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AMBIENT WELL-BEING PARAMETERS IN THE INDOOR SPACES OF OFFICE BUILDINGS. CASE STUDY

Nicoleta Ionac [1], Adrian-Cătălin Mihoc[2], Paula Tăbleţ[3]

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Abstract. This study highlights the variation values of several important microclimatic parameters inside an office building. This way, during one year time period, from February 2010 to February 2011,, we have recorded the natural wet temperature, the predicted mean vote – PMV, the predicted percent of dissatisfied people– PPD, WBGT indoor, WBGT outdoor, the draught risk, the luminous intensity and the sound level. Then, we could calculate the monthly, daily and hourly variation of these microclimatic and ambient comfort parameters. The recordings of the data were made by means of a microclimatic indoor station, a sound level meter and a light meter. The results helped us understand better how the values of these microclimatic parameters may influence the working conditions inside an office building, if the microclimate is one of thermal comfort or discomfort, or if it is beneficial or harmful to the development in good conditions of working activities within collective environments.

Introduction

The present study aims at assessing the state of well-being as reflected by different ambient parameters in the indoor space of an office building. This study originates from the idea of observing the effect of these parameters on work efficiency especially that there were obvious differences between the data that were recorded inside the office building and those recorded outside the building in the neighboring surroundings. Therefore, we wanted to analyze the extent to which the indoor air-parameters were influenced by the outer climatic factors and also to show the contribution (as reflected by its positive or negative effects on human body and well-being) of the industrial air-conditioning facilities existing in the building, to creating an artificial climate which may be beneficial or, on the contrary, harmful to its inhabitants' health **[2]**.

Data were recorded for approximately 1 year-long period (from February 2010 to February 2011). Due to unforeseen conditions (such as electric blackouts, holidays, building closures and impossibility of physical presence in certain

[1]Prof. PhD., University of Bucharest, Romania, rinmozel@yahoo.com
[2] Ph.D. Student, University of Bucharest, Romania, biagyydog@yahoo.com
[3] Ph.D. Student, University of Bucharest, Romania, tablet.paula@unibuc.ro

moments to make analysis) the data of certain parameters could not have been collected throughout the entire period. However, we have filled the gaps with data that were calculated on mathematical methods of homogeneity.

1.Location and period of instrumental observations

All instrumental records were made in 5, Fabrica de Glucoza Street, Bucharest sector 2. Here lies an office building (NOVO F) with two underground and 13 ground floors (Figure 1). Located in the northern part of the capital-city, it makes part of a modern technology park, in which numerous multi-national companies from various domains, like IT or banking, are carrying out their activities **[4]**

. Fig. 1 - NOVO F Office building

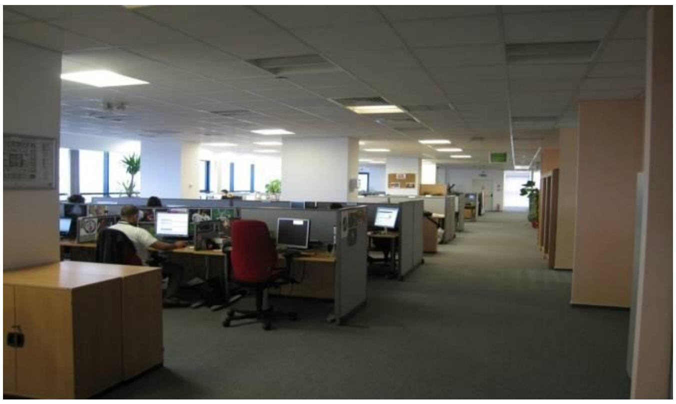

Fig. 2 - Office cubicles (11^{th} floor, NOVO F)

The actual measurements were made on the 11th floor of this building and, more precisely, the measurements with the indoor weather station, were performed in cubicle no. 18 on this floor (Figure 2), which contains a total of approximately 270 cubicles (this number increased throughout the period of measurements by adding new cubicles to the old ones and, thus, by reducing the indoor space of one individual cubicle).

