of the BLH problem is confirmed by modern scientific books and publications by authoritative scientists. [1,5,6,7]

Fig. 1 shows a comparison of photopic eye sensitivity, actinic UV, blue light and thermal hazard spectrums according to IEC 62471 Photobiological Safety of Lamps and Lamp Systems. [2]

The human eye is sensitive to light across a broad spectrum, ranging from ultraviolet (UV) to visible and infrared light. Blue light, with wavelengths between approximately 400 to 500 nanometers, lies at the higher-energy end of the visible spectrum and plays a crucial role in regulating our sleep-wake cycle. In natural settings, exposure to blue light during the day is essential for maintaining proper circadian rhythms, alertness, and mood. However, excessive or untimely exposure to blue light, especially during evening hours, can disrupt the natural sleep-wake cycle, leading to various health issues. [8]

Domestic lamps, including LEDs, compact fluorescent lamps (CFLs), and traditional incandescent bulbs, have replaced conventional lighting sources in households due to their energy efficiency and longer lifespan. LEDs, in particular, have gained popularity due to their low energy consumption and versatile applications. Nonetheless, their high blue light content has raised concerns regarding their potential impact on human health.



Figure 1. Photopic eye sensitivity, actinic UV, blue light and thermal hazards spectrums. [2]

In contemporary indoor lighting lamps, light-emitting diodes (LED) based on a Blue LED + Yellow phosphor are mainly used. In both cases, the presence of a blue LED emitting in a narrow wavelength range with a maximum close to that of the blue light hazard wavelength range of (400÷500) nm, makes it highly likely that the eye-safe levels of blue light will be exceeded. Fig. 1 shows a typical spectrum of Blue LED + Yellow phosphor technology LED. Blue light is directly emitted by the GaNbased LED luminescence (peak at about 465 nm) and the more broadband Stokes-shifted light emitted by the Ce3+:YAG (Yttrium aluminium garnet—Y3A-15O12) phosphorescence, which emits at roughly 500–700 nm. [2,9] pages: 009-018



Figure 2. Spectrum formation of Blue LED + Yellow phosphor technology LEDs

Studies have shown that prolonged exposure to blue light, especially during the evening, can suppress the production of melatonin, a hormone responsible for regulating sleep. This disruption can lead to sleep disturbances, insomnia, and even contribute to the development of chronic health conditions, including obesity, diabetes, and cardiovascular diseases. Moreover, blue light exposure can cause eye strain, visual discomfort, and in extreme cases, retinal damage, leading to an increased risk of age-related macular degeneration (AMD).

One of the quantitative indicators giving information about the potential danger of the spectrum of a given light source is the blue light hazard efficacy of luminous radiation $K_{B,V}$ [10,11,12], expressed in (W/lm), with a mathematical definition:

$$K_{B,V} = \frac{\int \phi_{\lambda}(\lambda) \cdot B(\lambda) \cdot d\lambda}{K_m \cdot \int \phi_{\lambda}(\lambda) \cdot V(\lambda) \cdot d\lambda}$$
(1)

where: $\Phi_{\lambda}(\lambda)$ is the radiometric spectral power distribution of the white light source (W/nm); λ is the wavelength variable (nm); $B(\lambda)$ is the blue light hazard weighting function defined in IEC 62471; K_m is the photopic luminous efficacy of radiation for a monochromatic source with a 555 nm wavelength (683 lm/W); $V(\lambda)$ is the luminous efficiency function of the human eye.

The watts in the dimension W/lm, calculated using formula (1), are the blue light hazard weighted optical watts of the source, designated as $W_{B'}$. Another possibility for the analytical representation of $K_{B,V}$ in IEC 62471 is through illuminance or luminance of the light sources - formula (2):

MEASUREMENT AND ANALYSIS OF THE SPECTRAL EMISSION OF DIFFERENT TYPES OF DOMESTIC LAMPS IN THE BLUE LIGHT HAZARD WAVELENGTH RANGE

$$K_{B,V} = \frac{E_B}{E} = \frac{L_B}{L} \tag{2}$$

pages: 009-018

where $E_B (W_B/m^2)$ and $L_B (W_B/(sr.m^2))$ values are used for calculation of $K_{B,V}$ value [1,11,13]. In the present study, according to the definition proposed by EN 62471 for for $K_{B,V}$ via illuminance, a (μ W/ cm²/lux) dimension is used.

