Lighting in Sick Building Syndrome: Urban and rural environments

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Abstract

Sick Building Syndrome (SBS) is characterized by a significant proportion of people experiencing allergy-like symptoms that disappear or diminish when they leave the building. The exact causes remain unknown and the inclusion of lighting into SBS models deserves further research.

Within this context, the field study described here measured different environmental variables and their perception, especially lighting, in 97 urban and rural users. This research provides data and results in order to contribute to a more holistic model of SBS, which could be useful to architects and designers interested in meeting the needs of users.

Keywords: Urban and rural environments, lighting, symptoms, sick building syndrome.

La iluminación en el Síndrome de Edificios Enfermos: ambientes urbanos y rurales

Resumen

El Síndrome de Edificios Enfermos (SBS en su sigla en inglés) se caracteriza por una significativa proporción de la población que experimenta síntomas de tipo alérgicos que desaparecen o disminuyen al abandonar el edificio. Las causas exactas aún se desconocen y la inclusión de la iluminación dentro de los modelos explicativos de SBS merece mayor investigación.

En tal contexto, el presente estudio de campo midió diferentes variables ambientales y su percepción, con hincapié en la iluminación, en 97 usuarios de locales urbanos y rurales. Este trabajo aporta datos y resultados para el desarrollo de un modelo más integral de SBS, lo cual brindaría una herramienta útil para arquitectos y diseñadores interesados en satisfacer las necesidades de los usuarios.

Palabras clave: Ambientes urbanos y rurales, iluminación, síntomas, síndrome de edificios enfermos.

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Introduction

Even though Sick Building Syndrome, as the set of physical and mental symptoms associated with the use of buildings, was discovered in the 1980s in urban working environments (offices), its study has now been extended to other contexts. Hence, this article provides a comparison in the perception and effects of environmental variables between users of urban offices and rural housing, where lighting is a common cause for complaint in both environments and where the socio-economic context also determines behaviours related with their use.

This article also aims to demonstrate that the role played by lighting in explanatory models of SBS is broad and deep, yet often approached only in terms of avoiding glare and flicker in lamps used in work stations.

There is increasing evidence that the conditions in buildings can affect our health; the current topics of discussion include exposure to lighting, noise and chemicals; availability of windows; and the quality of housing in general. These findings have had a limited influence on the design, construction and running of buildings, partly owing to the limited interaction between the relevant disciplines (Veitch, 2008).

A large proportion of the population experiences health problems related with the use of buildings. Generally, this phenomenon has been characterized as "Sick Building Syndrome" (SBS) (WHO, 1983). This term covers a wide range of symptoms with no clearly identifiable cause; however, this is what sets it apart from other building related illnesses which are caused by factors that are closely linked to the building, such as the legionella bacteria often distributed via aerosols emitted by cooling towers located in the upper sections of buildings.

Researchers have compiled a list of symptoms of general unwellness which have been linked to sick buildings. The list includes irritation of the eyes, nose and throat (dry, sore, hoarse); irritation of the skin (itching, dry skin, soreness); somatic symptoms (headache, nausea, drowsiness, fatigue); non-specific allergic reactions (watery eyes, nasal congestion, asthmatic symptoms); and complaints about sensory alterations (bad smells, taste). (Bell, Greene, Fisher and Baum, 1996).

The exact causes of SBS are still unknown; however Project COST 613 (European Concerted Action, 1989) has identified four major groups of risk factors: physical (temperature, relative humidity, ventilation, artificial lighting, noise and vibrations, ions, particles and fibres); chemical (tobacco smoke, formaldehyde, volatile organic components, gaseous substances such as carbon dioxide, carbon monoxide, nitrogen dioxide, ozone, sulphuric dioxide and odours); biological (microorganisms, mould); and psychological (stress, individual vulnerability). The report produced by this project also offers recommended levels for each factor.