7. Instruments and methods used

Instrumental measurements were made by means of three scientific equipments of high accuracy: an indoor air weather station, a sound level meter and a light meter.

The most important equipment we used was the *Casella Microtherm* microclimatic indoor weather station which allows the automatic monitoring of microclimatic parameters (radiant temperature, dew point temperature, vapor pressure, speed air currents) as well as of ambient comfort parameters (PPD, PMV, intensity of turbulent exchange) **[1].** Thus, we could calculate various other ambient parameters of distress (human body heat exchange, heat stress index, allowed exposure time, effective heat load, sweat rate, pulse and blood pressure etc).

The *MICROTHERM* - *INDOOR CLIMATE SYSTEM* (Figure 3) is made of a central unit at which we can connect, through a serial port, a hub with 6 specific locations for different micro-environmental sensors. This can be installed directly on the upper surface of the central unit or on a tripod. Each sensor is mounted on a sustaining arm of the hub, being connected to the corresponding port. The system also has a power cord and a serial port which can be connected to a PC or laptop. It also contains an incorporated battery which allows a functioning autonomy of approximately 2 months.

The main unit allows the monitoring and continuous recording of data, as well as their calculation by means of an integrated software in its internal memory. This has a limited capacity so that once the internal memory is completed, the new data overwrites the old data. The data-logger allows the interruption of records not only directly through the front panel and the incorporated LCD display, but also with the assistance of the PC *WinIAQ* software **[3]**.

We preferred the continuous recording of data for a period of approximately 30 days (the period in which the memory reached almost 100% of its capacity), of course mentioning that they have been gathered every 30 minutes.

The base sensors of the *MICROTHERM – INDOOR CLIMATE SYSTEM* allow the continuous monitoring of some important microclimatic parameters like radiant temperature, air temperature (both dry and wet), air humidity, speed air currents, intensity of turbulent exchange, etc., and they consisted of a black globe thermometer, a probe for measuring the unidirectional air-flows and a sensor of measuring air temperature and humidity of solid bodies.

The measurement programming was possible with the aid of *WinIAQ* software installed on Windows Vista operating system (32-bits). The measurements profiles are pre-established, but the communication parameters between the central unit and laptop must be defined first for a correct functioning. After making the connection, the sensors and measurement times are selected and the command is sent to the main unit. The data are manually downloaded with the same software.

Fig. 3 **-** Casella MicroTherm – Indoor Climate System

The parameters recorded and automatically calculated by the indoor weather station, which are of interest for this study, were the following:

- **NW** **Natural wet** (^{0}C) – the actual temperature of the surrounding air, depending on the dry air temperature, effective air speed of the air currents surrounding the operator, air humidity and medium radiant temperature.
- **PMV** **Predicted mean vote** (units) – the index which expresses the medium sensation of thermal comfort/ discomfort of a larger group exposed to the same type of environment.
- **PPD** **Predicted percent dissatisfied** (units) – the quantifying index of the satisfaction/ dissatisfaction state of a certain number of people towards the thermal comfort of the environment they are located in.

- **WBGT in WBGT indoor** (^{0}C) – the effective temperature which a subject perceives during the period of time in which he undertakes an activity inside a building which is not directly exposed to solar radiation.
- **WBGT out WBGT outdoor** (^{0}C) – the effective temperature which a subject perceives during the period of time in which he undertakes an activity inside a building which is directly exposed to solar radiation.
- **DR Draught risk** (%) – the percent of potentially affected people by the draught sensation.

The TESTO 545 LUX METER (luminous intensity measuring instrument - Figure 4) has a silicon photodiode sensor and a resolution from 0 to 100,000 lux (10 lux) (Fig. 6). The measuring times were daily, at 10, 14, 18 hours, Monday to Friday. Two measuring locations were chosen, one in the middle of the floor (to capture the values of artificial light intensity), the other one near the window (to evaluate the difference from the natural light).