2. LABORATORY SETUP FOR MEASUREMENTS

The measurements of the spectral power distribution (SPD) in range (380÷780) nm, electrical, photometric and colourimetric parameters and efficacy of the lamps studied are performed using a CCD spectroradiometer system Lisun LMS-9000B with an integrating sphere in Gabrovo Tech Park (Fig. 3). [14] The power supply with pure sinewave rated voltage and measurement of the electrical, photometric and colourimetric parameters and efficacy of the domestic lamps studied are realized by the specialized software product LMS-9000 Lisun CCD Spectroradiometer, shown in Fig. 4.

In LMS-9000 Lisun CCD Spectroradiometer software, the spectral power distribution data (W/ nm) in the wavelength range (380÷780) nm of the domestic lamps studied are exported and recorded in CSV file format, shown in Fig. 5. Then spectral power distribution data are processed in f.luxome-

Figure 3. Measurement of the spectral emission of the studied domestic lamps with a CCD spectroradiometer system

	100	00000	0 t						11/5-000	Laun CCD Spec	transformete	er - DIVSMEEST/Spectro_2023/V	ecelina Statar	rova LED_08.2	125. Irra					-	0	×
9	Integrat	tion Spitere Test																				10
1. at	36	DOL AC PLANT	Tearle - Luthage (A)	30 - 10	1 N Deb	112	Arden Tana	mail I Ware	sta:													
10	20	V Auto =	barar De Fressan oy Btd	a - +	Q Goe	ENIN Calibrate	100	I La warm	up Settier													
Contig	Option	Frint Auton	Carley Citt. Turne	001 - 14	P B Press	Cattors	V 4400	10 241 44	hunter	Shart												
Sectors	. Net	fiapoit	Panarfawar				. 11	100		1616												
Die.	Report No.	Test Tear	Serv	Number	Votaar M	Correct IN	Pager MI	Forem Fastar	CCT NO	OE+	CET	Daning Westingth (with	50:04	White Class	Lorenza File del	Radianti Paterer NA	Efficiency In W1	Energy Billionnia	Ges	84	8	
30	744	JICES-08-04 11 19-92 3	Velocitized Burtooch ew 210	743	235.50	0.0520	5.810	0.3428	3717	0.4614	0.4255	347.8	1.7 (#2700)	ANS 27008	814.93	2.479	144.74	D #1/2019/2015 (ITRE 1-	4.7499/00	85.1		
11	745	2023-08-04 11/28/22 0	D.DCR.677.000.1500.88048-0	245	235,200	0.0400	7.548	0.4568	2134	0.4371	0.4507	192.1	1.7 (F1000)	AND 3000	4\$7.22	1.162	43.09	CIFU 2016/0015 s7446	3.758w.500	81.6	1 1	
19.	745	2023-03-04 11-12-42	(ED Marsie & do 7W	745	235.300	0,0720	3,010	0.4636	4165	0.7904	4.2627	431.3	174 64500	64	73.60	0.249	14.14	6 (FU 2015/2015 -EM-2	4 7 Kite AM	T0.7	1	2
11	747	2025-05-06 11 (21-17	ALC: NAME AND	747	750.400	001100	1.000	0.1448	2940	CASTR	0.4011	1015	11(*1000	AND STOCK	181.01	0.489	15.21	G (F) (2019/2019 of Mrs	A.A.188.555	04.5		21
14	748	2023-08-04 11-45-14 -0	OSEAM DURINE Value 11W 8	7.88	2331-200	0.0280	10.783	0.5530	2642	0.4691	0.4163	5818	4.1(F2700	ANG 2700M	414.98	1152	19.61	GIEU INTRICTOS ACUAR	Q.6189.446	61.3		21
15	540	2022/08/08 12:02:12	190 Techina T Guy atters	242	210,200	0.000	2.838	0.0055	2011	0.1855	a tett	179.0	2.9 (84100)	AND ATTEN	261.03	0.054	82.28	C ALL TRUNCING +FALL	2 222 - 544	82.2	1	21
15	750	2023-03-04 12:05:20	IFD Technics 1 SW 45005	755	230,300	0.0400	5430	0.5660	1010	0.3434	0.5767	179.7	2.5/74000	4105 4100	121.75	1.567	19.61	G ITU 2010/2015 -TM-5	0.610x.335	ATC		1