The World Health Organization has also identified common features pertaining to sick buildings (WHO, 1984):

> They often have forced ventilation (including systems of air conditioning); the construction materials are poor quality; the interior surfaces are covered with textiles (carpets, fabric upholstered furniture, etc.); they are energy efficient, relatively warm and possess a consistent ambient temperature; they are hermetic, the windows cannot be opened; the lighting causes high levels of glare and/or flicker; low level of user control over ventilation, heating and lighting; insufficient cleaning; chemical contaminants such as tobacco smoke, ozone (from photocopiers and printers, etc.), or volatile organic compounds; dust particles or fibres in the air; and computer screens.

Open-plan offices with large expanses of glass and the intense use of synthetic materials would also play a role, along with; poor ventilation; interior contaminants such as chemicals released by adhesive carpets; cleaning fluids, solvents; noise, poor office and work station layout; low salaries (Claims, 2005).

Owing to the major world energy crisis, efforts to save energy will continue for many years and energy-efficient but sick buildings often cost society more than it gains in energy savings. As regards the energy used for lighting, in the late 1990s, the International Commission on Illumination (CIE) began to shift its emphasis away from lighting for visibility purposes to a broader definition of *quality of illumination*, which incorporates human needs, architectural integration and economic limitations, including energy (Rea, 2000).

Through various field studies, Çakir (1991) reached two major conclusions: firstly, that artificial lighting should be considered an important contributing factor in 'sick building syndrome' in general; secondly, that there are effective means of improving lighting conditions and avoiding the negative impacts on health and wellbeing, even if fluorescent lamps are used. However, this maintains that the positive effect of natural light cannot be replaced by anything.

The theory of evolutionary adjustment (Hughes, 1980; Thorington, Parascandola and Cunningham, 1971; Wurtman, 1975 a, b), based on the fact that natural light was the only source of illumination throughout most of the period in which human beings evolved, posits that all physiological processes should function optimally when they are exposed to natural light. According to this hypothesis, any deviation in daily exposure to natural light would cause abnormal functions; hence electrical lighting as a primary source of exposure would be 'unplanned phototherapy' with non-specific undesired consequences (Veitch, 2001). Numerous laboratory, clinical and field studies have demonstrated that the light that penetrates the eye can influence the physiology, state of mind and behaviour of human beings (Tonello, 2001).

Edwards and Torcellini (2002) show that the appropriate use of natural lights decreases the occurrence of headaches, seasonal affective disorder and eye strain. However, the inappropriate use of natural light can have negative effects owing to the possibility of extremely high levels of illumination, glare and high temperatures.

In general, the positive aspects of a home include the satisfaction of biological, aesthetic and communication needs, also facilitating parenting/child-rearing, domestic chores, family development, personal wellbeing and the promotion of health. (WHO-PAHO, 2000)

Problem

The World Health Organization defines Health as the state of total physical, mental and social wellbeing, and not merely the absence of illness. Hence, identifying and understanding both environmental factors (stimuli, stressors) and the vulnerability of human beings to them, offers us important tools not only to understand illness but also to treat and prevent it.

Hence, studying the physical environment with which we interact is essential so that its design responds efficiently to human needs, in other words, to ensure it is optimum to fulfil its sensorial functions and to promote the physical and mental health of its users. For example, environmental variables such as noise and lighting can have non-auditory and non-visual effects that are damaging to the health (Ewans, 2000; Hygge, 1991; Küller, Ballal, Laike, Mikellides and Tonello, 2006; Tonello, 2008; Vallet, 1993).

In order to further develop knowledge about the role of lighting in the context of SBS, the perception and effects of different environmental variables were compared, especially lighting, as well as symptoms of discomfort and/or illness associated with the interior physical environment. For this purpose, offices were taken for the analysis of urban environments and houses for rural environments, both in Tucumán (North West Argentina, latitude 27º South).

Methodology

The methodology involved taking physical measurements of the environments (building surveys, levels of illumination, noise, temperature and humidity), and subjective evaluations of these environmental variables through questionnaires administered to users.

The level of illuminance (lx) was measured using Minolta illuminance meters fine-tuned to V(λ) with a cosine correction; temperature (ºC) and ambient humidity (%) were measured using a Data Logger Mod. H 01-001-01 Code DTH 0B070, and noise (dBA) with a digital decibel meter with a range from 35 to 100dB & 65 to 130 dB.

