Advanced Materials Research
ISSN: 1662-8985, Vol. 1041, pp 403-407
doi:10.4028/www.scientific.net/AMR.1041.403

Submitted: 2014-06-10
Revised: 2014-07-18
Accepted: 2014-08-06
Online: 2014-10-27

Evaluation of Indoor Daylight Parameters during Long–term Observations in the Rooms Equipped with Intensive Coloured Surfaces

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Keywords: Daylight Spectral Characteristics, Experiment In Situ, Colour Rendering Index, Non-Visual Response

Abstract. Examination, design and control of internal light conditions belong to important actual architectural issues. In most cases the reason is increasingly growing interest in non-visual response of human on the ambient light properties. Sick Building Syndrome (SBS) is assumed to be caused by complex of inappropriate indoor environment circumstances. Unsuitable light conditions are regarded to be one of them. This paper deals with comparison of internal light parameters such as photopic illuminance level E_V, Spectral Power Distribution (SPD) and definition of peak wavelength value recorded in tested office rooms, which were scaled down to models for easier handling. Models are equipped with different selected coloured wallpapers and flooring materials, whereby one model remains with all surfaces in neutral colours. The outputs of measured parameters are compared with each other and also with outdoor levels of the same light properties. There is also defined filtration efficacy of blue light component assumed to be most effective for controlling of non-visual sensory system of human body. This observation may provide more complex overview on selection of internal surfaces colours in long-term occupied spaces, taking health and wellbeing into consideration.

Introduction

Natural daylighting has crucial influence on the health conditions, productivity and wellbeing of human due to light's visual and non-visual effects [1]. The visual conditions of indoor daylight climate depends especially on external daylight circumstances and shading, but serious impact have also the factors like dimensions of window openings, glazing properties, internal coloured surfaces and other [2]. This paper deals with experiment devoted to measuring of spectral characteristics modification caused by internal coloured surfaces. Main monitored parameters are SPD, indoor illuminance levels and blue dose of light, which is most efficient for non–visual human response. There are used same–sized models of office room designed in the scale 1:5 with one window opening. One model is designed as reference model with all surfaces in white colour and rest represent the tested models in Fig.1.

Description of the Experiment

During the investigation, four model rooms were used. The location of models was on the flat roof over STU, Faculty of Civil Engineering. All of the models were exposed to natural daylight without any artificial light source, see in Fig. 1. One, the reference model, the first on the photo, had all of the surfaces in white colour. The rest three models had white ceiling and coloured walls and dark–brown flooring. Orientation of openings was oriented to South-East without any shading. There was high probability of glare occurence, but our measurement focused especially on changes in SPD, illuminance level and blue dose of light caused by internal coloured surfaces. The experiment consisted of two measurements. The first, short–term measurement, determined the changes in SPD of indoor daylight parameters caused by interior surface`s colour. The measurement of spectral characteristics of indoor daylight was made with spectrophotometer Konica Minolta CL-

500A. The device recorded the internal daylight conditions step by step in all models during short time, so the results were comparable. The measurements were made in various phases of the day. There were measured daylight parameters such as SPD and Photopic illuminance level E_V. The experiment proved the power of internal coloured surfaces impact on the indoor daylight spectral characteristics. The long-term examination consists of photopic illuminance recorded in models on vertical planes in height of 1200 mm (scaled to 240 mm) and their comparison with each other. There were used the Lightwatchers, the special wireless devices, which enabled to record photopic illuminance levels, blue irradiance and colour of the light in the interior [3].