Fig. 4. Testo 545 Lux Meter

Fig. 5 - Testo 816 Sound Meter

3.Results and discussions

Variation of monthly means. Significant fluctuations have been recorded for all observed parameters. However, we can distinguish a pattern of variation for each one of these, even if the external meteorological and climatic influence is, nevertheless, obvious.

Natural wet, WBGT indoor and WBGT outdoor indices have a similar trend, with a maximum in August, of over 26 °C, and a minimum in October, of only 23 °C. October and December 2010 have shown to be the coldest months, due to the external factors which determined low exterior temperatures all that period. A progressive increase is observed starting with December, until August, and then a sharp decrease (Figure 6).

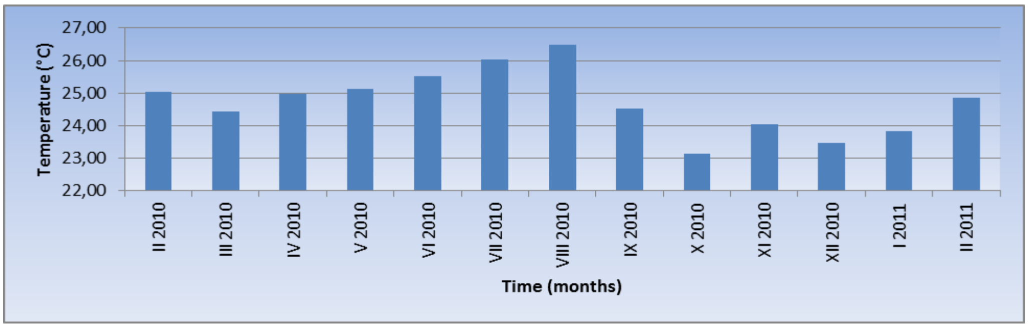

Fig. 6 - Variation of NW (°C) monthly means

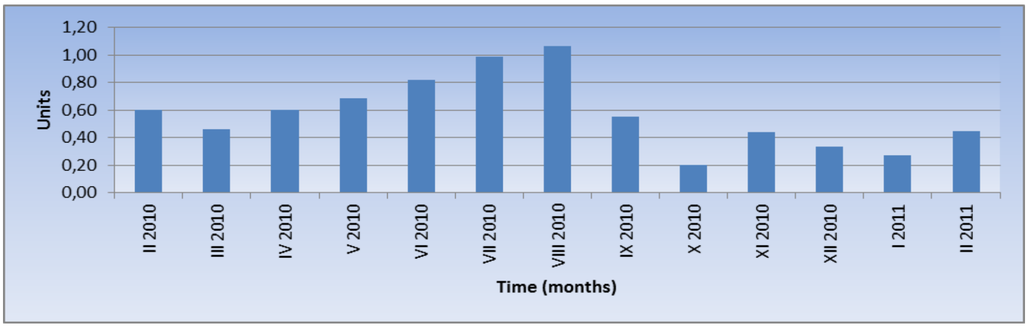

Fig. 7 - Variation of PMV (units) monthly means

The same pattern is detected for PMV too. However, values indicate a neutral to optimum environment (Figure 7), with significant differences between spring-summer and autumn-winter. Among the external influences, we can also add the technical ones: intervention of air-conditioning installations which were set to start functioning at a temperature of 22 °C during summer and at 23 °C in winter (of course these values oscillated depending on daily outdoor air-temperatures).

The predicted percent of thermally satisfied / dissatisfied people (PPD) (units) measured similar values. A sudden decrease can be seen in September, in contrast with the gradual increase from March-August, as well as major differences also appear between the summer months and the autumn and winter ones (Figure 8).

The draught risk has an irregular pattern of evolution throughout the period of instrumental observations. In this respect, the higher values from September 2010 and lower values of February and December 2010 are relevant (Figure 9).

