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UV-VIS photobiological safety of fluorescent lamps in UV-VIS range

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Abstract:
Exposure to optical radiation generated by light sources used for general lighting purposes should not cause any harm due to photobiological effects for skin and eye.
This article indicates if there is an issue of photobiological safety of fluorescent lamps in respect to following hazards:

- Actinic UV (200-400nm)
- Eye UVA (near UV) –(315-400nm)
- Blue-light (300-700nm)

Based on measurements of CFL representatives (integrated and non integrated) available on the market, performed according IEC 62471 it can be stated that for specific applications and extended espousers times not all lamps meet proposed requirements under specific conditions.

1. Introduction.

Availability of definitions concerning different effects of optical radiation should implicate availability of clear method for evaluating light sources used for general lighting services especially compact fluorescent ones which are more and more common in domestic applications nowadays. Since photobiological hazards are defined it should be an obligatory task for lamp/system manufacturers to verify and describe the data acc. clear guidelines. Good attempt towards such an approach is following IEC 62471 recommendations which in fact should be a part of an obligatory safety standard for all lamp types but it is not a case at this moment.
Another problem is that really simple and user friendly instrument allowing to check photobilogical safety of lamps is not available on the market and still quite advanced equipment is required for measurements which make it more difficult for checking.

This article presents results from test of some fluorescent lamps and indicates potential issues related to low pressure fluorescent lamps vs. photobiological safety but does not judge the impact but refers to guidelines gathered in IEC 62471.

2. Measurements.

Exposure to optical radiation generated by light sources used for general purposes should not cause any harm due to photobiological effects for skin and eye.
Measurements assuring photobiological safety of lamps were performed for CFL-ni (Philips PL-L/PL-H) and CFL-i representatives: (Philips Tornado 23W865&827). Irradiance was measured with the use monochromator with the resolution of 1nm.

2.1 Retinal blue light hazard

Blue hazard with the visible radiation form 400 to 500 nm may cause a retinal injury. and should be commonly considered since the effect is covered by radiation in the range available in all fluorescent lamps and content differs for different colour temperatures.

a) Non integrated compact fluorescent lamps

Blue light hazards for non point light sources have to be evaluated bases on radiance measurements. Measurements were performed for “high power” compact fluorescent lamps: 80 W with 2G11 base (Philips PL-L80W865) and120 W with 2G8 base (PL-H120W850). Spectral radiance was measured acc. IEC62471 5.2.2.2 [Alternative method] and weighted with B(λ) spectral weighting function.
Blue light radiance was calculated acc.:

$$L_B = \sum_{300}^{700} L_\lambda \cdot B(\lambda) \cdot \Delta\lambda$$

$L_\lambda(\lambda)$ = spectral radiance in W m^{-2} sr^{-1} nm^{-1},
$B(\lambda)$ = blue-light hazard weighting function,
$\Delta\lambda$ = bandwidth in nm,
IEC 62471 requirements:
for $t > 10^4$ s L_b <100 W m^{-2} sr^{-1} nm^{-1}
t = exposure duration in seconds.

results :

			Measurements	
Risk	**Symbol**	**unit**	**2G11 80W 6500K**	**2G8 120W 5000K**
Blue light - B(λ)	L_B	W/m^2 sr^{-1}	27	73

Table 1. Blue hazard based on radiance for CFL-ni

Based on radiance measurements weighted with blue-light hazard weighting function tested lamps fulfill requirements in respect to blue light hazard (L_b <100 W m^{-2} sr^{-1} nm^{-1}) , so there is no risk for retina caused by blue light while exposed to these lamps which could be perceived as critical examples.

b) Compact fluorescent lamps – integrated (self ballasted)

Very common light sources nowadays in our surrounding – integrated compact fluorescent lamps can be considered to be point sources and so evaluated based on irradiance measurements. Hazard values were checked at the distance of 200 mm which is most critical while In fact acc. IEC 62471 measuring distance according IEC 62471 should be corresponding to the illuminance level of 500 lx however should not be shorter then 200mm. It is clear that 200 mm is more critical criteria and so despite the fact that illuminance level at this distance caused by tested 23W CFL-i lamps is higher than 500 lx (almost 2k lx) such a situation was also evaluated as possible in real environment where it replaces incandescent lamps in variety of applications.