For the urban study, the questionnaires were self-administered, and in the rural study they were administered by researchers. Simultaneously, physical measurements were taken in the buildings.

The questionnaire answered by office workers was divided into two sections: the first enquired about their perception of environmental conditions in general, and specifically lighting in their places of work.

Using a 5-point scale (never, rarely, sometimes, often, always), possible problems with environmental factors were evaluated such as annoying noises, vibrations, stale air, unpleasant smells, excessive heat, dry air, static electricity, solvents, etc; and technical lighting factors such as glaring light, flickering bulbs, direct sunlight, reflections on the screen, etc. Furthermore, using semantic differentials such as pleasant-unpleasant, strong-weak, cold-warm, natural-artificial, etc, and on a 5-point scale, the subjects' experience of lighting at their workstation was evaluated.

The second part of the survey included a list of symptoms of discomfort related with the use of buildings and developed within the framework of the European Union Joule Project (Laike and Küller, 2000). It encompassed 41 symptoms, such as muscle pain, eczema, allergy, eye and breathing problems, headache, nausea, and psychosomatic complaints, which were rated according to a 5-point scale (see Table I).

TABLE I
Discomfort measures used in the study

Watery eyes	Acidity	Shivers
Tired eyes	Neck pain	Headache
Dry eyes	Shoulder pain	Migraine
Blurred vision	Muscle pain	Dizziness/nausea
Sensitivity to light	Lumbago	Sensation of being unwell
Eyestrain	Sharp pains in hands/arms	Stomach pain
Humming/buzzing in ears	Sharp pains in feet/legs	Difficulty concentrating
Sensitivity to sound	Dry skin	Anxiety
Sharp pains in the nose	Redness	Irritation
Itchy nose	Burning skin sensation	Stress
Nasal dryness	Stinging	Depression
Rhinitis	Eczema	Tiredness
Metallic taste	Dyspnoea	Allergy
Dry mouth	Perspiration	

The questionnaire applied to the rural zone comprised two parts: the first, a survey about the physical characteristics of the property, types and uses of energy, type of lamps and lights, and details about the family unit. The second part was an opinion survey that used open-ended questions to ascertain people's desires and wishes about what they consider necessary to improve their living conditions, the use of natural resources for nourishment and health (this question was included because the area studied is widely known for its vast array of herbs and vegetables in general, as well as their domestic application for therapeutic purposes and in cooking throughout this area of Argentina), disposition of toxic products, etc. The perception of environmental conditions in the property (little ventilation, very damp, suffocating, dark, unpleasant smells, etc.) was evaluated using a 4-point scale (always, often, sometimes, never). The level of control over these conditions was evaluated using a 7-point scale, from none to total. The variations in state of mind caused by the physical environment, as well as psycho-physical symptoms, were evaluated on a 4-point scale (not at all, a little, a fair amount, a lot).

The differences in the number of points on the classificatory scales are due to theoretical considerations pertaining to the item evaluated and the characteristics of the subjects.

Subjects and places

The urban sample (N = 67) comprised 38 women and 29 men with an average age of 42 (SD = 10.1).

In the rural area, the sample encompassed 30 homes (5-6 people per home) surveyed in the village and surrounding areas. The information was provided by homemakers.

The selection procedure for both the urban and rural samples was a simple random sampling process, having informed the participants that they would be surveyed with their prior consent. In the urban case, the informant was the head of human resources for the office, and in the rural case, the representative of the *Comuna*, who attended a meeting regarding the objectives and characteristics of this research study.

In the case of urban environments, a comparison was made between two buildings belonging to the National University of Tucumán, one built in 1910 (building A), and another renovated in 1990 (building B). The offices in both buildings are open plan, with air conditioning and lighting provided by fluorescent bulbs with conventional ballasts (day light and warm white 36 W and 40 W), without glare protection in building A. The contribution of natural light was scarce in both buildings.

The rural area chosen was a *Comuna* with around 3,500 inhabitants (mostly smallholder farming families) living in 500 houses distributed in an area of 150 Km^2 including mountains and pastureland. In general, between 5 and 9 people live in each home. The most common form of employment among the heads of the family is working as an employee of the *Comuna*, followed by day labourer and unemployed. The families surveyed claim that 100% of their children go to school, possibly because they are given food there.