10	100	THE POPPH LEVEL	LET HERE IN THE AVEN	797	153.00	0.0400	1.000	0.0000	47.16	0.5459	0.0000	578.0	0.4 (micros)	ABOL ATTON	105.75	7.555	244.74	E BALLER AVERAGE ATTAC	A TRANSPORT	81.0	1.1	
		2002/02/04 04 02/04/04	LED WYNE OF BEI BUILDER	141	110.000	20.000	2	10 1000		0.1100	A	1000	and a second	and and	E36.63		22.24	P (State in sector of the s	a passa dag	74.9		2
12	736	2023-00-04 1213:00 1	S 4-ENC Ander Gibli SW 1200	rad	230,200	DIDALIC	2,495	114966	2024	0.1300	2 Augusta	101.0	-++= #2700	Lut	siteary	1.774	87.46	P (to sent) sent inter	, Transferd	18.4	-	-
	100	The second second	INDEX TAC INCOME	711	100.000	0.10710	77.117.	100110	1111	0.0010	0.0100	CHINY:	0.1.001100	4.001 100000	122211	1.000	21.27	B COLUMN TO THE OTHER	11100.000	Contra Co		-
24		2022 00 04 12 12 14 25	1270 Linners P. Full 22008		100,000	20.000	0.000	0.5276		0.0010	diam'r.	683.5	0.0.07700	4801 77000	120011	1.010	No. of L	P (11) 1000 1000 -1110	t time (44	07.2		
41		align of the street	LED DESIGN SAFE STAR	785	100.000	0.0416	0.000		week	0.000	Scott -	NOC.0	0.000000	Participation and an and an	10.00	1.00	19.01	T (but an induced a group	a head had	91.8		
- 22	.790	2022-00-04 12:33/20 1	D Utilet a risinert ov 2700	100	(30%00	provedo	28/6	0.2458	69.29	0.4994	0.4600	363.6	2.00.5200	ANDLENUK	04130	69(8	194-28	C IED SOURCEUP INNES	HLCOOM YSS	010		5
-23	757	2025-286-06 19:01:27 0	Small burb of Sizh Hille 21	757	280,3121	0.02.00	91.790	0.5278	8142	0.3142	0.5654	\$90.5	2.1 (48203	uns cours	1851.11	5.204	111.68	e lett sure sure and	L ALIM VO	61.5	-	
Pho	aoynthetic	al Raciant Flux (9x)	1.675 W	100	(au) (4			a (a.) at	100		1 < >	•							(Mara) a		Coupries and	
Pho	asynthetic	al Photon Flux (\$p)	7.548 umpl/s		-300 -2	130 -130 -7		2 30 12	100	1.00									(m.m	1	(W/mm)	
Pho	asynthetic	Photon Efficacy (Kal	1.268 umpl/)	Refi7.	2		1												425	1	CC OTTEMAN	
Pho	osynthetic	Radiant Efficiency (ne)	0.286	R1-29			15												10		0.015804	
Raff	ant Stream	vcy (e)	D.JBT	\$2.60	2					0.4									477	e	0.011303	11
R/B			0.7																120	2	0.014785	-8
R/H	1.1.1	2022	\$15	KING			22	-											100		0.014031	
Pho	an Hus (40	20 - 392mm)	2,000 umut/s	R4:79															17	8	0.013121	
Pao	an Fka (%	00-900mm)	3405 umol/y	RABD						E 0.8									155		0.012283	
190	DIVERSION PRO	007001818)	1.852 LPROFY	8985						1									18	8	0.011435	
Pho	In FLA PT	FIT 700-500rem)	GI042 Umotins	110					21	8			-						10	1	0.000713	
Pag	on Film (Fi	FUY (DUGUMPA)	T 100 umat/s	6/10/			1			3									~	-	0.010100	
Vac	000.000	Carboner)	CATT	R8.03						0.4									-	1	0.000630	
400	471.505	ang .	1.00 and/a	R9-4			1			•											6 555525	
VAR	1770 400m	nd .	2.146 condition	R1074	4														~	2	0.00000200	
ver	1000- 200au	-	1700 cmcl/s	811.7			6													2	0.0000002	
100	(TO)- 181-	eri)	C 010 umol/s	1 minut						0.2											o states	
VPE	231.000+	eri .	C 000 smell/r	R125	5														40	-	w 909312	
1.00	art They Ga	00-500nm)	0.53J W	RIBE	2		1												-81	1	0.005011	
Red	red Flue 154	00-600mm	0.795 W	RI4S	7					35					100	and the second second	100	12	46	1	0.007724	
Red	ant Place (64	06+700mm	0.147W	R157	2					8.0	11	450 500		50	100	alo	201	753 6	411	12	0.00/418	
Raf	ant Flor (7)	00-800nmi	0.007 \v	10000					-		T.	100		Wavel	enoth inmit			7.5 1 5		1	0,00/045	
		State Sector T							_										-A7.	£7. 1	0.006705	-