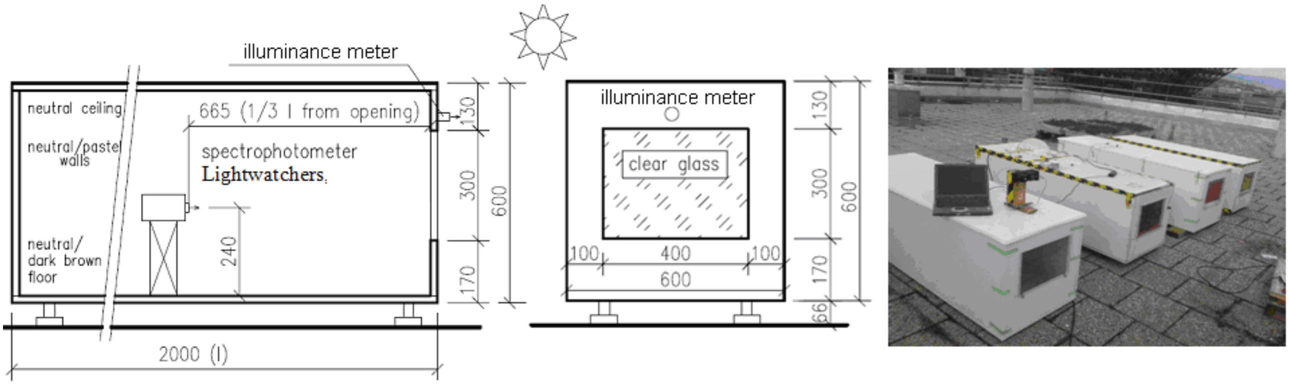

Figure 1. Model dimensions in scale 1:5, design of internal surfaces and location of devices.

Results

Spectral reflectance of used wallpapers is illustrated in Fig. 2. There was used Spectrophotometer Konica Minolta CM-5. Absolute values of reflectance according V(λ) and C(λ) are defined in (1-2). The results of measurement are shown in Table 1.

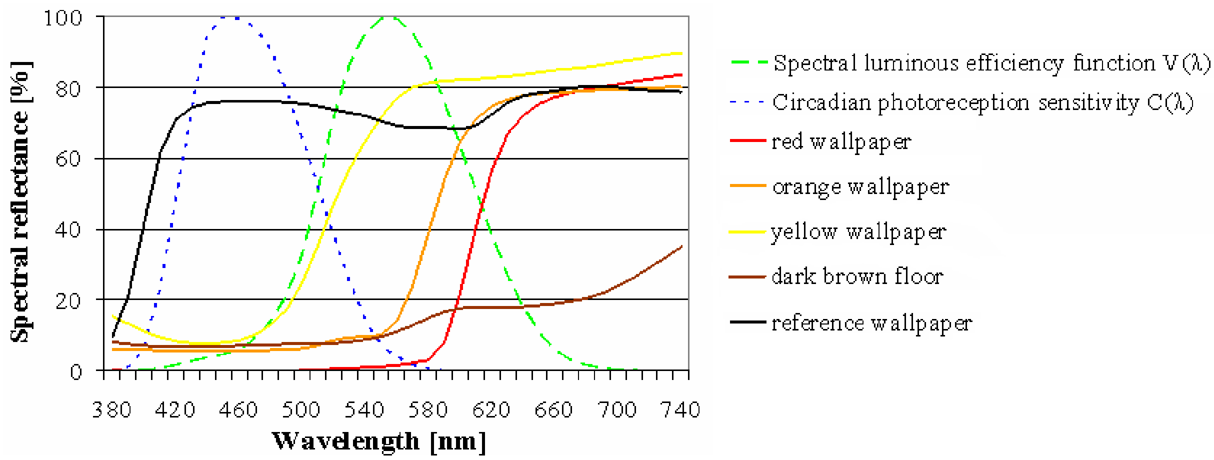

Figure 2. The results of spectral reflectance of wallpaper samples and flooring.

$$\rho_c = \frac{\sum_{\lambda=380nm}^{580nm} D_\lambda . \rho(\lambda).C(\lambda).\Delta\lambda}{\sum_{\lambda=380nm}^{580nm} D_\lambda .C(\lambda).\Delta\lambda} \qquad \rho_V = \frac{\sum_{\lambda=380nm}^{780nm} D_\lambda . \rho(\lambda).V(\lambda).\Delta\lambda}{\sum_{\lambda=380nm}^{780nm} D_\lambda .V(\lambda).\Delta\lambda} \qquad (1,2)$$

Where

D_λ is relative spectral distribution of the light source D_{65} [–];

$\rho(\lambda)$ is spectral reflectance of a surface [1/nm];

$\rho_c(\lambda)$ is absolute circadian spectral reflectance of a surface [–];
$\rho_V(\lambda)$ is absolute photopic spectral reflectance of a surface [–];
$C(\lambda)$ is circadian photoreception sensitivity [–];
$V(\lambda)$ is spectral luminous efficiency function [–];
$\Delta\lambda$ is increment of the wavelength range [nm].

On Fig. 3 is illustrated the SPD recorded in all models and also outside. The measurement was done on 4th of June 2014 at 00:40 PM. The differences in SPD levels were noticeable even though the spectrophotometer was oriented directly to window in 1/3 of length from opening.