Most of the homes have drinking water and electricity. Water, pumped from a well or drawn from neighbouring mountain slopes, is distributed via rubber pipes.

The houses are located on different sized plots of land (between approximately 0.5 and 50 hectares) and are built from different materials: the walls from baked bricks, cement blocks, stones, cane[1] and mud, and wood. The roofs are made from sheets of galvanized metal, card covered with tar or dried corn supported by trunks.

As regards the layout, most of these homes are divided into a series of separate areas or units: bedrooms and porch, kitchen, bathroom, corn stores. The areas used for cooking possess deficient ventilation and low levels of natural light. Electricity is used for lighting (incandescent lamps) and for powering domestic appliances, such as the refrigerator, radio, etc. Kerosene is used in burners which are often lit owing to power failures or because there is no electricity supply at all. Candles are used as sources of lighting in indoor environments and domestic chapels (Kirschbaum, Cabello, Manzano, Raitelli and Tonello, 2006).

Results

Comparing urban and rural settings, the environmental variables that set them apart are noise (high levels from traffic, in the urban case) and temperature/humidity. In the rural case, perceptions of the latter depend on external weather conditions, since homes are perceived as warm in summer and cold in winter, owing to deficiencies in the construction materials, and in numerous cases the precariousness of the domestic units.

In offices, on the other hand, air conditioning and equipment dry out the air and cause static electricity, respectively.

As regards contaminants, in the rural case, the main contaminating sources are derived from human activities such as cooking and heat generation, especially using bio-fuels such as wood and animal excrement, smoke and certain types of construction materials.

In the urban case, organic solvents are the main contaminants.

In both settings, the use of artificial lighting (mostly fluorescent in the city and incandescent in the countryside) is permanent throughout almost the whole day. Tables II, III and IV show low values of illuminance and it is demonstrated particularly in the rural case that, when only artificial lighting is used, values are much lower than recommended, whereas the levels of natural lighting are more than sufficient to carry out everyday tasks. Both urban and rural users do not take advantage of the availability of natural light for different reasons: the entry of noise in the urban case, and the entry of wind and soil/dust in the countryside, where for economic reasons, windows are not glazed, but instead are just covered with shutters.

TABLE II

Environmental indicators in offices (mean values for Illuminance, Temperature, Humidity and Noise)

Buildings	**A**	**B**
Illum. (lx)	211	198
Temp. (ºC)	25	24
Humidity (%)	33	50
Noise (dBA)	61	62

Values registered in spring at 11 a.m., with clear sky conditions.

TABLE III

Environmental indicators in rural housing (mean values for Temperature, Humidity and Noise)

Temperature [ºC]	**Humidity** [%]	**Noise** [dB]
16	35	30

Values registered in winter at 11 a.m. with clear sky conditions.

Perception of environmental conditions

Tables V and VI show that in the rural sample, perceptions of environmental conditions and their control are determined by the quality of the construction materials and the design of the houses; hence temperature and humidity are variables in relation to which a lower level of control is perceived.

In the case of the offices investigated in the city of San Miguel de Tucumán, since both buildings are open plan, the sensation of discomfort increases owing to the lack of control over the limited environmental conditions typical in this kind of space distribution. Hence, complaints about lighting in workstations (reflection and flicker from the ceiling lighting and reflections from the screen) are added to the effect of the environmental index comprising the variables: annoying noise, bad smells, mouldy smell, draughts of cold air, excessive heat, dry air, humid air, static electricity, bad posture when working, and organic solvents, which significantly affect building work related symptoms (BWRS). Many of the complaints about lighting in general can be attributed to the lack of louvers (device to control lighting distribution) and the use of

TABLE IV
Record of illuminance inside rural homes

Exterior conditions	Interior with natural and artificial lighting	Interior just with natural lighting	Interior just with artificial lighting	Interior just with natural lighting
Overcast sky Date: 23/04/07 Exterior Illuminance: 7600 lx	 . 32 lux	 . 28 lux	 . 21 lux	 . 26 lux
Clear sky 13/08/07 Exterior Illuminance: 37000 lx	 . 89 lux	 . 90 lux	 . 30 lux	 . 70 lux

