Tinted Glass Curtain Wall and its Implications on the Occupants' Health – Case Study of a Tight Office Building in Algiers

Imane J. Chabane [1] and Rafik Bensalem [2]

Laboratory "Architecture and Environment"
Polytechnic school of architecture and urban design (EPAU), Algiers, Algeria
[1] imane_chabane@hotmail.com / [2] lae_epau@wissal.dz

ABSTRACT: Today in Algiers, we can observe the tendency from designers to envelop the new office buildings by glass curtain walls.
To conciliate between outdoor image of modernity and indoor needs of privacy and sun rays protection; the most used glass is tinted and reflective on outdoors.
Through this glass tint, the natural light is highly reduced in offices, particularly those non-exposed to sunshine, and the lighting environment becomes almost static with very low changing levels of sensation. In this paper, our interest is focused on effects of this lighting environment on the occupants' health, especially the visual and biopsychological effects. The results of survey undertaken in a tight office building situated in Algiers, have shown some negative effects as eyes' strain, tiredness, deficiency in notion of time, etc., disturbing the occupants in their work tasks.

Keywords: Tinted glass, Lighting environment, Health, Work office, Case study

1. INTRODUCTION

Until the late 1990s, it has been stated that lighting is only a visual perceived stimulus for which a developed and institutionalised system of photometry generated full recommendations for a healthy vision indoors and outdoors [1, 2].

Today, a new approach tends to characterize lighting quality in a much broader way than the threshold of vision margin, taking into consideration maintenance of good health, task performance, interpersonal communication and aesthetic appreciation [1]. By the rapidly emerging science of circadian photobiology, controlled laboratory and clinical studies has demonstrated that "light processed through the eye can influence human physiology, mood and behaviour" [1,3,4,5]. Non-visual photoreceptors in the retina have been observed to affect directly the hormonal system responsible of the day/night circadian rhythm. The sensitivity of both visual and non-visual receptors to light quality is so different that a new photometry is necessary, because the quantity, spectrum, spatial distribution, timing and duration, of light exposure for circadian impression are largely different than those important to vision [2,6].

It is admitted that insufficient light levels could cause lower concentration, reduced performance and affect well-being. In opposition, high levels have a positive effect on the human alertness, health and vigilance [7].

Today we talk about "good lighting" or "healthy lighting", to designate the lighting that responds to both visual and biopsychological human needs [1,7]. In this field, the natural light remains the "ideal" healthy light that is reclaimed by space users, and recommended by space designers. It is known to be an influent factor in the environmental satisfaction, characterized by being "more bright", generating a good space quality, and known to be "better quality" than the artificial light, affecting positively the physical health, especially the eyes' health [1,2,3,7,8].

In most work offices, "natural light" can be difficult to fulfil, even in narrow buildings where it is highly dimmed by a tinted window glass, designed to ensure privacy for occupants and reflecting the direct sunshine.

In this article, our interest is focused on the occupants' health in the tight work office environment, where the window glass is highly tinted.

2. LIGHTING EXPOSURE EFFECTS ON HUMAN HEALTH

2.1 Visual effects

The visual effects of lighting exposure are well known and comfort recommendations are highly spread in ergonomic field. That is why in this background, we centre our interest on the biopsychological effects that are relatively more recent in the architectural research field.

2.2 Biopsychological effects

Light is the main but not the only input that synchronizes the biological clock to solar (24 hours) day [4,6,8,9,10]. Insufficient exposure to the right light in term of quantity, duration, spectrum and timing, may leads to disruption in synchronisation with the solar day and so decrements in physiological

functions, neurobehavioral performance and sleep, usually occur [6].

In the last 30 years, it becomes clear that "light/dark" cycles regulate much cyclical human behaviour, including seasonal depression, sleep/wake patterns, body temperature, brain activity, subjective alertness, and performance [1,2,6,7,8].

Light exposure suppresses the "melatonin" secretion that is a hormone produced by the pineal gland under conditions of darkness, inducing sleep [2,4,6,8,9]. Disruption of lighting exposure induces disturbance of the "melatonin" secretion and so the circadian cycle, which can result in poor sleep quality, lack of alertness, seasonal depression and immune deficiencies [2,4,7,8].

Even though the photobiological processes are in an early stage of understanding, it is known that the human sensitivity to these processes is different from the visual sensitivity, trough six main characteristics: quantity, spectrum, timing, duration, spatial distribution, and illuminance position [1,2,4,6].