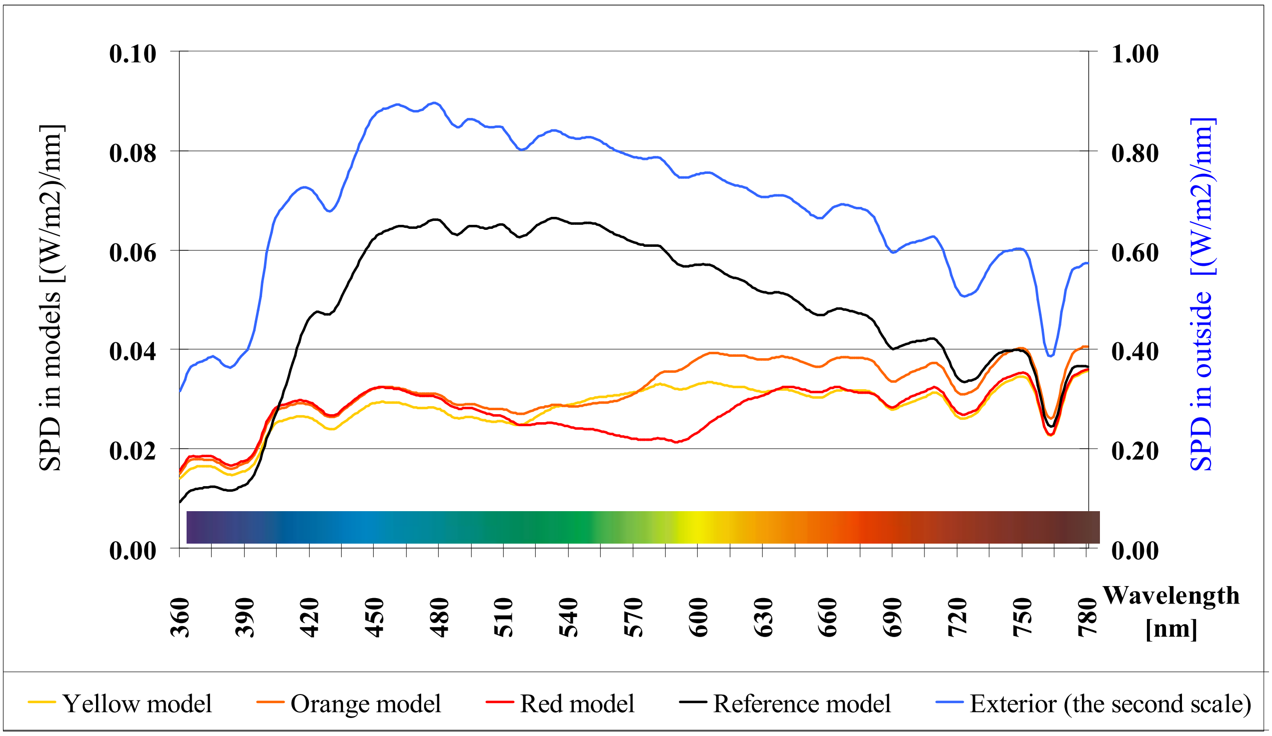

Figure 3. SPD of indoor daylight in all of the models and in outside (the right scale).

Table 1. The results of absolute spectral reflectance of the samples according $V_{(\lambda)}$ and $C_{(\lambda)}$, absolute dose of SPD and photopic illuminance levels in models in comparison with reference model results.

Sample of coloured surface	Absolute reflectance level		The model	Absolute dose of visible spectrum [(W/m^2)/nm]		The proportion of *SPD* in coloured model compared to reference model		The photopic illuminance level *Ev*	The ratio of photopic illuminance
	photopic	circadian		Wavelength interval [nm]		Wavelength interval [nm]			
	ρ_V[-]	ρ_c[-]		380-580	380-780	380-580	380-780	[lx]	[-]
yellow	0.65	0.17	yellow	5.327	11.520	0.487	0.579	2187	0.49
orange	0.27	0.06	orange	5.676	12.983	0.519	0.653	2327	0.52
red	0.10	0.01	red	5.290	11.221	0.484	0.564	1811	0.40
reference	0.72	0.75	reference	10.933	19.894	1.000	1.000	4479	1.00
dark-brown	0.12	0.07							

It can be seen (Tab. 1), that the effect of internal surface´s colour variation is reflected on the internal illuminance levels. Continuous measurements in course of days are shown on the Fig. 4. In the model room equipped with dark brown flooring material and selected wall colours resulted in the decrease of 50 % in the photopic light levels obtained in internal space. The comparison of non-visual effects of the light, where the resulting ratios for all models, are defined, can be seen in Fig. 6. Altogether the selected colours on the walls significantly suppressed the portion of the blue light in the interiors of the model rooms, see Fig. 4. The Lightwatcher device can record and evaluate the colour of light, which can be seen in raster diagram (Fig. 5).