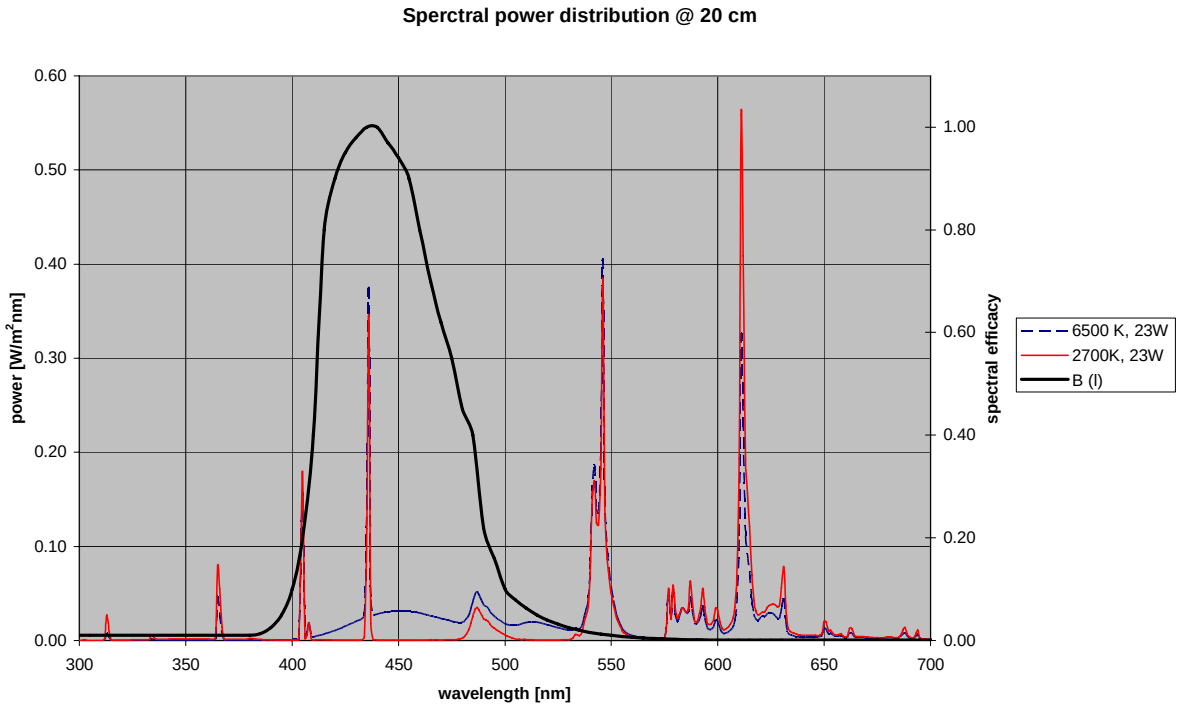

Figure 1. Spectral power distribution of CFl-i 23W 827&865 and spectral weighting function for blue light hazard

results:

			Measurements		Emmision limits		
Risk	**Symbol**	**unit**	**23W 6500K @200mm**	**23W 2700K @200mm**	**Exempt**	**low risk**	**Mod risk**
Blue light - B(λ)	E_B	W/m^2	2.08	0.71	1	1	400

Table 2. Blue hazard based on irradiance for CFL-I lamps

E_B- blue light hazard weighted irradiance

Based on measurement results at 20 cm maximum exposure duration for 23W 6500K lamp is below 1 min.:

$t_{max}=100/E_B$ s $t_{max}=48$ s

and so for Blue light hazard of CFL-i lamps with high colour temperature if accessible from short distance (for example on the desk lamp) they may introduce unwanted photochemical effect for the retina.

2.2 Actinic and Near UV hazards (irradiance)

Based on irradiance at distance corresponding to illuminance of 500lx actinic and near UV effects were evaluated for different color temperatures 3000K, 4000K and 6500K (Philips PL-L36W 830, 840, 865) and for Philips Tornado 23W 827 and 865 integrated types at 200mm distance.