- Typical light levels recommended in a work office environment (about 500 lx from white light source) is sufficient for visual processes, but barely sufficient to stimulate photobiological system (1000 to 1500 lx may be necessary), even after one hour exposure [6,7].
- Concerning spectrum, "the visual system is most sensitive to the middle wavelength portion of spectrum, while the photobiological system is responsive to the short wavelength portion" [2,6].
- The visual process does not depend on timing of light exposure; it is reactive to light stimulation at any time of day or night. However, the biological processes are differently sensitive to earlier time exposure and later time exposure.
- Duration of light exposure, needed to suppress "melatonin" (about 10 minutes) is longer than duration of light exposure needed to activate the visual system (less than 1 second) [6].
- For the visual system, light distribution in a space is critical to visual performance, whereas the circadian system does not respond to this factor, and only the overall amount of light reaching retina is required [2,6].
- In the work office environment, current lighting recommendations for different tasks performed on a horizontal plane, are based on visual criteria of horizontal illuminance levels, whereas for the biological stimulation, the vertical or retinal illuminance is a key factor [2,7].

Concerning this last characteristic, the "natural light" through window is the main source of vertical illuminance in most common architectural models of office buildings. It is recommended as a "primary" light source and artificial light as a "secondary" source, in work office environment [3,11,12].

The natural light is the "ideal" healthy lighting because it offers a large margin of wavelength varying during a day at different times for different durations [1,7,10]. Its intensity is continuously varying, regulating the activity/rest cycle during a day, oppositely to the artificial light with fixed intensity that generally induces users' strain and tiredness after long exposure [10].

Natural light is the suitable dynamic light source that responds to visual and biopsychological needs. Independently of the climatic context, space users prefer natural light than artificial light because it generates a pleasant ambience and procure well-being sensation [3,10,11]. These sensations are well-founded because the biological regulation of the "melatonin" secretion by natural light variation induces simultaneously, regulation of the mood factor regulator that is "cortisol". High levels of "cortisol", generated by the "melatonin" suppression (generally on morning), corresponds to sociability and good mood, and inversely low "cortisol" levels correspond to self-concentration and introversion [5].

In the research field, the most known biopsychological effect of less natural light exposure is the "Seasonal Affective Disorder" (SAD). It concerns about 5 to 10% of population living in high north latitudes, where natural light levels are very low during autumn and winter (SAD syndrome disappears during spring and summer) [5]. This syndrome is generally treated by artificial phototherapy, but sunlight exposure remains the best recommended therapy [3].

Natural light is the main source of information about outdoor environment, in term of weather and daytime. Even if the common media (TV, radio, internet…) constitute an important source of information about weather and climate changes, in our daily habits a rapid glance through a clear glassed window remains more informative and influent on our clothes wearing and day planning.

The natural light is also an important source of sensorial variation. In the naturally ventilated environments, the operable window is the main source of sensorial variation by stimulating our olfactory, auditory and visual senses. However, in the tight environment with fixed windows, the "changing levels of sensation" concern only variation of natural light stimulation through the window glass. During day, invariable environmental conditions are known to affect the human alertness level, inducing boredom and tiredness and even a reduction in brain skills [3,4,10,12], mainly because it does not respond to the activity/rest cycle demands. That is why in unwindowed environments, researchers tend to develop varying systems of artificial light, but it remains evident that the "sensorial changing" needs are the best satisfied by the natural world variation.

In resume, independently of the climatic context, the "natural light" is the most expected light source in the indoor environments, because it holds and maintains the occupants' good health by responding to their visual and biopsychological needs.

3. THE CASE STUDY

The case study is a tight glassed office building situated in the south-Mediterranean climate of Algiers

city (Lat.° 36,47N), where we count generally more than 250 sunny days per year. The environment in this office building is controlled by a heating, ventilation and air conditioning (HVAC) system. It is composed of three blocks (8,9,10 floors) and one central courtyard in each block (Fig.1). The global plan is a rectangular shape with two kinds of offices: peripheral with view on exterior and central with view on the courtyard. In this paper, our interest is focused on the peripheral offices (Fig.2), without the central ones. From the 2nd to the 8th floor, the plan is repetitive. The building façades have the following orientations: North-East, North-West, South-West, and South-East. To facilitate nomination of the offices orientation, they are respectively replaced by: North, West, South, and East.