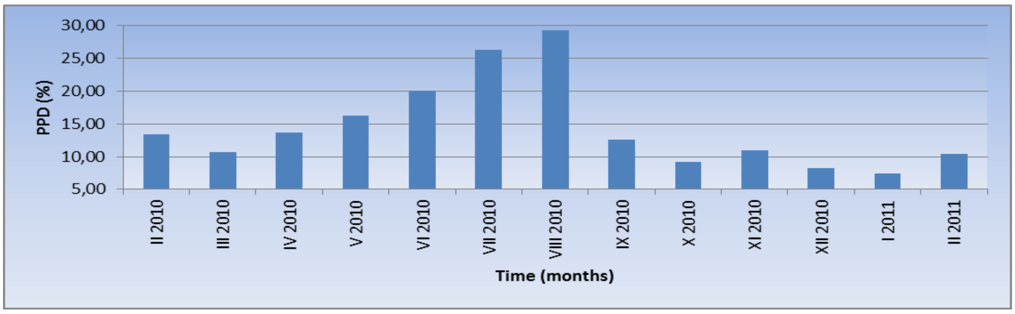

Fig. 8 - Variation of PPD (% - units) monthly means

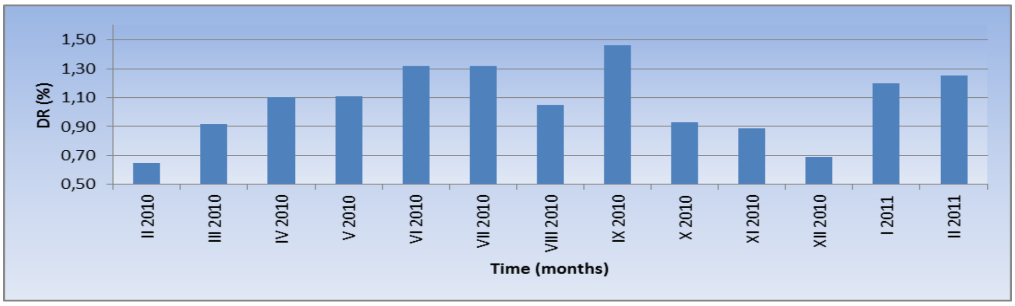

Fig. 9 - Variation of DR (%) monthly means

The luminous intensity has values which differ from spring (when values of 200-250 lux have been measured) to autumn and winter (when the corresponding values decrease to 100-150 lux), as it is shown in Figure 10. These pretty high differences are given not only by the atmospheric conditions from the autumn and winter months, but also by the technical ones, and here we refer especially to the shielding of the windows with vertical blinds which absorb most of the sun-rays, depending on exposure, and the neon light devices which are most intensely used in winter.