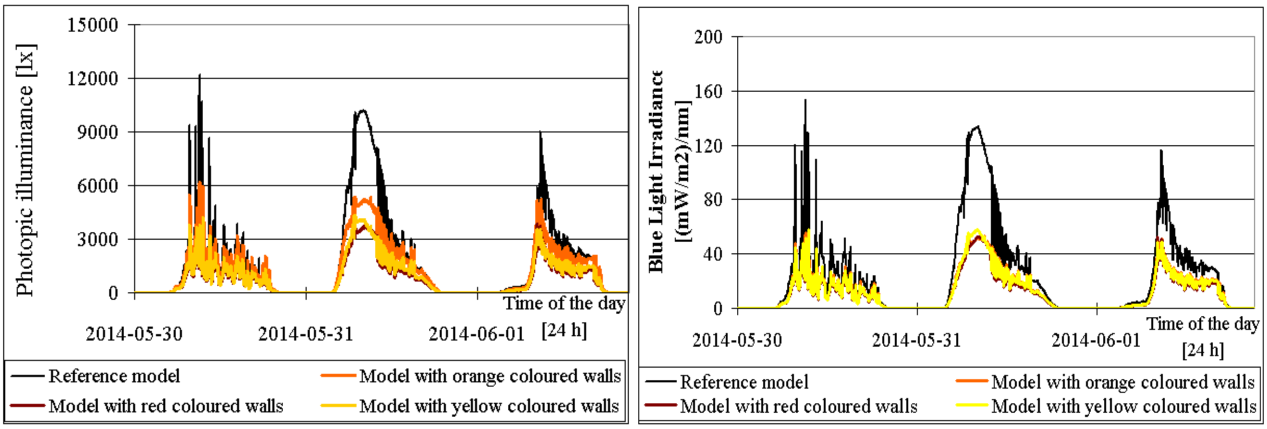

Figure 4. Levels of internal illuminances (left) and blue doses (right) of light in various models in the courses of the days.