Figure 4. LMS-9000 Lisun CCD Spectroradiometer software used to control the measurement process

terTM online application and service, shown in Fig. 6. [15]

lamps, three halogen lamps, six compact fluorescent lamps (CFL), two metal halide lamps (MHL), two xenon lamps, and three LED lamps, are studied. Fig. 7 shows part of the domestic lamps studied.

Eighteen domestic lamps with different power and correlated colour temperature: two incandescent

×	AutoSave	Off 🗄	9-	Q - ⊂ − LE	D LEDVANCEI 2.5W 3	000	oK_BLH ∽						ρs	earch		
F	ile <u>Home</u>	Insert Pag	ge Lay	out Formula	is Data Revie	w	View Aut	omate	Help							
			Calibri	~)	11 - A^ A	Ξ	= = *		ab Ce Wrap Text	t		Gene	ral			
	Paste	oy v mat Painter	B I	⊻ - ⊞ -	• <u>•</u> • <u>A</u> •		= = =	42	Merge &	Ce	nter ~		- %	,	- 85	0 A
	Clipboar	ر d rd		Font	5			Aligna	ient		L		Num	ber		
4	4 ~	$: \times \checkmark f$														
	A	В	c	D	E	F	G		н		J		•	<		Ì
	Wavelength	Spectrum, W/	'nm	Wavelength	Spectrum, W/nm		Wavelength	Spect	um, W/nm	V	Vavelengt	h Sp	ectrun	n, W/ı	nm	
Ì	380	0.000	022	415	0.000019		451		0.003152	t	48	7		0.001	474	
	381		0	416	0.000023		452		0.003399	Г	48	8		0.001	538	
	382	0.000	0011	417	0.000035		453		0.003581		48	9		0.001	594	
	383	0.000	0015	418	0.000031		454		0.003671		49	0		0.001	557	
	384	0.000	8000	419	0.000032		455		0.003667		49	1		0.001	739	
	385	0.000	0007	420	0.000032		456		0.003567		49	2		0.001	817	
	386	0.000	0005	421	0.000032		457		0.003396		49	3		0.001	894	
	387	0.000	0009	422	0.000028		458		0.003161	Γ	49	4		0.001	986	
ĺ	388	0.000	0018	423	0.000041		459		0.002929	Γ	49	5		0.002	075	
		LED LEDVANO	CEI 2.5	W 3000K_BLH	(+)			,								

Figure 5. Recording spectral power distribution data in CSV file format



Figure 6. Online application and service f.luxometer™ used to process the spectral power distribution data in CSV format

pages: 009-018

MEASUREMENT AND ANALYSIS OF THE SPECTRAL EMISSION OF DIFFERENT TYPES OF DOMESTIC LAMPS IN THE BLUE LIGHT HAZARD WAVELENGTH RANGE



a. Tungsten incandescent and halogen lamps



b. Compact fluorescent lamps



c. Metal halide lamps

d. Xenon lamps

e. LED lamps

Figure 7. Appearance of the domestic lamps studied

Before the measurements of the colour characteristics each tested lamp is warmed up to a steady state mode according to established international lighting standards. [16,17]

3. MEASUREMENT RESULTS AND ANALYSIS

In the CCD spectroradiometer system Lisun LMS-9000B, the photometric, colourimetric pa-

rameters, and efficacy of the domestic lamps, are measured.