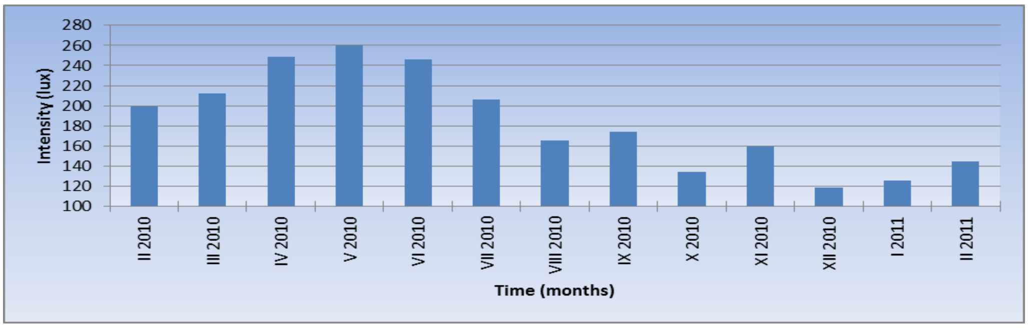

Fig. 10 - Variation of luminous intensity (lux) monthly means

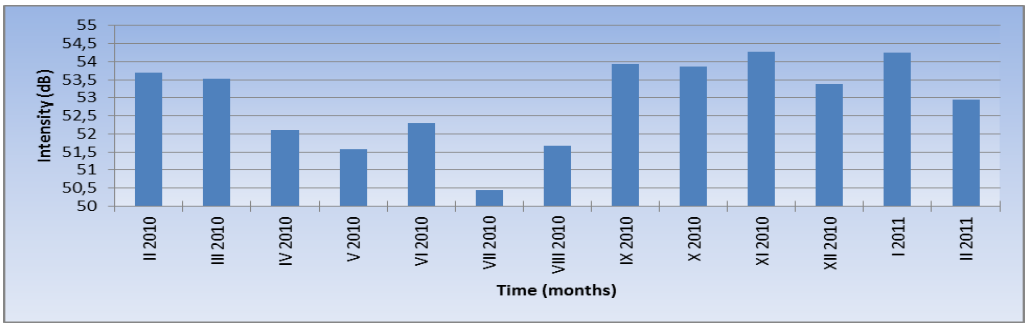

Fig. 11 - Variation of noise intensity (dB) monthly means

Noise is the only parameter with a relatively constant variation throughout the analyzed period, with values between 52 to 54 decibels (Figure 11). Of course, we have one exception, August 2010 with a monthly average of little over 50 decibels. This low value can be explained by the absence of the employees from work, due to their time off for holidays; from the daily notes we took, we could clearly see that most of the employees preferred taking their vacation in August.

Variation of daily means. To clearly point out the difference of variation between the parameters taken into consideration, we have chosen two characteristic months with continuous data series, February 2011 and July 2010. The measurements were ended on February 25, 2011; hence the graphical representation is missing for the last 3 days. However, the evolution trend of each parameter is clear enough so that the automatic calculation of the missing data was neither necessary nor wanted (this way we wanted to establish a concrete data series, without any change).

The effective indoor (WBGT in) and outdoor (WBGT out) temperature has a similar trend for both considered months, with a progressive growth from the beginning to the end of the interval, for July 2010 (with a slight decrease after the 25th, then a new increase). The automatic station has recorded almost 25 °C in the first days of the month (5 and 8), then 27 °C (18 and 24) (Figures 12 and 13). February 2011 has a more irregular evolution with lows below 24 °C (5 and 19), but for a singular high value which reaches 26 °C (9). Although the values keep around 25 °C, in three occasions these increased over the values from July, in 8, 9 and 10 (with the maximum in the 9th).

Natural wet shows similar values to those shown above.