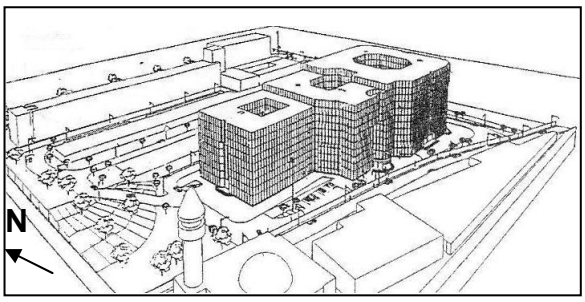


Figure 1: Western view of the case study (three blocks with three courtyards).

- Central and peripheral façades are enveloped by a hermetical glass curtain wall, equipped with smoke extractor-windows, each office being equipped with at least one (max of opening = 9 cm).
- The curtain wall units are composed of double glazing system with: interior clear glass (6 mm), air space (10 mm) and exterior tinted “stopsol” glass (8 mm).
- Sunshine is controlled by interior blinds.
- The artificial lighting units are composed of four dimmable fluorescent bulbs with reflective component controlled by a dimmer switch in each office (Fig.2).

Figure 2: Interior photography of a peripheral office (with tinted glass in background).

4. METHODOLOGY

Data analysed in this paper are part of a global investigation, undertaken during summer of 2003, where all environmental factors related to the glass envelop have been assessed.

4.1 The assessment tools

The assessment tools are constituted of a direct questionnaire and illuminance measures:

- Through the questionnaire tool, we assessed: the occupants’ expectancies and beliefs related to the light factor; their evaluation of the lighting environment; the visual and the biopsychological effects of the lighting environment (Tab.1).

Table 1: Construction of questionnaire

Objectives	Asking about
Occupants’ expectancies and believes	– Important factors in cause of the environmental satisfaction, in general. – Occupants’ preference by choosing between natural light, artificial light and combined light. (Their choose must be justified)
Evaluation of the lighting environment	Evaluation of : – The natural light (sufficient/ insufficient). – The artificial light (comfortable/ uncomfortable). – The combined light (adequate/ excessive/ insufficient). – The glass tint.
Visual effects of the lighting environment	– Eyes’ health: eyes strain and view drop. – Glare sensation (important / negligible).
Biopsychological effects of the lighting environment	– Informative aspects: weather and notion of time. – Healthy aspects: tiredness, and illnesses frequency.

- By using a luxmeter (Testo 545), we assessed the illuminance levels (lx), received on the occupants’ work plane (on desk). Two measures have been collected: one concerns the combined artificial and natural lights, and the other measure concerned only the natural light level, received on work plane.

4.2 Sample composition

The collected data concerns 91 respondents occupying peripheral offices (from total of 147 respondents of both central and peripheral offices). The survey has been conducted in the 2nd, 4th, 6th and 8th floor (4 from 7 common plan floors), and the spatial distribution rates for the four orientations of the building, have been respected.

5. RESULTS AND DISCUSSION

Concerning the lighting environment, the “natural light” is highly expected in the work office environment by 87% of respondents. This dominant majority believes that natural light (including daylight and sunlight) is necessary in an environment for good psychological and physical health, and particularly to maintain good eyes’ health.

These results correspond to much results cited in literature, related to the occupants’ satisfaction in work office environment, in different climatic context [3,11,12].

5.1 Lighting evaluation

5.1.1 Combined light (both natural and artificial lights)

62% of respondents are satisfied about the general lighting environment, and 38% are not satisfied according to their offices orientation (24% excessive and 14% insufficient).

An important rate of complaints about "glare" (53%) has been recorded, mostly in the Southern and the eastern offices, directly exposed to sunshine.

The majority of occupants are satisfied about the artificial light, assessed as "comfortable" (65%), especially because it can be controlled by a dimmer switch. However, 31% assessed it as "uncomfortable", essentially because they consider it as unhealthy or excessively bright.

Even if all these offices are peripheral, with a view on the exterior environment, no less than 65% of their occupants use the artificial light during all year, and 27% only use it when weather is bad (only 1% never use the artificial light). This important use frequency reflects inability of the natural light to ensure the occupants' visual task needs and that for two main reasons. The first concerns its insufficiency in the less exposed offices to sunshine factor. The second reason concerns the excessive sunshine exposure in southern and eastern offices which occupants block by opaque blinds, and so it becomes unavoidable to use the artificial light.

