Analysis of the acoustic, thermal and luminous performance at the Instituto Federal de Minas Gerais (Federal Institute of Minas Gerais) – Santa Luzia

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ABSTRACT: The architect João Filgueiras Lima participated in the 1990s, in the project known as the *Centro de Atenção Integral à Criança e ao Adolescente (CIACs)* (Integral Care Center for Children and Adolescents), where he designed buildings taking into account his concern with environmental comfort. Currently the campus of the *Instituto Federal of Minas Gerais- Santa Luzia* (Federal Institute of Minas Gerais- Santa Luzia), occupies some of these buildings**.** Despite the architect's concern with environmental comfort, the campus employees report dissatisfaction with the thermal, luminous and anthropometric comfort inside the buildings. Thus, this project aims to study and understand such issues by using as a method the application of questionnaires and measurements with the decibel meter, light meter, anemometer equipment and WBGT on the institution's work environments**.** Twenty environments are being analyzed**.** The analysis of the teacher's lounge is presented in this document, where measurements are compared to rates established by the norms relevant to this work. The lighting of this environment is inadequate and the thermal comfort exceeds the rates (WBGT) recommended for such an environment. But the level of noise and the wind speed are in accordance with the norms. Anthropometric measurements have not yet been done and the results presented are consistent with the measurements done during the seasons of summer and autumn of 2016.

Keywords *Environmental comfort, ergonomics, Sustainability, well-being, building, workstation.*

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1. INTRODUCTION

The buildings, now occupied by the Instituto Federal de Minas Gerais, in the city of Santa Luzia, were designed as part of *"Minha Gente"*(My People) program created by President Fernando Collor de Melo, in the 1990s. These buildings should house the *CAIC's* project (*Centro de Atenção Integral à Criânça e o Adolescente*)[Integral Care Center for Children and Adolescents], inspired by the models of the *Centros Integrados de Educação Pública* (Integrated Public Education Centers) (*CIEPS*), Brizola's government brand. It aimed to provide integral care to children and adolescents with day cares, preschools, elementary schools and high schools, medical and dental care and community sports and coexistence (Galter, 2014).

The initial goal consisted in constructing 5,000 schools of integral functionality and to meet such demand, a construction in cramped time and cost was required. The architect João Filgueiras Lima (Lelé) was invited to the project for his knowledge and experience in relation to construction rationalization, modular coordination, fast and low-cost construction and his concern for the environmental comfort, evident in his works for the use of sheds, promoting natural lighting and ventilation. (Goulart, 2014).

The choice of the construction system of reinforced mortar, originally proposed for *CAICs*, occurred because, Lelé believed that the system should be easily learned by the community, so that the community itself executed the work, employing local people. In a book published by the *MEC / CEDATE (Ministerio de Educação e Cultura; e Centro de Desenvolvimento e Apoio Técnico à Educação)(*Ministry of Education and Culture, and Center of Development and Technical Support for Education) in 1984, Lelé said that the armed mortar model is economical, provides better control on the environmental comfort, resistance, durability, little maintenance cost, and the increase in the use of raw materials and local labor and of surrounding regions. Also, it doesn't require skilled labor and its executed in a short period of time. (Lima, 2004).

The instruction for the schools' construction was that the main framework would be in the North-South direction, so that the most long linear facades were facing this direction. The protection against insolation and rain of the north facade was resolved with large overhangs. The sheds should allow permanent cross ventilation (Latorraca, 2014). The orientation of the sheds would be aligned with the main facades, but not always did this orientation correspond to the direction of prevailing winds, preventing the effectiveness of this solution for cross ventilation.

Lelé, in an interview, said that the project aimed to achieve an average degree of environmental comfort and be extremely economical. According to Lelé, the works were not supervised and there was negligence from the parties involved, which made Lelé resign the project, and may have contributed to Lelé's goals not materializing (Goulart, 2014).

Despite the concerns reported by the author João Filgueiras on the project, the complaints by workers occupying the buildings of the *IFMG* Campus in Santa Luzia since 2014 are constant. The complaints relate to the conditions of environmental comfort (acoustic, luminous, thermal and anthropometric) at their workstations.