TABLE V
M and SD of perceived environmental conditions in the rural area

	Mean	Standard Dev.
Little ventilation	2.9	1.27
Too much ventil.	2.8	1.08
Dry	2.4	1.27
Humid	2.2	1.09
Hot	1.9	1.02
Cold	2.1	.99
Luminous	2.3	1.35
Dark	3.1	1.20
Noisy	3.9	.65
Silence	1.2	.70
Smoke	2.9	1.24
Suffocating	2.7	1.18
Unpleasant smell	3.7	.70

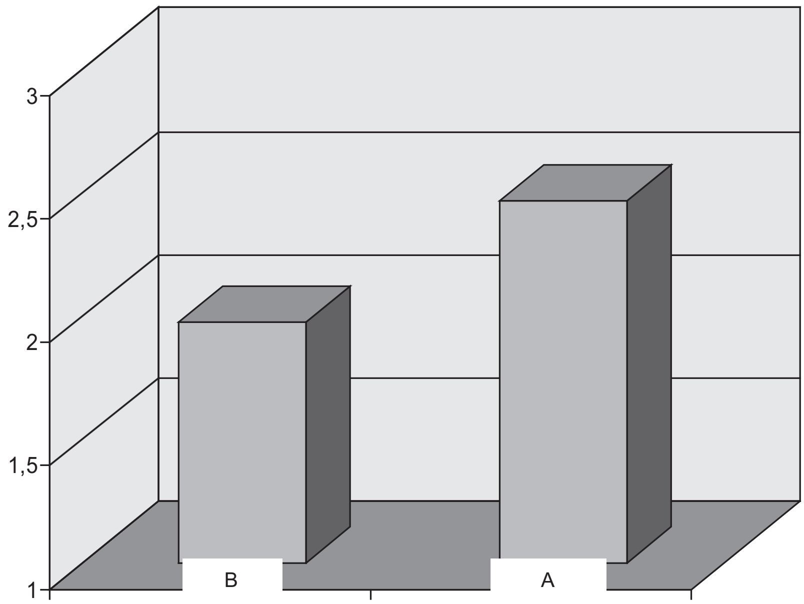
TABLE VI
M and SD for control of environmental variables in the rural area

	Mean	Standard Dev.
Temperature	3.0	2.42
Ventilation	4.8	2.37
Lighting	5.9	1.71
Noise	5.7	2.18

conventional ballast (see Figure 1). Furthermore, the type of task carried out in building A contributed to the frequency and severity of the symptoms, since the workers have to handle files sometimes covered with dust and mould.

FIGURE 1

Complaints about lighting in both buildings (On a 5-point scale; differences between the buildings: F(3, 185) = 7.9, p < .001)

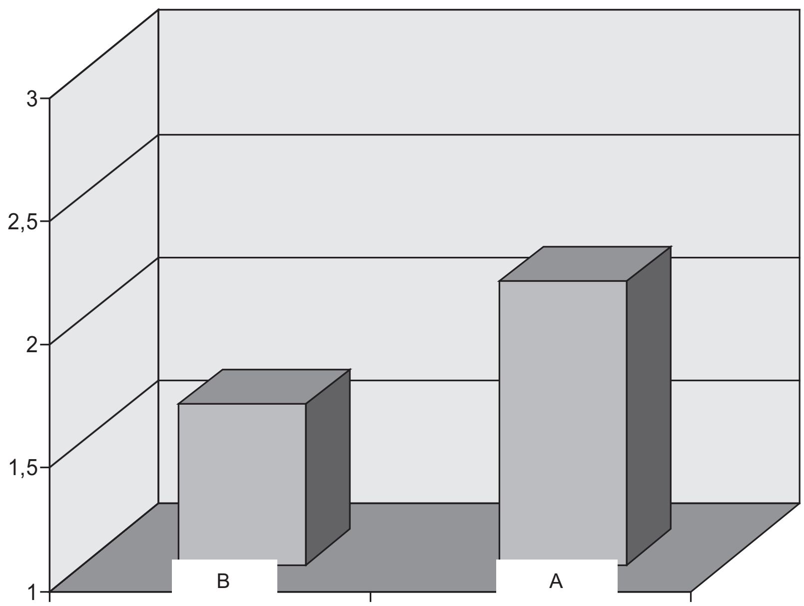


Symptoms of Discomfort

The 41 symptoms associated with the use of offices were compiled in an index, which shows the higher frequency of symptoms in building A (see Figure 2).