Simultaneously to the occupants' evaluation, the illuminance levels recorded with the luxmeter instrument reveal that in 35% of the offices, the levels correspond to the ergonomic margin of [200 to 500 lx] recommended for visual needs [10,11] and in 43% the levels are superior to 500 lx. (Tab.2)

According to one of two controversial illuminance margins (1000 to 1500 lx) cited in literature [2,7] that responds to biopsychological needs; the lighting environment in this case study does not satisfy or badly, its occupants' biopsychological needs. Actually, only 2% of the recorded levels are superior to 1000 lx.

Table 2: Illuminance levels of natural light and combined light on work plane

		Natural light	Combined light
Illuminance levels (lx)	--	02 %	07 %
	< 120 lx	**53** %	07 %
	[120 - 200[	24 %	09 %
	[200 – 500]	**15** %	**35** %
	> 500	03 %	**43** %
	Total	100%	100%

Discussion

Majority of the occupants (nearly two thirds) is satisfied about the combined light and minority is not satisfied because the artificial light is considered as "unhealthy", and in different orientations it is considered as "too bright" or "insufficient".

This combined light seems to be ergonomic for the visual needs, only in term of quantity (illuminance levels), but not in term of quality (colour temperature, spectrum, etc.) and space distribution (contrast, surfaces reflecting index, etc.). Because a non-negligible rate of occupants complained about "glare", and about "eyes' strain" and "view drop", as we shall present in the topics bellow. In reaction to this lighting environment, some occupants have unscrewed the nearer light fluorescent bulbs, upon their work plane, and others installed a desk light on their work plane.

We can notice also that some occupants have observed changing on their skin and hair, which they related to the fluorescent light.

Concerning adequacy of this combined light to the biopsychological needs, the illuminance levels recorded in the offices sample, seem to be "insufficient" according to literature (because inferior to 1000 lx). However some controversial hypothesis consider that the circadian system can be sensitive to a very low light level as 3,5 lx, in particular conditions [2].

We are unable to decide in favour of one of these two considerations, both are still in progress. However in this case study; it remains possible to observe the lighting effects on the biopsychological health of the occupants, through their complaints about "tiredness", deficiency in "notion of time", and "constant bad weather".

5.1.2 Natural light and glass tint

The natural light is assessed by occupants in summer and winter. In summer, 71% are satisfied about "sufficient" natural light in their offices, whereas in winter, 84% are not satisfied because it is "insufficient".

Concerning the glass tint of window, 52% of respondents are satisfied about it, because it ensures their visual privacy from exterior visual intrusion. However, 40% are not satisfied and evaluate it as "dark" and "gloomy" (Fig.3), inducing to some occupants a feeling of "sadness" (8% have a neutral position). This negative feeling can be explained by the low levels of the "cortisol" secretion [5], induced by the insufficient illuminance levels of the natural light and combined light in some offices, particularly those oriented on north and west.

Figure 3: Important tone of the glass tint

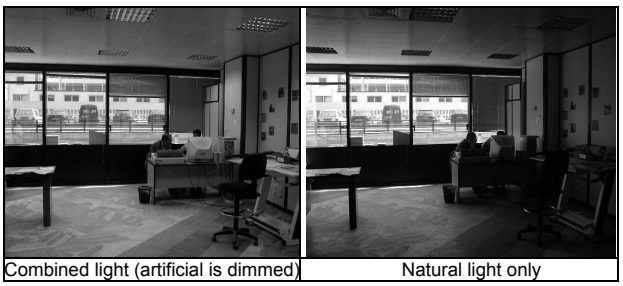
During summer, more than half of the illuminance measures (53%), collected were lower than the recommended threshold level of 120 lx (Tab.2), and only 15% correspond to the ergonomic margin of [200 to 500 lx] recommended in the office environments, where VDT screen is used [10,11].

Discussion

On one side, we can observe that 84% of respondents assessed the natural light as "sufficient" and satisfying during summer, while 74% of the collected measures are lower than the ergonomic margin of [200 to 500 lx]. Two explanations could be attributed to this contradiction:

- Firstly, most of respondents are far from window, and some investigations cited in literature [11] have shown that generally this category of occupants "overestimate" the natural light quantity received on their work plane.
- Secondly, it is well known that availability of "natural light" is an influent factor on the occupants' environmental satisfaction, even if the illuminance levels do not respond to the visual tasks needs [3,11,12]. So, satisfying natural light quantity, perceived by the occupants, make them considering it as the "main source" and the artificial light as a "secondary" light source, even if the real illuminance levels are inversed.