Table 1 shows the results of measured correlated colour temperature CCT, chromaticity coordinates CIE x and CIE y, dominant wavelength, luminous flux, radiant power, colour rendering index Ra and strong red colour sample R9, colour fidelity index Rf, and colour gamut Rg, and efficacy of tested domestic lamps.

Table 1. Measured photometric and colourimetric parameters and efficacy of tested domestic lamps

Lamp	CCT (K)	CIE x	CIE y	Dominant wavelength (nm)	Luminous flux (lm)	Radiant power (W)	Efficacy (lm/W)	Ra	R9	Rf	Rg
Tungsten incandescent-100W	2634	0.4662	0.4131	584.4	1028.08	7.98	10.53	99.7	99	100	100
Tungsten incandescent-150W	2773	0.4544	0.4100	583.8	1787.23	13.173	11.67	99.8	99	100	100
Dichroic halogen-14.7W	2460	0.4873	0.4248	584.5	88.43	0.681	6.00	97.1	90	95	95
Dichroic halogen-15W	2500	0.4795	0.4178	584.9	97.98	0.778	6.50	99.0	96	98	98
Halogen-53W	2765	0.456	0.4120	583.6	267.00	1.937	5.03	99.6	99	99	99
CFL-11W	2642	0.4691	0.4193	583.8	424.98	1.152	39.61	81.3	-9	72	104
CFL SL-15W	5916	0.3227	0.3512	528.6	765.01	2.377	61.55	73.3	16	74	95
CFL PL-15W	2720	0.4639	0.4205	583.1	563.65	1.618	37.70	82.3	-6	74	103
CFL-21W	6336	0.3133	0.3517	504.1	507.55	1.574	33.61	77.8	24	80	97
CFL-23W	7146	0.3021	0.3256	488.5	1413.99	4.694	67.62	80.8	41	81	99
CFL-55W	3929	0.3864	0.3884	577.3	2603.44	7.516	46.26	78.5	16	76	100
MHL SDM-R-35W	2985	0.436	0.4003	583.4	2308.18	7.801	53.94	83.6	-29	81	100
MHL-35W	3094	0.4307	0.4023	582.4	3114.51	10.24	72.33	79.8	-53	77	99
Xenon lamp-60W	6798	0.3046	0.345	507.7	1978.36	7.833	33.48	56.9	-117	62	85
Xenon lamp-75W	6578	0.3091	0.3441	497.5	2655.72	10.74	35.56	63.8	-88	68	88
LED lamp-6W	6072	0.3193	0.3495	507.7	549.79	1.682	93.82	82.2	-4	83	91
LED lamp-7W	4472	0.3623	0.3673	576.1	389.64	1.179	62.74	82.1	4	83	97
LED filament lamp-4W	1585	0.5764	0.3998	593.4	60.59	0.321	14.82	90.8	60	86	89

Plamen Tsankov, Veselina Stefanova, Milko Yovchev, Ivaylo Stoyanov

The spectral power distribution data (W/nm) of the studied lamps, measured in a spectroradiometer LMS-9000B and exported in CSV format, are processed using the f.luxometerTM application and service to calculate the results about the blue light hazard wavelength range. Spectral power distributions of the domestic lamps and blue light hazard wavelength range are compared graphically in Fig. 8.





m) LED lamp-7W



Figure 8. Comparison between SPD of the domestic lamps studied and the BLH wavelength range

In Table 2, results for the measured correlated colour temperature and calculated blue light (weighted power) in μ W/cm², blue light hazard factor (weighted power/lux) $K_{_{B,V}}$ in $\mu W/cm^2/lux,$ and dominant wavelength of the tested indoor LED lamps, are systematized.