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In order to understand the factors that contribute to the situation of discomfort reported by *IFMG*'s staff, this work, by *AET (Análise Ergonômica do Trabalho*)[Ergonomic Analysis of Work] aims to survey the conditions of thermal, luminous, anthropometric and acoustic comfort. Also intends, from the data obtained at a later stage, to propose solutions to improve the ergonomics of the space, from the adequacy of the environment to the needs of the employees, bringing well-being and consequently better performance in the activities performed. The campus operation started in 2014 with the undergraduate course of architecture and the high school integrated with building technician that are held during the day, and the undergraduations in Engeneering and interior design, and landscape technician course, held in the evening.

2. INSTRUMENTS AND METHODS

The methodology consisted primarily in the study of the weather of the city of Santa Luzia-MG through the *Atlas de Minas Gerais* of the *CEMIG* then there were made bibliographical research about the characteristics present in the works of the architect Lelé and his CAIC project, where today the IFMG Campus of Santa Luzia is located.

Later, surveys were done throughout site visits, record of the elements in buildings through photographs, questionnaires applied to IFMG teachers to understand how they feel affected by the local environmental situation. Measurements were made by quantitative means with *IBUTG* equipment *(Índice de Bulbo Úmido Termômetro de Globo)*[Humid Bulb Globe Thermometer Index] that assesses exposure to heat; light meter that measures the intensity of light; anemometer used to measure wind speed; and the decibel meter used to measure the sound pressure level. The data were compared with the requirements established by the norms *NBR 5413- Iluminância de Interiores* (Luminosity of Interiors) , *NBR 10152- Níveis de Ruído Para Conforto Acústico* (Noise Levels For Acoustic Comfort), *NR 15- Atividades e Operações Insalubres* (Unhealthy Activities and Operations), *NR 17- Ergonomia* (Ergonomics).

3. DATA SURVEY

The measurements with decibel meter, light meter, anemometer and WBGT were made in the institution's operating hours in the morning and afternoon when faced with most complaints from employees regarding the environmental comfort. The first measurement started at 7:30 am, a time when students and teachers are already active in the classrooms. The end of the first measurement took place at the time of 8:50 am. During this interval time, all indoor work of IFMG officials was subjected to data collection of thermal, luminescent, sound and ventilation comfort. There was no measurement outside of the campus. Soon after, measurements were made from 9:30 to 10:10 am, 01:20 to 01:55 pm and 03: 30 to 04: 30 pm**.** Measurements' times were determined in accordance with schedule of classes and breaks. Equipment used for data collection remained about 2 minutes on each space for the stabilization of values for the measurements. Surveys, still in progress, will be held in all seasons. Until now measurements were carried out only in two days, one in summer and one in the fall. For a more accurate diagnosis of thermal discomfort situation, more measurements will be required to be held in the next months. In the case of measurements on the acoustic and luminal comfort, because these factors are not so closely tied to weather

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conditions, it is believed that from the measurements already performed it can already have a preliminary diagnosis of the comfort conditions. The choice of the measurement day was performed having the criteria of a day with the typical characteristics of the season. The summer measurement was made on March 17, 2016, and the fall one occurred on June 8, 2016. The survey data followed the same criteria of time, place and waiting time for equipment stabilization. On the day chosen for measurement in the summer season, the institution opened at 9 am, therefore, no measurements at the time of 7: 30am.

Questionnaires were administered on the same days of measurements at the time of 03:30 pm to 04: 30 pm, because it is the time that brings most discomfort inside the building, with regard to heat and noise, as reported by employees. The questions addressed all content related to the measurements, in other words, thermal, luminescent and noise comfort, as well as questions relating to clothing, BMI (Body Mass Index) and other issues that may influence the thermal sensation of each user. In addition, the questionnaire's format of closed questions, gave the opportunity for the employees to show their satisfaction with the thermal sensation and noise at the workplace. The intention is to compare the data obtained by means of measurements and of the questionnaire to understand if the data obtained by the measurements is consistent with the employees' accounts.