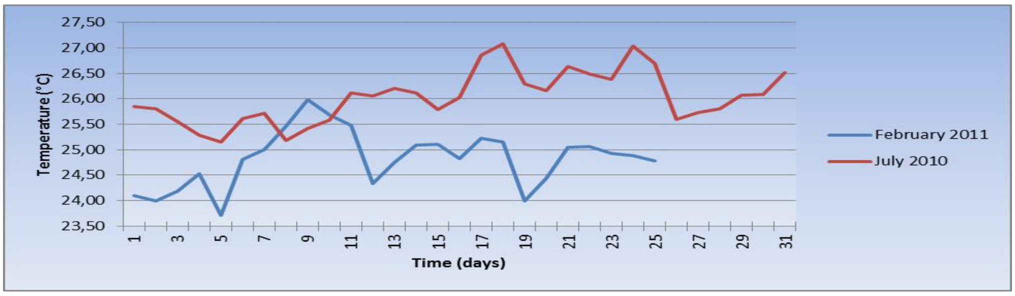

Fig. 12 - Variation of WBGT out (°C) daily means

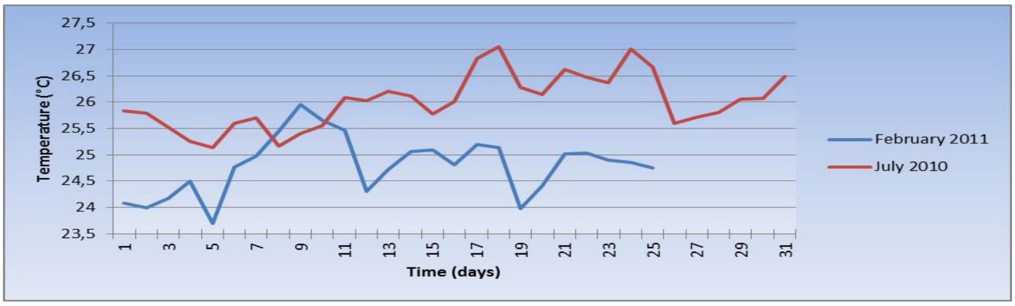

Fig. 13 - Variation of WBGT in (°C) daily means

The predicted mean vote, as well as the predictable degree of thermal satisfaction or dissatisfaction had a similar trend, with higher values throughout the interval, especially during the summer months rather than the winter ones. February had a relatively linear evolution (between 0.3 and 0.5 for PMV, and