Table 2. Measured correlated colour temperature and calculated blue light (weighted power), blue light hazard	l
factor (weighted power/lux), and dominant wavelength of the tested domestic lamps	

Lamp	Correlated colour temperature, K	Blue light (weighted power), µW/cm ²	Blue light hazard factor (weighted power/lux), µW/cm ² /lux	Dominant wavelength, nm
LED filament lamp-4W	1582	0.003	0.0044	593.4
Dichroic halogen lamp-14.7W	2460	0.015	0.0166	584.5
Dichroic halogen lamp-15W	2500	0.020	0.0202	584.9
Tungsten incandescent-100W	2634	0.253	0.0246	584.4
CFL-11W	2642	0.105	0.0247	583.8
CFL PL-15W	2720	0.143	0.0254	583.1
Halogen-53W	2765	0.072	0.0269	583.6
Tungsten incandescent-150W	2773	0.499	0.0279	583.8
MHL SDM-R-35W	2985	0.921	0.0399	583.4
MHL-35W	3094	4.200	0.0420	582.4
CFL-55W	3929	1.340	0.0517	577.3
LED lamp-7W	4472	0.229	0.0587	576.1
CFL SL-15W	5916	0.622	0.0814	528.6
LED lamp-6W	6072	0.396	0.0720	507.7
CFL-21W	6336	0.414	0.0816	504.1
Xenon lamp-75W	6578	2.700	0.1020	497.5
Xenon lamp-60W	6798	2.050	0.1040	507.7
CFL-23W	7146	1.390	0.0984	488.5



Figure 9. Graphical and defined linear analytical dependence of blue light hazard efficacy of luminous radiation $K_{B,v}$ on the correlated colour temperature CCT of the measured domestic lamps

The analysis of the results in Table 2 shows an approximately linear relationship between CCT and blue light hazard factor (weighted power/lux) $K_{B,V}$ in μ W/cm²/lux for the 18 domestic lamps tested. In Fig. 9, graphical and defined linear analytical dependence of blue light hazard efficacy of luminous radiation $K_{B,V}$ on the correlated colour temperature CCT of the measured domestic lamps.

4. CONCLUSIONS

The analysis of the results shows a linear increase trend in the blue light hazard factor $K_{_{\rm B\,V}}$ with an increase in the correlated colour temperature CCT of the measured light sources not only for LED lamps, which has been a frequently researched issue in recent years, but also for the older technology domestic lamps they replace, even for tungsten incandescent and incandescent halogen lamps, which, as heat emitter technology, have a lower emission intensity in the blue of the spectrum - Table 2 and Fig. 9. It is even found that at similar levels of colour temperature, CFLs and Xenon lamps have higher $K_{_{\rm BV}}$ values than LED lamps. For a more precise assessment of the real danger of falling into a risk group for blue light hazard, according to the standard IEC 62471, at the next stage, it is necessary to examine the luminance of the light source or luminaire to the eye for the specific light distribution of their optical system.

From research, it can be concluded that LED lamps, at the same light temperature and other conditions, have the same or lower light emissions in the blue light hazard wavelength range than other domestic light sources. The most important conclusion is that regardless of the technology of light sources, to provide safer household lighting with reduced blue light hazard emissions, it is advisable to use lamps with "warm" or "soft white" light, or with as much as possible -low colour temperature.

The obtained results confirm the expediency of the research and the accuracy of work of the laboratory setup created at the Technical University - Gabrovo for researching the problems with dangerous blue light, which can also be used for other research on direct or indirect photobiological effects of light.

5. ACKNOWLEDGEMENT

This work was supported by the European Regional Development Fund within the OP "Science and Education for Smart Growth 2014 - 2020", Project CoC "Smart Mechatronic, Eco- And Energy Saving Systems And Technologies", № BG-05M2OP001-1.002-0023.