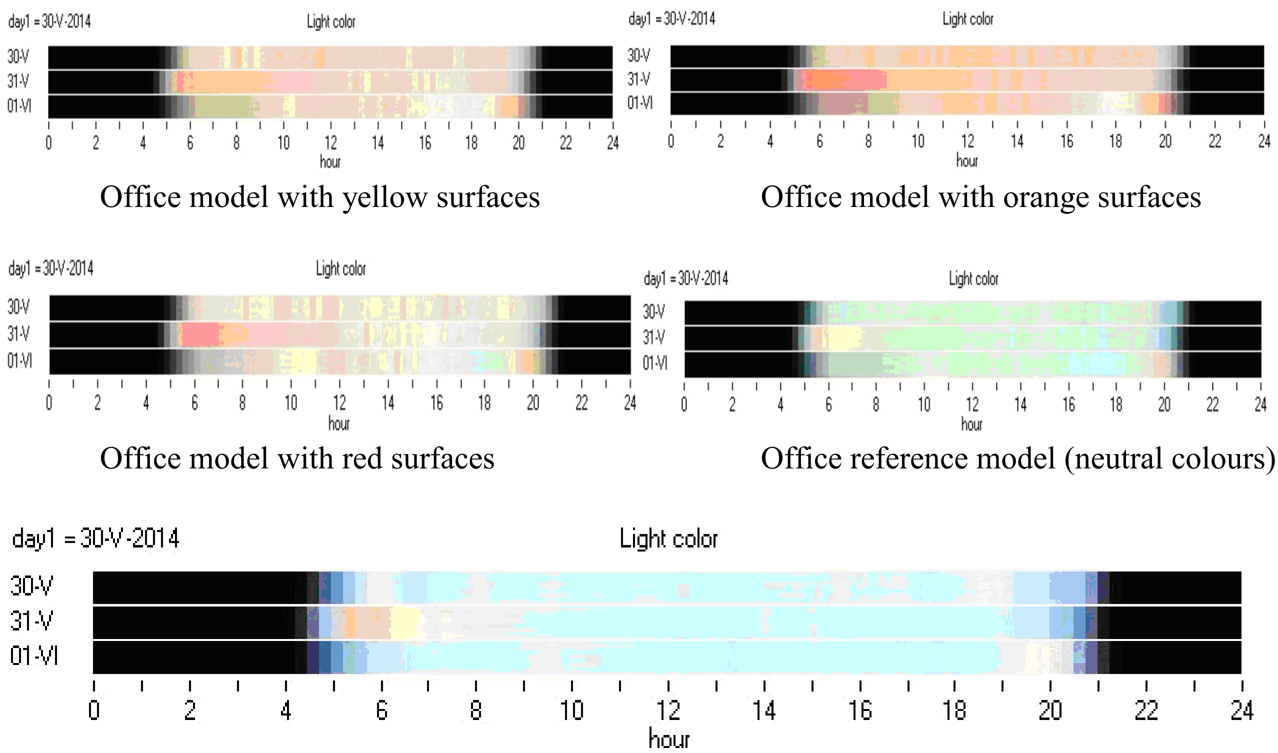

Figure 5. Raster diagrams of light colours in external environment in comparison to internal light colours of particular models (small graphs). (The quality of final images may be decreased during inserting in the MS Word).

It is clearly visible, that spectral composition of the light in reference room (without coloured surfaces) gets very close to the outdoor – natural one. The effects of coloured surfaces can be seen in other raster diagrams, where the colour of the light is influenced even though the light sensors were installed and directed against window openings.

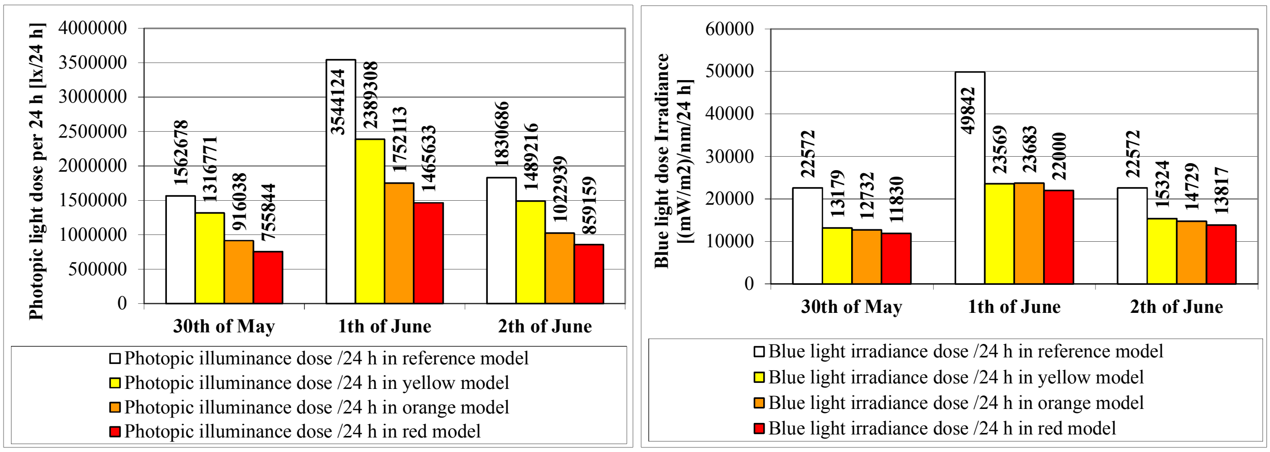

Figure 6. Total doses of visible light (left) and blue light (right) in the course of the days.

Conclusion

Although the differences between reference room and other test models were captured, they were not as distinctive as expected. This can be explained with the fact, that the overall intensities of daylight during summer time are simply too high to highlight the effect of coloured wall finishes. Also the absence of any shading device points towards the fact, that a huge amount of glare could be present in the model rooms. It is expected, that the effect of coloured surfaces would be much higher during the winter season, when ambient light conditions can enhance the colouring effects in the internal space. The glare issue can be eliminated with different sensor position in the various distances from the window opening as well as different direction of view. In the cases where the field of vision will include smaller portion of the window opening it will be expected to gain higher differences in spectral composition between model rooms due to higher portion of interreflections between various interior surfaces. On the bases of the experiment the white colour appears to be most effective for indoor spaces from both visual and non-visual response. It was already proven, that non–visual response demands higher illuminance levels than visual response. Selected samples of yellow, red and orange wallpaper in combination with dark brown flooring provided approximately only half doses of SPD in comparison with reference model with spectrally neutral colours. It is planned to repeat the experiment during winter season with more complex measurement including more measuring positions and variations of spectral filters. The establishment of precise requirements for non-visual indoor daylight evaluation is a long–lasting issue. There is necessity for more research.

Acknowledgements

This article was supported by Slovak Research and Development Agency under the contract No. APVV 0150-10 and project VEGA 1/0320/12.

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