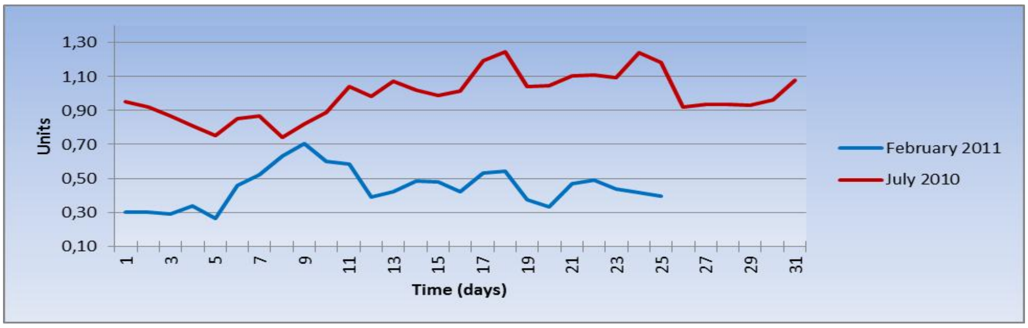

Fig. 14 - Variation of PMV (units) daily means

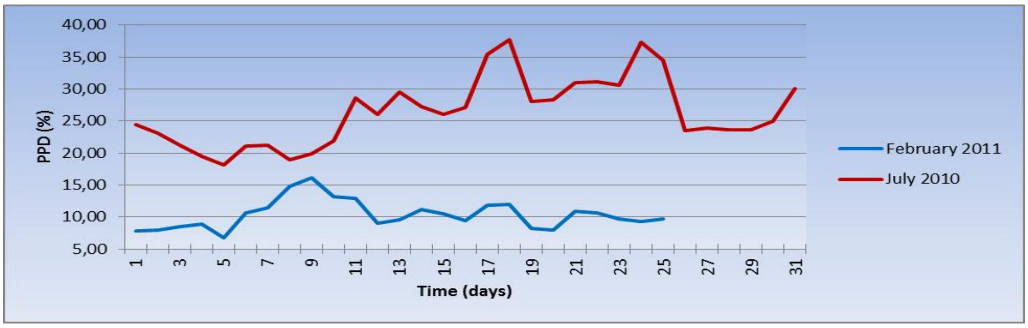

Fig. 15 - Variation of PPD (% - units) daily means

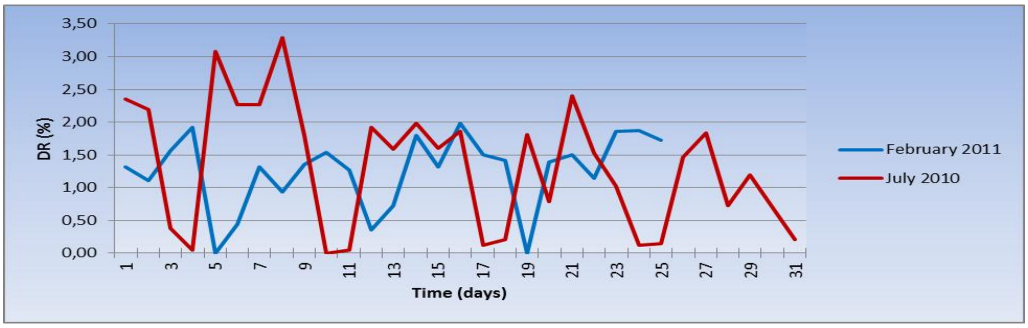

Fig. 16 - Variation of DR (%) daily means

around 10 for PPD); the only upward trend has been recorded between days 6 and 9 (when it almost reached the July values), followed by a descending line until the 12th day, after which the same linear path is back again. July has a more pronounced evolution especially for PPD (with values between 20% and 35 %), while PPD values keep around 1 (with repeated ups and downs), as can be seen in Figures 14 and 15.

The luminous intensity shows much lower values for February (under 125 lux) than for July (with values between 175 and 275 lux). Noise intensity has a similar trend for both months, with values between 50 and 52 dB, the maximum reaching 58 dB.

The draught risk (Figure 16) has the most irregular pattern especially for July, with sudden increases and decreases from one day to another (usually between 0 to 2%), and in two occasions (days 5 and 9) they even exceeded the 3 % threshold. February varies a little less, with values between 0 and 1.5%.

Variation of hourly means. Natural wet varied between 25°C and 26.5 °C for July. We can see a pattern with a temperature decrease from 26°C to 25°C from midnight to 9 in the morning, then an increase to 26.5 °C until two at midday, where it keeps constant until 11 late at night, when it starts decreasing again.

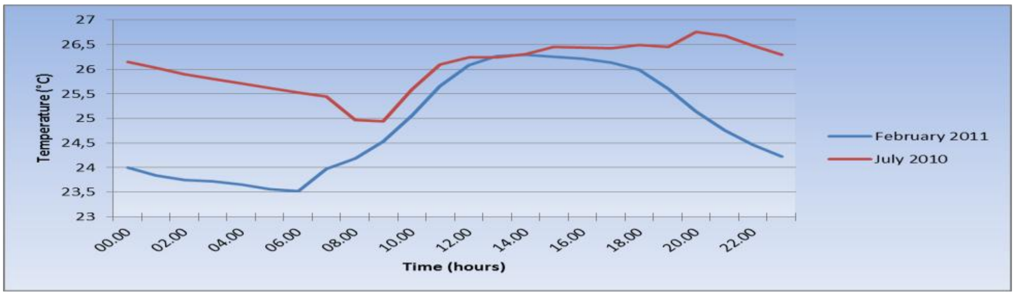

Fig. 17 - Variation of NW (°C) hourly means

February has a similar pattern, but for the fact that values decrease from 24°C to 23.5 °C until 6 in the morning, then again increase over 26°C until 12 at noon, when the values remain constant until almost 6 in the evening, when they progressively start decreasing to almost 24°C at 11 pm (Figure 17).

Effective indoor and outdoor temperatures had a similar pattern of evolution for both months.

The predicted mean vote (PMV) had values between 0.9 and 1.1 for July, and from 0.3 to 0.7 for February, much like the predicted mean vote of thermal satisfaction or dissatisfaction (between 20 to 30% in July, and between 5 to 15% in February).

The draught risk has shown an interesting pattern of evolution especially for the hours 6-10 in the mornings of July, with a sudden increase from 0 to 5%, then a sudden decrease until 12 at noon to 2%, when it continued to drop after 5 pm, reaching 0 at 11 pm. February had a similar evolution with a constant growth from 6 in the morning (0%)

until 2 in the afternoon when it reached the maximum of 3%, when it began to decrease from 6 until 8 in the evening when it reached 0% (Figure 18).