6. REFERENCES

- Bommel, W. Interior lighting Fundamentals, Technology And Application. Springer, 2019, pp. 137-257.
- [2] Tsankov, P.T. (2020). Lighting Technologies. In: Pavlovic, T. (eds) The Sun and Photovoltaic Technologies. Green Energy and Technology. Springer, Cham, 2020, pp. 213-270.
- [3] Xue, C. et al. High Performance Non-Doped Blue-Hazard-Free Hybrid White Organic Light-Emitting Diodes with Stable High Color Rendering Index and Low Efficiency Roll-Off. Opt. Mater., vol. 106, 2020.
- [4] Bauer, S. Blue-Light Hazard of Light-Emitting Diodes Assessed with Gaussian Functions. International Journal of Environmental Research and Public Health, 2021, pp. 4-8. doi. org/10.3390/ijerph18020680.
- [5] Nikolova, K., I. Petrinska, D. Ivanov, D. Pavlov. Investigation of the Photobiological Risk from Blue Light of a Human-Centric Lighting System - Case Study. 2019 11th Electrical Engineering Faculty Conference (BulEF), 2019.
- [6] Brainard, G. et al. Sensitivity of the Human Circadian System to Short-Wavelength (420-nm) Light. Journal of Biological Rhythms, vol. 23, Issue 5, 2008.
- [7] Pawlak, A. Evaluation of the Hazard Caused by Blue Light Emitted by LED Sources. Lighting Conference of the Visegrad Countries (Lumen V4), 2018.
- [8] Dai, Q. et al. Circadian-Effect Engineering of Solid-State Lighting Spectra for Beneficial and Tunable Lighting. Opt. Exp., vol. 24, pp. 20049–20059, 2016.
- [9] Ye, L. et al. Phosphor-Converted Laser-Based Illuminant with High Color Rendering Index and Low Blue. IEEE Photonics Journal, Vol. 14, 2022.
- [10] Standard IEC 62471:2006/CIE S 009:2002 Photobiological Safety of Lamps and Lamp Systems.
- [11] IEC TR 62778 Application of IEC 62471 for the Assessment of Blue Light Hazard to Light Sources and Luminaires.
- [12] Sims, P. Safety Understanding IEC 62778 and Using KV,B to Calculate White Light Eye Safe-

ty Risk Groups. LUMINUS, 2022.

- [13] https://luminusdevices.zendesk.com/hc/en-us/ articles/10087466808589-Safety-Understanding-IEC-62778-and-Using-KV-B-to-Calculate-White-Light-Eye-Safety-Risk-Groups
- [14] High Precision CCD Spectroradiometer LMS-9000B with Integrating Sphere – User's Manual, LISUN GROUP.
- [15] https://fluxometer.com/rainbow/
- [16] CIE 84:1989 Measurement of Luminous Flux.
- [17] CIE 177:2007 Colour Rendering of White LED Light Sources.

МЈЕРЕЊЕ И АНАЛИЗА СПЕКТРАЛНЕ ЕМИСИЈЕ РАЗЛИЧИТИХ ТИПОВА ДОМАЋИХ ЛАМПИ У ОПАСНОСТИ ТАЛАСНИХ ДУЖИНА ПЛАВЕ СВЈЕТЛОСТИ

Сажетак: Последњих година све више су заступљена истраживања фотобиолошког утицаја свјетлости на човјека. Значајан дио овог истраживања усмерен је на штетне ефекте, као што је опасност од плаве светлости (БЛХ) на мрежњачу људског ока, за шта постоје стандардизовани индикатори у међународним нормативним документима. Тренутно истраживање представља лабораторијска мјерења и резултате за спектралну емисију у опсегу таласних дужина опасности плаве свјетлости за неколико домаћих сијалица: конвенционалне сијалице са волфрамовим влакном, халогене и метал халогене сијалице, компактне флуоресцентне сијалице и најсавременије ЛЕД сијалице. Мјерења се врше у специјализованој лабораторији у Технолошком парку Техничког *универзитета – Габрово* помоћу фотометра са спектрорадиометром у интегрисаној сфери и обрађују се специјализованим софтвером. Приказана су графичка поређења спектралних дистрибуција сијалица у видљивом дјелу електромагнетног спектра са опасним опсегом таласних дужина плаве свјетлости. Подаци о главним фотометријским и колорним карактеристикама - свјетлосном току, свјетлосној ефикасности, координатама хроматичности, температури боје, индексу приказивања боја и индикаторима за процјену присуства опасне плаве свјетлости - плавој светлости (пондерисана снага) и фактору опасности плаве свјетлости (пондерисана снага). / лук), за различите типове сијалица, приказани су у табелама. Дати су закључци и препоруке у вези са избором врсте кућне лампе и њених карактеристика боје за ограничавање нивоа опасног плавог свјетла.

Кључне ријечи: опасност од плаве свјетлости, кућна лампа, свјетлећа диода, спектрална дистрибуција лампе, спектрорадиометарско мјерење.

Paper received: 18 September 2023 Paper accepted: 23 May 2024



This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License