4. THE INSTITUTO FEDERAL DE MINAS GERAIS (FEDERAL INSTITUTE OF MINAS GERAIS) – SANTA LUZIA CAMPUS

Figure 1. The building implementation and solar orientation and prevailing wind. Source: Adapted by the authors from Google Maps

The image above (Figure 1) shows the buildings of the campus *IFMG*- Santa Luzia. As illustrated, the main facades of the assessed buildings, blocks 1 and 2, are oriented due northwest and southeast.

As previously mentioned, Lelé's original design recommended that in the deployment, the orientation of the facades facing north and south and the sheds facing south allowing cross ventilation would be respected. But, it is important to highlight that each site has a different climate, which may represent different orientations in regard to the solar orientation and in regard to the wind, to better match the weather.

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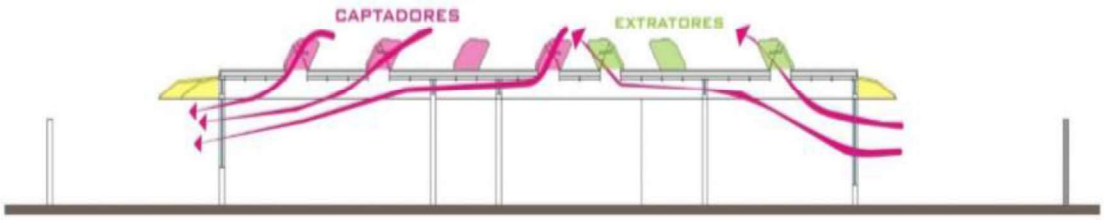

Figure 2. Ventilation scheme naturally BLOCK 1 Source : Goulart, 2014

The greatest frequency of winds for the city of Santa Luzia, according to the Wind Atlas of CEMIG (2010), are the winds of northeast, east and southeast origin, with standard speeds of 1m/s for these directions. The sheds and windows of the main facades have northwest and southeast orientations. To meet the project's objectives of guaranteeing natural ventilation, the project foresaw that the facades with the windows facing the prevailing wind, the entrance being through the window and the air outlet by the shed, as illustrated in Figure 2. Already in environments with openings for the facades opposing the prevailing wind, which do not receive it directly, this should enter the sheds and exit the windows. In the case of the studied building, this solution was not considered satisfactory, since users do not have the habit or means to regulate sheds. In most environments, these are closed because there are few rods that allow users to regulate its opening. Thus, the cross ventilation is limited, not contributing to the improvement of location's thermal comfort board. The fact of the sheds having a very opaque material, greatly reduces the intensity of natural lighting that falls onto the roof of the environment, making it necessary to use artificial light even during the day. In addition, artificial lighting circuits do not allow the integration with the natural lighting coming from the windows, since the same outlet, activates both the line of light fixtures next to the windows, as well as those on the opposite side, distant from the same. On the other hand, some control of the intensity of natural lighting and ventilation through the windows (Figure 3) is allowed, because these are formed by opaque pivoting panels, of easy manipulation by the users.

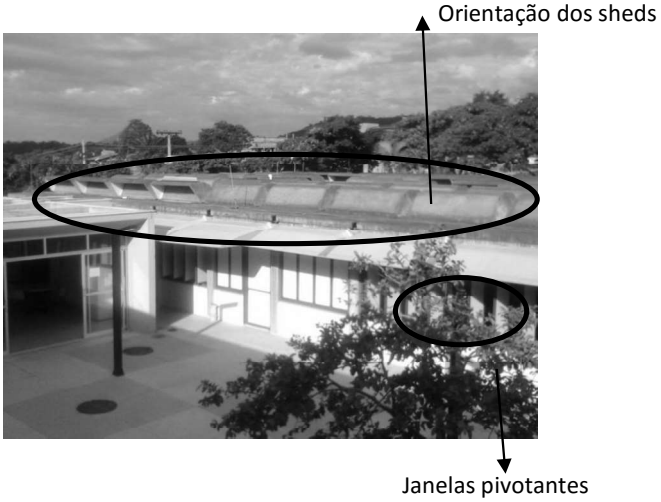

Figure 3. Shed's orientation and pivoting windows system. Source: authors

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The northwest and southeast facades of the buildings have yellow awnings, thus allowing, a greater shading in the rooms, avoiding the incidence of direct solar radiation, which could bring an increase in internal temperature. Regarding the acoustics, it was reported by users interference noise from neighboring rooms during the classes. It is believed that this fact is due to the presence of awnings, whose geometry contributes to the reflection of sound from one room to the other, as well as the construction system, with very slender parts and crannies at the meeting of building elements such as beams, system coverage, which make the sound pass on to the neighboring environment, and high windows on the side walls of the classrooms adjacent to the corridors.

