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# Field Study of Thermal Comfort in Naturally Ventilated Classrooms of Cameroon

**Nematchoua Modeste Kameni [a*], René Tchinda [b] Noël Djongyang [c]**

[a] Environmental Energy Technologies Laboratory, University of Yaounde I, Cameroon
[b] LISIE, University Institute of Technology Fotso Victor, University of Dschang, Cameroon
[c] Department of Physics, Faculty of Science, University of Ngaoundere; Cameroon

**Corresponding author: kameni.modeste@yahoo.fr**

## Abstract:

**Thermal comfort is an important factor in a classroom. This paper presents the results of a field study campaign in three classrooms of the University of Yaounde I in Cameroon. An adaptive approach was used. The questionnaire was formulated according to the adaptive and statistical model prescribed by UNI EN ISO 10551. Various values of air temperature, wind speed, and relative humidity were measured at the same time students were filling the questionnaire. The study was conducted during three seasons (little rainy season, little dry season, and great rainy season). Several correlations were established according to the model of Fanger (PMV, PPD) and that of Wray. The temperatures of neutrality for the three seasons were found between 23.4 °C and 25.7 °C. The vote of thermal acceptability showed that during the three seasons, 66.02 % of the students found their environment acceptable, while the votes of thermal preference were: “want warmer” during the little rainy season, “want no change” during the little dry season and “want cooler” during the great rainy season.**

**Keywords**: Thermal Comfort, Classroom, Students, Teachers, Thermal sensation, Thermal acceptability.

## 1.0 Introduction

Thermal comfort can be defined as the satisfaction toward a given environment. Its evaluation is based on some international standards such as ISO, ASHRAE and takes into consideration parameters related to the individuals and their environment. The assessment of thermal comfort in buildings is important not only for the quality of indoor environment, but also for the optimization of the energy required to get it. Developing models to evaluate thermal comfort asymmetrical environments or transient conditions has being an hotspot of recent studies(Djongyang,2011 ; Dili,2011 ; Sekhar,2011). A study of thermal comfort in a given area makes possible to determine the acceptable range of environmental parameters. This permits to propose some architectural recommendations and to determine building materials best adapted to each type of climate(Jannot,1993) . Thermal comfort is also an important factor for human health. It includes simultaneously physiological, psychological and sociological facts. The conditions of acceptable thermal environment are defined in the standards of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE,2004). This standard gives the conditions under which more people in good health will find a given environment comfortable. The model of Fanger’s PMV model based on the steady state heat transfer theory is the standard basis of thermal comfort(Fanger,1970). According to (Nicol,2004), the PMV does not accurately predict the vote of the occupants on the ASHRAE's scale and the thermal sensation in summer are in particular over-estimated. Surveys carried out by De Dear and Brager in naturally-ventilated buildings showed the same phenomenon(Brager,1998). Many literatures showed that the adaptive approach is necessary to evaluate thermal comfort. However, it should not be separated from the rational approach of Fanger(Djongyang,2010) . Several studies were carried-out in the last decades to evaluate thermal comfort in apartments, residences, offices and classrooms throughout the world; e.g. (Nyuk,2003) determined the range of acceptable temperature and showed that in a naturally ventilated environment in tropical climate (Singapore), the range of comfort differs from that indicated in ASHRAE 55. (Paolo,2008) showed that thermal preferences and feelings vary according to the seasons. (Hussein,2009) showed that it is possible to obtain an environment where more than 80% of individuals find acceptable. (Orosa,2011) developed a new PMV model which takes into consideration indices related to the individuals, as well as the real effect of clothing (permeability). Similar studies were made in the Netherlands, India, Japan, China, Tunisia(Nicol,2004; Bouden,2005 ; Goto,2007 ; Mui,2005) . Few works are made on the field of thermal comfort in the sub-Saharan Africa in general and particularly in the wet-tropical region(Djongyang,2011). (Ogbonna,2008) in a field survey in Jos (Nigeria), recommended the range of acceptable conditions in tropical classrooms . The works of (Zingano,2001) in Malawi (East-Africa), specified the importance of the comfortable temperature. (Tchinda,2010) studied comfort during the Harmattan season in North-Cameroon. They determined some comfort parameters for individuals in their living environments (modern and traditional buildings). The study of thermal comfort in classrooms has never been made in Cameroon. Thus the purpose of this paper is to study thermal comfort in some classrooms of the University of Yaounde I. The new adaptive approach was used.