On another side, it is astonishing to observe so low illuminance levels of natural light, during summer, when we know that glass surface is dominant in the exterior wall of offices, and that offices' depth does not exceed twice of the width. This state is related to the "tone" of the glass tint, which suppresses non-negligible amount of natural light (Fig.3, 4).



Combined light (artificial is dimmed) | Natural light only

Figure 4: The lighting environmental Contrast between using the artificial light and without it.

5.1.3 Synthesis

In our Mediterranean climate, frequent use of the artificial light reflects inability of the glass tint to ensure sufficient daylight in northern and western offices; and its inability to block direct sunshine in the southern and eastern offices.

Using the same glass tint in all façade orientations seems to be a controversial solution. Northern and western offices need a clearer glass tint to let more daylight entering; and in southern and eastern offices another device as "brise-soleil" for example, could be more appropriate to block direct sunshine rays.

5.2 Lighting environment effects on the occupants' health

5.2.1 Visual effects

33% of respondents complained about "view drop" since they occupy this environment. This rate represents only one third of the occupants, but remains very important and causes can not be totally attributed to the lighting environment because the occupants' age and their eyes' sensitivity can constitute more plausible causes.

Majority of occupants, concerned by the "view drop" have attributed it to the artificial light or VDT screen use. But, we observed that those older than 40 years are most affected by the "view drop".

Less grave than "view drop" but more complained by occupants, is the "eyes' strain" that constitute a dominant bad effect, expressed by 82% of respondents. This effect disturbs the concerned occupants in their work tasks and may induce frequent headaches and general tiredness.

"View drop" and "eyes' strain" are the main visual effects we observed, and that we can undoubtedly attribute to the lighting environment, even if partly.

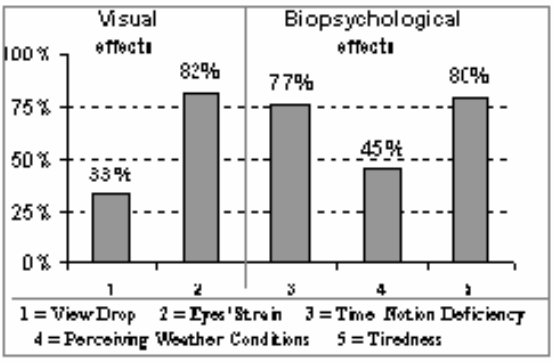


Figure 5: The lighting environment effects on the occupants' health.

5.2.2 Biopsychological effects

In this study, three biopsychological effects have been observed, which can be directly related to the lighting exposure: deficiency in "notion of time", difficulty to perceive weather outside, and high rate of tiredness. Other illnesses complained in this environment could be related to the immune deficiencies as irritations, repeated flu, etc., induced by disruption of the "melatonin" secretion, due to disruption of the lighting exposure.

Concerning "notion of time", only 23% of occupants are able to guess all (different) hours during their work time (most of them occupy eastern or southern offices, directly exposed to sunshine) and almost the same rate (22%) represents whose haven't any notion of time. The higher rate of 55% concerns occupants able to guess only some hours as: 10h00, by hearing the children' voices during their break in a near school; or 12h00 by hearing their colleagues in corridor; or at 13h20 by hearing the prayer call, etc. In this category, notion of time is more influenced by auditory stimulation than visual stimulation.

The glass tint seems to be the main cause of deficiency in notion of time, which concerns three quarters of the respondents. Lack in natural light variation and unvarying artificial light exposure reduce the occupants' perception of visual stimuli variation, and this fact can increase the occupants' feeling of

"enclosure" and "isolation", initially generated by the tight character of environment.

In literature, perception of the "weather conditions" and their changing, constitute an important factor of the environmental satisfaction [3,12] because it responds to the occupants' need of connexion with external world. In our case study, only 55% of respondents (mostly occupying eastern and southern offices) can clearly perceive the weather conditions and 45% are unable to do it, perceiving most of the time a "bad weather", even in summer. These occupants' offices are generally oriented on west and north, with little exposure to direct sunshine. The glass tint, in these offices, constitutes a "grey filter" making appear a bad weather most of the time (this fact induces some occupants to feel "sadness"). These occupants have to ask their colleagues coming from outdoors, or go to offices exposed to sunshine, or open the smoke-extractor window, etc., to be informed about the weather conditions.

Deficiency in notion of time (77%) and difficulty to perceive the "weather conditions" (45%) reflect clearly incapacity of the glass tint to ensure an adequate "changing level of visual sensation", particularly in offices not exposed to direct sunshine. This let us consider that during all year, at least half of the occupants are exposed to invariable environmental conditions. According to literature, this fact is known to affect their alertness level, inducing boredom and tiredness, and a reduction in brain skills [3,4,10,12].