5. OBTAINED RESULTS

To check the existing discomfort in the buildings of the Santa Luzia Campus, quantitative and qualitative assessments were performed. Questionnaires were used on the days of measurement to understand the perception of workers and compare them with the data obtained by the WBGT equipment, light meter, anemometer and decibel meter. The measurements were divided by seasons. So far, only the summer and fall seasons passed through measurements, however the collection of quantitative and qualitative data is still underway. It is also within the proposal to analyze the furniture used by employees to determine their ergonomic adjustments, stage that has not yet been performed.

All work environments were evaluated, but in this article, the result of the teachers' lounge was the only one considered, where the largest group of the institution's servers is found.

5.1. Questionnaires

On March 17 (summer) and on June 8, 2016 (autumn), questionnaires of manual filling were delivered, with multiple-choice questions to teachers present on campus. The questionnaires were delivered and completed in the time of 04: 30 pm. This schedule was defined by the fact that in informal talk, this was the most critical time in relation to thermal discomfort. While the staff filled the questionnaires in their work stations, the research fellows performed the measurements using the equipment already mentioned. Fifteen employees responded to the questionnaire, ten on March 14 and five on June 8, totaling eleven female and four male**.** The questionnaire's questions were focused on the environments' thermal, anthropometric, luminous and acoustic issues. Among the answers it is important to note that 53.3% of the interviewed have between 31 and 40 years of age; 33.3% between 20 and 30 years of age; 6.7% between 41 and 50 years age and 6.7% have over 50 years of age.

The types of jobs held by the teachers interviewed, in accordance with the Annex III of NR15 (2015), are activities that fit into light and moderate work.

Among the responses provided and arranged in table 1 and 2, most teachers say they feel dissatisfied with the comfort of the working environment, being the major cause of discomfort the thermal issue.

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ENVIRONMENTAL COMFORT SATISFACTION

	Very satisfied	Satisfied	Somewhat satisfied	Dissatisfied
Summer	6,7%	20%	26,7%	46,7%
Autumm	0%	0%	80%	20%

Table 1. Answer the questionnaires. Environmental Comfort Satisfaction Summer and Fall / 16. Source: Authors

WHAT BOTHERS THE ENVIRONMENTAL COMFORT THE MOST

	Lighting	Thermal Comfort	Noises	Ergonomic Inadequacy	Dissatisfied with all items (lighting, anthropometry, acoustics and thermal comfort)	Satisfied
Summer	20%	67%	0%	0%	6,7%	6,7%
Autumm	0%	80%	0%	0%	20%	0%

Table 2. Answer the questionnaires. Environmental Comfort Satisfaction Summer and Fall / 16. Source: Authors

Another important factor to point out is that 66.7% of the interviewed feel glare while being in front of the computer screen and 50% of the interviewed believe that the reason is the reflection of artificial light (lamp) on the computer screen and the other 50% report not knowing the reason.

5.2. Measurements

The measurements were performed with the application of the questionnaire to assess real-time quantitative and qualitative results and compare them. Three measurements were made throughout the extent of teachers' lounge (Figure 4) and then the average values were calculated.