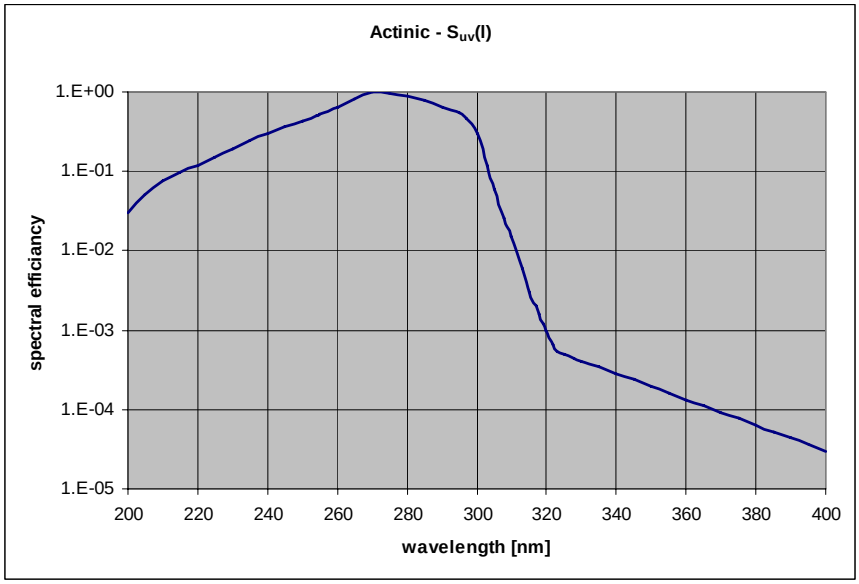

Figure 2. Spectral weighting function for actinic hazard [4]

- Actinic UV (200-400nm) (weighting function acc. figure 2)

$$E_s \cdot t = \sum_{200}^{400} \sum_{t} E_\lambda(\lambda,t) \cdot S_{UV}(\lambda) \cdot \Delta t \cdot \Delta\lambda \le 30 \qquad \text{J·m}^{-2}$$

where:

$E_\lambda(\lambda,t)$ is the spectral irradiance in $\text{W·m}^{-2}\text{·nm}^{-1}$,
$S_{UV}(\lambda)$ is the actinic ultraviolet hazard weighting function,
$\Delta\lambda$ is the bandwidth in nm,
t is the exposure duration in seconds.

- Near UV (315-400nm)

$$E_{UVA} \cdot t = \sum_{315}^{400} \sum_{t} E_\lambda(\lambda,t) \cdot \Delta t \cdot \Delta\lambda \le 10000 \quad \text{J·m}^{-2} \qquad (t < 1000\ \text{s})$$

$$E_{UVA} \le 10 \qquad \text{W·m}^{-2} \qquad (t \ge 1000\ \text{s})$$

where:

$E_\lambda(\lambda,t)$ is the spectral irradiance in $\text{W·m}^{-2}\text{·nm}^{-1}$,
$\Delta\lambda$ is the bandwidth in nm,
t is the exposure duration in seconds.

results:
a) Compact fluorescent – non integrated (distance corresponding to illuminance of 500lx)

			Measurements			Emmision limits		
Risk	Symbol	unit	6500K	4000K	3000K	Exempt	low risk	Mod risk
Actinic UV - $S_{uv}(\lambda)$	E_s	W/m^2	0.00001	0.00003	0.00004	0.00100	0.00300	0.03000
Near UV	E_{UVA}	W/m^2	0.04	0.05	0.08	10	33	100

table 3. Actininc and near UV hazards results for CFL-ni

b) Compact fluorescent - integrated

			Measurements		Emmision limits		
Risk	**Symbol**	**unit**	**23W 6500K @200mm**	**23W 2700K @200mm**	**Exempt**	**low risk**	**Mod risk**
Actinic UV - $S_{uv}(\lambda)$	E_s	W/m^2	0.0002	0.0010	0.00100	0.00300	0.03000
Near UV	E_{UVA}	W/m^2	0.13	0.26	10	33	100

table 4. Actinic and near UV hazards results for CFL-i

It can be stated that in case of above mentioned effects there is no any risk of safety issue for actinic and near UV hazards for both CFL-i and CFL-ni representatives used for general lighting purposes.

3. Conclusions.

Photobilogical safety requirements of tested fluorescent lamps checked acc. IEC 62471 in respect to blue, actinic and near UV hazards are fulfilled. However it can be noticed that Blue hazard could be critical if applied at a short distance. It is also visible that with higher colour temperature of fluorescent lamp more blue radiation is available which of course implicates higher E_b irradiance. With 23W 6500 K compact fluorescent lamp without outer bulb expose longer than 1 minute could already be harmful to the retina. It is a signal that all lamps should be checked for photobiological effects as a routine safety release. Higher colour temperatures of light sources used for general lighting services are more often used nowadays due to their effects on human circadian cycle while at the same time can be danger to the retina. In respect to non integrated compact and tabular fluorescent lamps risk is much smaller also since distance and access is usually limited by the luminaire but CFL-i lamps and also increasing amount of high power LED with high temperature content should be carefully considered also for side photobiological effect in visual range which influence human wellness.

4. Literature.

[1] CIE Publication: CIE 027:2004: Light and Health: on-visual effects
[2] CIE Publication: CIE no 63/E:-1984 The spectroradiometric measurements of light sources.
[3] Decusatis C.: Handbook of applied Photometry, maple-Vail Book manufacturing Group, New York 1997.
[4] IEC 62471- 2006 :Photobiological safety of lamps and lamp systems.