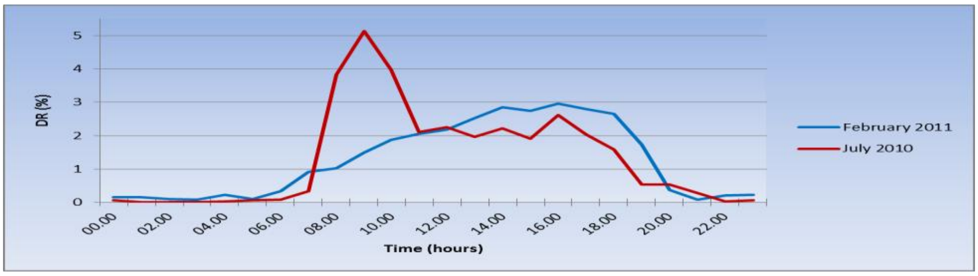

Fig. 18 - Variation of DR (%) hourly means

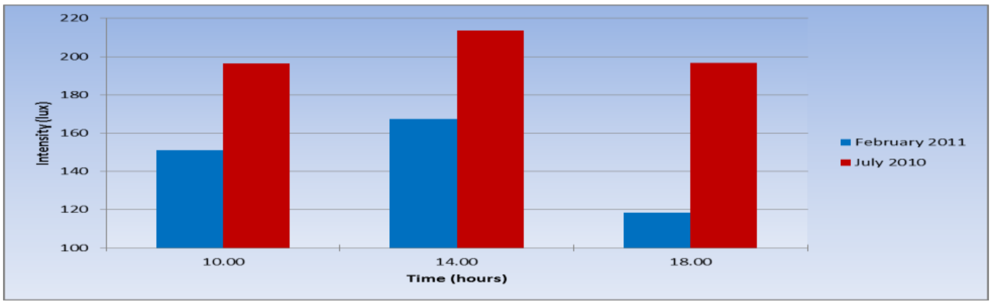

Fig. 19 **-** Variation of luminous intensity (lux) hourly means

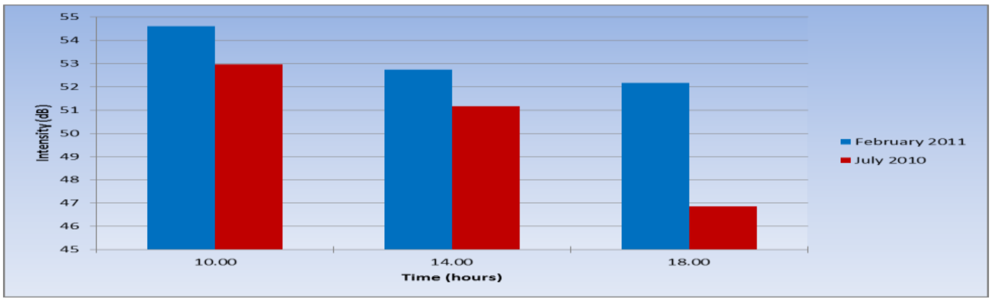

Fig. 20 - Variation of noise intensity (dB) hourly means

However the noise intensity had much higher values for all the three intervals in February, when we have recorded approximately 54 dB in the 10th day, 52 dB in day 14, and 52 dB in day 18. It's interesting to notice the high difference between the two months for this last interval, when we recorded an average value below 47 dB, mainly because most employees were off for their holidays and few still remained at work (Figure 20).

The luminous intensity had higher values in July for all the three measurement intervals. So, for July, the values kept constant around 200 lux, while for February, around 150 in days 10 and 14, and below 120 in the 18th day (Figure 19).

Conclusions

Following the preliminary data gathered in this study, we have noticed similarities for certain periods of the study for 8 measured parameters. If analyzing the monthly variation, we may notice high differences of values between October and September, but especially in August (for air-temperature parameters, these differences were higher than 3 degrees). The daily and hourly variations have similar patterns which overlap at the hours when employees come to and leave the location, but with a general trend of increase in the morning, stagnation at midday, and decrease in the evening. This is highly visible especially in summer, for the draught risk in particular.

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