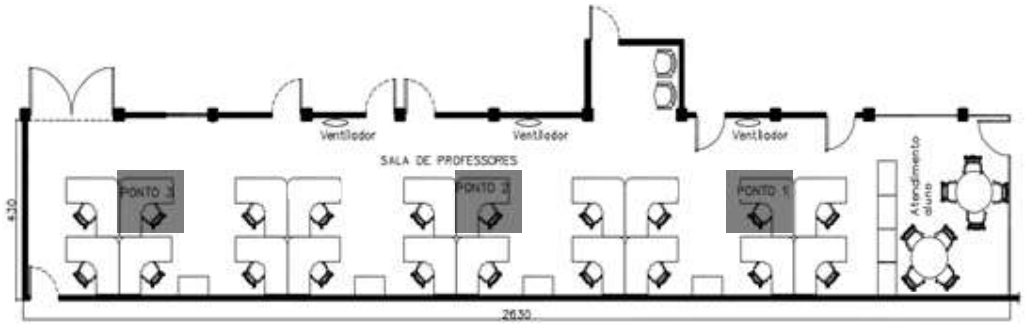

Figure 4. Technical Plant Teachers' Lounge- IFMG Santa Luzia. Source: Prepared by the authors

As the result of the questionnaires, the noise was not pointed out as a problem in the workplace. According to the measurements made with the decibel meter equipment (sound pressure level meter), and compared to the *ABNT NBR 10152 (1990)* that establishes noise levels for acoustic comfort, the result obtained in this measurement is found to be within the allowed parameters (Graph 1). It was considered the classification of the teachers' lounge environment as "computer room" in office typology, according to the Table 1 of the above standard, which shows that the noise level tolerated for this type of environment, is in the 45 range 65 DB (A). It is important to highlight that the teacher's lounge does not have side windows, just sheds on the roof, which may have contributed to the low ambient noise level, since the absence of side openings, means that there is less interference from external noise within the environment.

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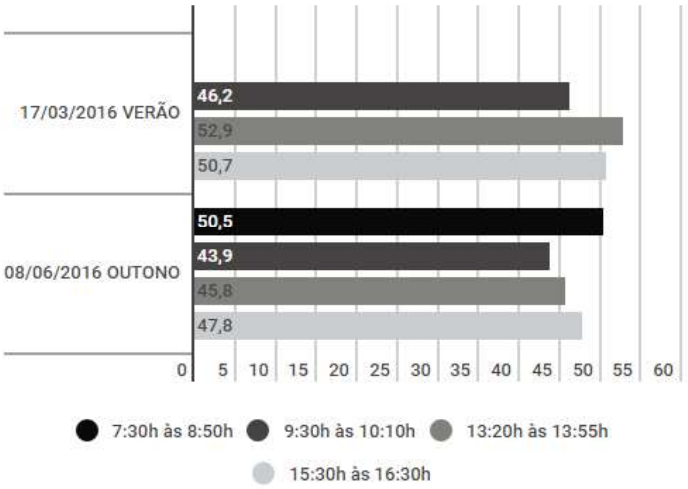

Graph 1. Comparison results in decibel measurements of the *IFMG's* teachers' lounge. Source: Prepared by the authors

In the analysis of the local lighting, the result was based on *NR17 (1978)* which states that in all workplaces there must be adequate lighting, appropriate to the nature of the activity and that lighting should be evenly distributed and diffused, installed so that it avoids glare, annoying reflections, shadows and excessive contrasts. You can see in Graph 2, that the lighting in the analyzed environment is poorly distributed, as soon as the results in lux (Graph 2) have great variations between the measurements at different points in the room. The three light meter measurements were considered individually, without the mean values to show the heterogeneous distribution of illumination on site. During all measurements, the room stood with lights on and sheds closed. Comparing the quantitative data with the answered questionnaires, such lighting besides not being uniform, it is not diffuse and therefore, causes glare on employees when they are at their desks and in front of the computer. It is to be observed through the answers to the questionnaire that some employees feel that obfuscation and others do not, so that the perception of difference may be justified by the non-uniformity of illumination intensity throughout the length of the room.

According to *ABNT NBR 5413 (1991)*, the suitable general lighting for the task area with normal visual requirements, average working machinery and offices is 500 - 700-1000 lux. According to the obtained data, the lighting of the teachers' lounge is below 300 lux in all the measurements, in other words, it is inadequate to the functions carried out at the site. It is important to remember that space has sheds on the roof which allow natural light into the environment, but as can be seen, are insufficient to ensure adequate levels of luminous comfort.

