APPLICATION OF THE MELATONIN SUPPRESSION ACTION SPECTRA FOR LIGHTING

Karl Schulmeister, Marko Weber

Seibersdorf Labor GmbH, Seibersdorf, Austria

ABSTRACT

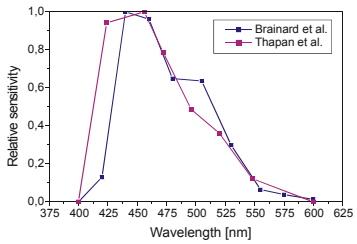
In recent years, two action spectra for the suppression of melatonin by exposure to light were published. From the published data, we have derived 'exposure limits' regarding the effect. Correcting the action spectra for lenticular absorption, and application of the action spectra on a number of light sources yields a typical exposure duration for each kind of light exposure (all normalized to 500 lux). The importance of the relative content of the blue wavelength range becomes apparent. A dose-response (in contrast to irradiance response) relationship was assumed.

see Schernhammer and Schulmeister:
Light at night and cancer risk, Photochemistry & Photobiology Vol 79 316 – 318 (2004)
Melatonin and cancer risk: does light at night compromise physiologic cancer protection by lowering serum melatonin levels? British Journal of Cancer, Vol 90, 941-943 (2004)

ACTION SPECTRA FOR MELATONIN SUPPRESSION

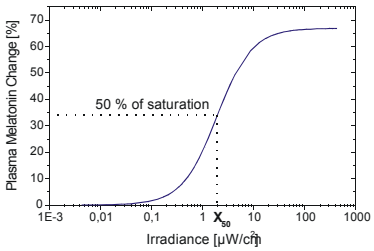
Brainard, et al. 2001. Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor. *The Journal of Neuroscience 21: 6405-6412.*
Thapan, et al. 2001. An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. *Journal of Physiology 535.1: 261-267.*

Reported retinal action spectra were corrected for lens absorption. For application for general lighting, need to be un-corrected. Sensitivity at 400 nm and below is set to zero.



DERIVING A THRESHOLD

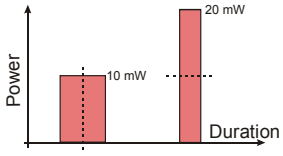
Studies provided irradiance response curves for each wavelength point. We chose X50 divided by 10 as 'threshold' for negligible melatonin suppression. Pupil diameter of studies (7 mm) also give an additional factor when applied to general situation with smaller pupil.



DOSE RELATIONSHIP?

Does effect depend on dose (energy, energy density) independent of over which time dose is delivered (independent of power, power density) or on momentary irradiance?
(Energy [J] = Power [W] * Duration [s])

Typical for photochemical effects: dose effect (total number of photons). Experimental results (McIntyre) support dose relationship up to at least 1 hour of exposure duration.



Lit.: McIntyre et al. 1989 Quantal Melatonin Suppression by Exposure to Low Intensity Light in Man; Life Sciences, Vol. 45, 327-332

THRESHOLD FOR NEGLIGIBLE MELATONIN SUPPRESSION

response curves for ~ 460 nm:

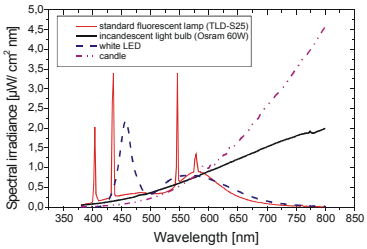
X50 by Brainard: 1.9 µW/cm² 90 min -> 11 mJ/cm²
X50 by Thapan: 4.3 µW/cm² 30 min -> 9 mJ/cm²

Dose - Response relationship (reciprocity) assumed
Threshold @ max sensitivity wavelength (factor 10):
Brainard .... 1.1 mJ/cm²
Thapan .... 0.9 mJ/cm²

Open issue: data are for Ganzfeld-illumination! Whole field of view filled with radiation; radiation that enters the eye is distributed over substantial part of the retina – effect might be quite different when radiation comes from a point source (small light bulb a distance away) and radiation that enters the eye is concentrated on small image on the retina.

LIGHT SOURCES

- We measured irradiance spectra of 14 light sources
- Normalised to produce 500 lx
- Weighted with melatonin suppression action spectra
- Integrated over w.l. -> effective irradiance (µW/cm²)



CRITICAL EXPOSURE DURATION

Exposure duration to reach threshold (s) = Threshold (J/cm²) /Effective Irradiance (W/cm²)

Lamp	Action spectra	Effective irradiance for 500 lux [µW/cm²]	Exposure duration for 500 lux	Exposure duration for 100 lux	Exposure duration for 20 lux
Philips dark-roomlamp red	Br.	0.84	37 h	185 h	926 h
Philips TLD 36W/yellow	Br.	5.65	6 h	28 h	138 h
Candle	Br.	14.10	2 h	11 h	55 h
Philips Ecotone 58W (827)	Br.	21.37	1.5 h	7.3 h	36 h
Osram Incandescent Light bulb 60W	Br.	23.91	1.3 h	6.5 h	33 h
Philips TLD-Standard 58W (25)	Br.	37.77	49 min	4.1 h	21 h
Philips TLD-Deluxe 90 58W (950)	Br.	45.03	41 min	3.5 h	17 h
High-Output LED white	Br.	71.90	26 min	2.2 h	11 h

Generally: the more relative blue wavelength contribution, the stronger effect on melatonin suppression. Warm (red) has light less to no effect.

PRACTICAL APPLICATION

Looking into the light source as measured is different to looking at (coloured) walls. Light sources are often out of the field of view. For instance, a red wall will reflect red wavelengths but absorb blue light, thus reducing the effect of melatonin suppression.

CONCLUSIONS

- Dose - Response relationship (Bunsen-Roscoe law) may be assumed for at least 1 hour exposure duration. If assumed, data by Brainard and Tapan compare well.
- Dependence on size of image on retina? (I.e. not only irradiance at cornea is relevant, also radiance (image size on retina)
- Simple worst case analysis: Choice of lamp spectrum and level of illumination may be critical to sustain or suppress melatonin production
- Difference of colour of objects in field of view vs. looking at the source has to be accounted for in practice

CONTACT
Dr. Karl Schulmeister, karl.schulmeister@seibersdorf-laboratories.at

Pleas note: This poster was originally published under our company's former name Austrian Research Centers.