FIGURE 2

Symptoms reported for both buildings (On a 5-point scale; Differences between the buildings: F(3, 171) = 18.0, p < .001)



Inhabitants in rural areas claim that they do not experience these symptoms. However, reports from the Provincial Health System show a high percentage of respiratory conditions such as influenza type illnesses (ILI).

Discussion

The design and organization of offices have changed rapidly in recent years, with a growing trend towards open-plan offices. These were promoted in the belief that they would provide greater organizational benefits such as egalitarian working conditions, increased communication, greater accessibility, greater team work and flexibility, and improved performance. However, empiric evidence in this respect is weak. The success of open-plan offices depends on many factors, including the type of activity carried out in this space. In contrast, there is consensus about the disadvantages: increase in noise and visual distraction, lack of privacy, impossibility of controlling the environment and poor environmental conditions that affect performance at work (CIBSE, 1999).

The lack of individual control over environmental conditions diminishes the sensation of comfort. And this is also common to the urban and rural settings studied.

In the rural case, the results generally show the existence of inadequately built habitats, which do not fulfil the function of acting as a moderating element to attenuate the impact of external environmental conditions; hence users state that they have a low level of control over temperature and humidity inside the houses. So, areas such as the kitchen and the porch are reported as places where people spend most time in winter and summer, respectively.

The study of the environmental variable 'lighting' showed that natural light, in most cases, is sufficient to meet the needs of the users. However, factors such as wind, dust and the need for privacy, in addition to deficient equipment and inadequate design of areas, prevent sufficient use being made of the full potential of this natural light source, preventing it from making a contribution to a good quality of lighting. This demonstrates the importance of investigating alternative strategies for its use. Currently, research is being conducted into designs and alternative technologies for rural houses in the area studied (Mas, 2008)

Furthermore, this study shows the widespread use of the common incandescent bulb as a source of artificial light; its low energy efficiency in addition to the scant use of natural light leads to an increase in energy costs for lighting.

In kitchens, located outside the house, mainly wood and coal are used as a source of heat and fuel used to cook food, burned on open stoves where combustion is incomplete, leading to the emission of contaminant particles and gases, which when combined with the inadequate ventilation of the area and the permanent presence of domestic animals, affects the health of users, especially respiratory conditions. The use of biomass fuels in homes responds, among other factors, to a complex function of local production systems, the status of natural resources, access to transport, socioeconomic structures and socio-cultural and technological variables (GIRA, 2003).

Conclusion

This study, on the one hand, develops research into lighting within the context of Sick Building Syndrome, and also extends it to other contexts such as the rural setting, showing differences and similarities in the environmental impact in asymmetric socio-economic contexts.

The positive effects of natural light are not replaceable by artificial lighting, which should be considered a supplement. Complaints about lighting (design and use of openings, devices, levels) are common in both offices and rural houses, added to noise and organic compounds (in the urban case) and temperature and smoke (in the rural setting), plus the lack of control over these environmental variables, all indicates the need for a comfortable, efficient and health-promoting interior design. In the rural case, the dominant cause to explain and resolve negative environmental and health-related effects is the poverty of the population studied.

Notes

[1] Sheets of cane tied together in a parallel arrangement, which have been used for a very long time to make roofs, ceilings, fences and frameworks. They can be made from bamboo or common river cane; if providing shade from the sun, they can be made from half-canes, to make the structure lighter. Common cane and bamboo are very long-lasting materials, resistant to humidity and the elements; the structure of their long laminated fibres to absorb water owing to the 'bottom-up' capillary structure and the fact that the sun's rays do not dry them out make them an ideal natural material to insulate and strengthen roofs and walls.

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