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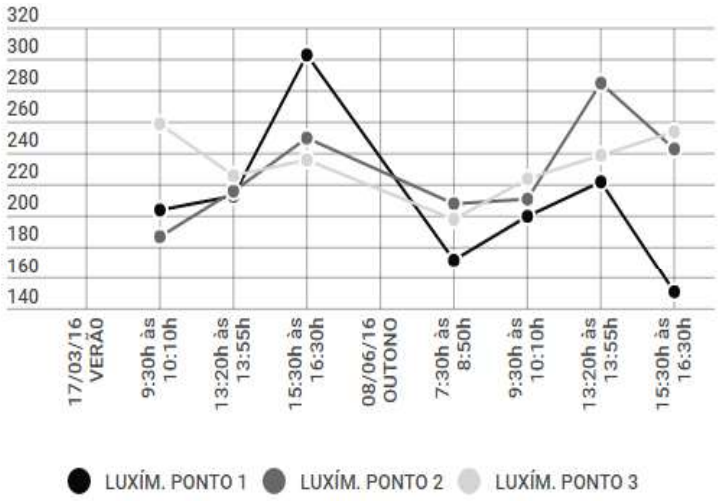

Figure 2. Results light meter - variations in lux in the months of March and June

The WBGT (Wet Bulb Globe Thermometer Index) has the purpose of measuring the thermal comfort, which was reported by teachers in the questionnaire as a major cause of discomfort. The measurements taken in the environment with the WBGT were compared to the *NR15*-Annex III, which sets the maximum measure of comfort 30 WBGT. The results of the teachers' lounge had a maximum of 31 WBGT on the summer month (chart 3), and thus the thermal comfort conditions in the studied environment are inadequate. It is noteworthy that the teachers' lounge does not have side windows, once the air circulation takes place by means of fans. There are sheds on the roof that are opened infrequently.

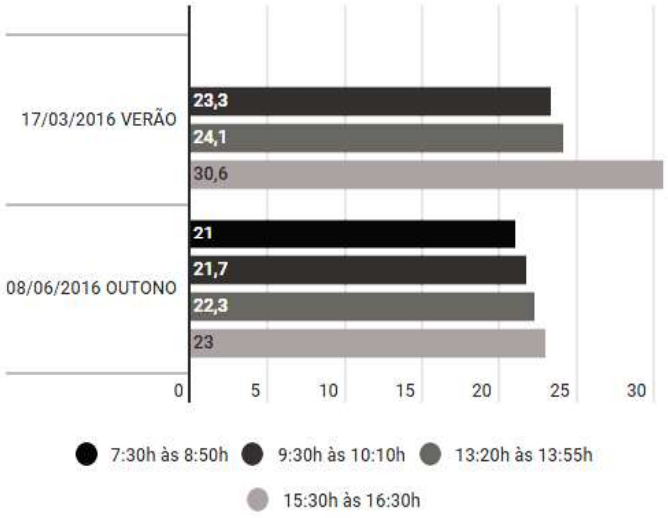

Figure 3. Results WBGT- comparisons summer and autumn 2016

The anemometer (equipment used to measure wind speed) in all measurements, seasons and times indicated the wind speed to zero. Only when the fans were connected, the speed ranged from 0.5 to 1.9 m/s. According to the sub item *17.5.2 NR17*, ideal wind speed for internal space is of a maximum of 0.75 m/s.

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6. CONCLUSIONS

From the analyses, it is concluded that the buildings of the *IFMG* - Santa Luzia have inadequate conditions of thermal and luminous comfort for the employees. Yet the acoustics in the staff room, from the data of measurements performed in March and June, despite the complaint of the employees is in accordance with the comfort index provided by the standard adopted as reference in this work.

The lighting of the teachers' lounge according to the measurements, it is not appropriate to the nature of the activity, having lux below indicated, in addition to poor distribution throughout the room. In the same way, thermal comfort, analyzed by WBGT is found to be above the permitted in the late summer, bringing discomfort to workers. Yet in the fall, the values indicate that the room is within the allowed parameters.

Qualitative data indicated the dissatisfaction of teachers with most of the analyzed topics and health ills employees believe are posed by environmental discomfort in the workplace.

It is important to remember that this article only refers to an environment of twenty being evaluated at the Institution. The studies carried out here have a very promising potential for the analysis and improvement of environmental comfort in many work environments.

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