In this study, we can confirm only the "tiredness" effect (other effects require an exhaustive investigation). 80% of respondents complain about tiredness during their occupation of their offices. Tiredness can also be related to work stress, social relations, etc., and not only to the environmental factors. But several studies, cited in literature, have shown that in tight environments where occupants are exposed to static artificial conditions, high rates of tiredness are frequently observed.

2.3.3 Synthesis

The lighting environment in this case study is uncomfortable and unhealthy.

It is uncomfortable because it induces high rate of "eyes' strain", probably caused by "glare", and an important rate of "view drop"; and it is unhealthy because it is static and invariable in most of half of the offices. This invariable environment induces difficulties to perceive changing levels of visual sensation. That is why, an important rate of deficiency in notion of time and difficulty to perceive the weather conditions, have been recorded. Difficulty to perceive the weather changing means that the outside landscape is constantly fixed and grey as a "bad weather". That is why some occupants have expressed the feeling of "isolation" and "sadness" in their offices.

These low changing levels of lighting sensation may have caused disruption in the rest/activity cycle too, that is why a high rate of "tiredness" has been observed.

6. CONCLUSION

The natural lighting is highly expected in the office environment and occupants believe that it is necessary for their good health and well-being. These believes are well founded, and the environmental studies have shown that a well designed naturally lighted indoor environment, responds to occupants health needs better than the artificial light.

Filtering this natural light to avoid glare and heat gain trough a "glass tint" device, should be designed for an optimum environment where firstly, the occupants' health and comfort are ensured in priority, and secondly energy is saved.

In our case study, we noticed that a "glass tint" alone can not satisfy three different functions at once, as: ensuring the occupants' visual privacy; blocking direct sunshine rays; and ensuring sufficient amount of daylight for visual and biopsychological needs.

These considerations have been sacrificed to satisfy the external aesthetical appearance of the building, in accordance with the stereotyped American curtain-wall.

The negative effects on the workers' health observed in this case study and mostly cited in literature, can induce heavy expenses by reducing the workers' performance. That is why these environmental considerations do not interest only the space designers but also owners and managers who could make considerable savings by ensuring a healthy environment where workers could be most productive and effective. Moreover, the well designed naturally lighted spaces, particularly in sunny climates, may induce considerable rates of energy saving.

Finally, we consider that the natural light in a Mediterranean city is a precious and free wealth that should be efficiently exploited to ensure healthy indoor environments as well as energy saving.

ACKNOWLEDGEMENT

Great appreciation to the survey respondents and the office building managers, for their patience, kindness and help. A distinguished appreciation to F. Gadiri and A. Chabane for their help and encouragements.

REFERENCES

[1] J.A. Veitch, « *Principles of healthy lighting: a role for daylight* », IRC-Pub., Canada (2003).

[2] M. S. Rea, "*Lighting much more than vision*", Proc. 5th International Lighting Research Symposium, Palo Alto, California – USA (2002).

[3] K. Tabet-Aoul « *The interaction of view, window design and shadow devices*». Ph.D., Sheffield University, London (1991).

[4] J.A. Veitch, « *Lighting quality contributions from biopsychological processes* », IRC, Canada (2001).

[5] I.C.L. Fonseca and al. « *Quality of light and its impact on man's health, mood and behaviour* ». Proc. 19th Conference of PLEA, Toulouse – France (2002).

[6] M. G. Figueiro "*Research Recap*", in Lighting Design and Application (LD+A), 33 (2), USA (2003).

[7] M.B.C Ariës and L. Zonneveldt, «*Architectural aspects of healthy lighting* ». Proc. 21st Conference of PLEA, Eindhoven – The Netherlands (2004).
[8] M. G. Figueiro and al. "*Daylight* and productivity", Proc. 5th International Lighting Research Symposium, Palo Alto, California – USA (2002).
[9] J. Caston, «*Psychophysiologie*», Ellipses, France (1993).
[10] S. Deoux et P. Deoux, « *L'écologie c'est la santé* », Frison-Roche, France (1993).
[11]E. Sundstom and M.G. Sunststrom «*Work places, the psychology of the physical environment in offices and factories*». Cambridge University press (1986).
[12] K.M.J. Farley and J.A. Veitch, « *A room with a view : a review of the effects of windows on work and well-being*», IRC-Pub., Canada (2001).