## 2.0 Material and Methods:

### *2.1 Study Area*

The University of Yaounde I is located on the hill of Ngoa Ekelle, in the west of the political capital of Cameroon. Yaounde is located at the edge of the large forest of south-Cameroon, approximately 300 km from the Atlantic Ocean coasts. The mean temperature ranges from 18° C to 28° C during the rainy season and 16° C to 35° C during the dry season. A subequatorial climate moderated by altitude (600-800m) reigns in the area. It includes four seasons:

- The great dry season (from mid-November to the end of March)
- The little rainy season (from April to mid-June)
- The little dry season (from mid-June to mid-August)
- The great rainy season (from mid-August to mid-November)

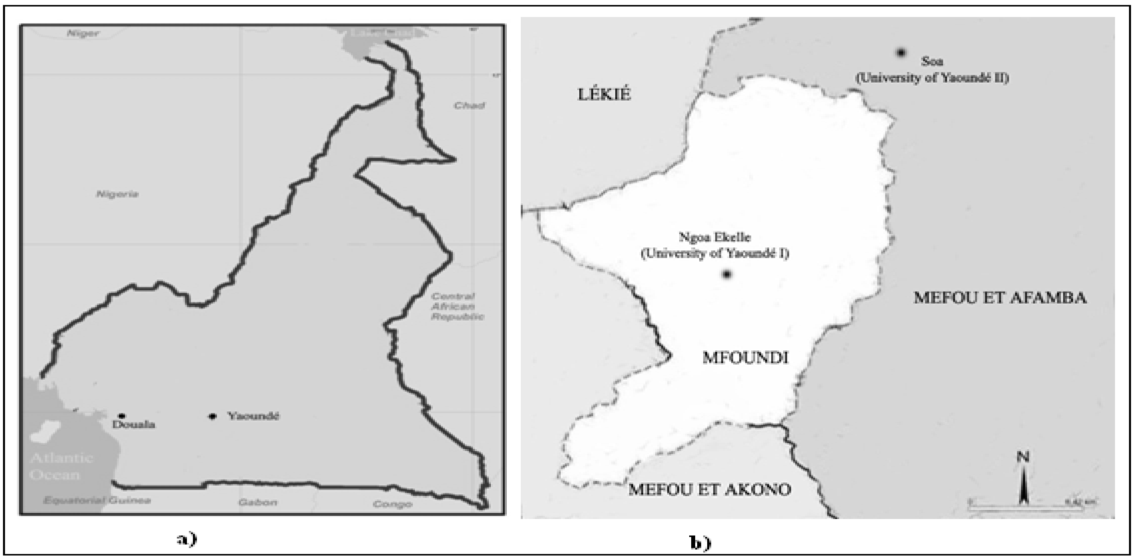


**Fig. 1**: Study area: (a). Cameroon map, (b). Yaounde map.

## *2.2 Material*

Outdoor parameters (temperature, moisture and wind speed) were obtained from the weather station of Yaounde were. Various values of indoor temperatures, relative humidity and wind speed were measured respectively by the means of a mercury thermometer (with a precision of ± 0.5 °C), an hygrometer (± 0.5 %), and an omnidirectional anemometer. A GPS was used to determine the geographical co-ordinates of the various classrooms. Three classrooms were considered during the study:

- Lecture hall A.1002 of the Faculty of Science (3°35'N, 11°30'1.1"E) (figure 2).

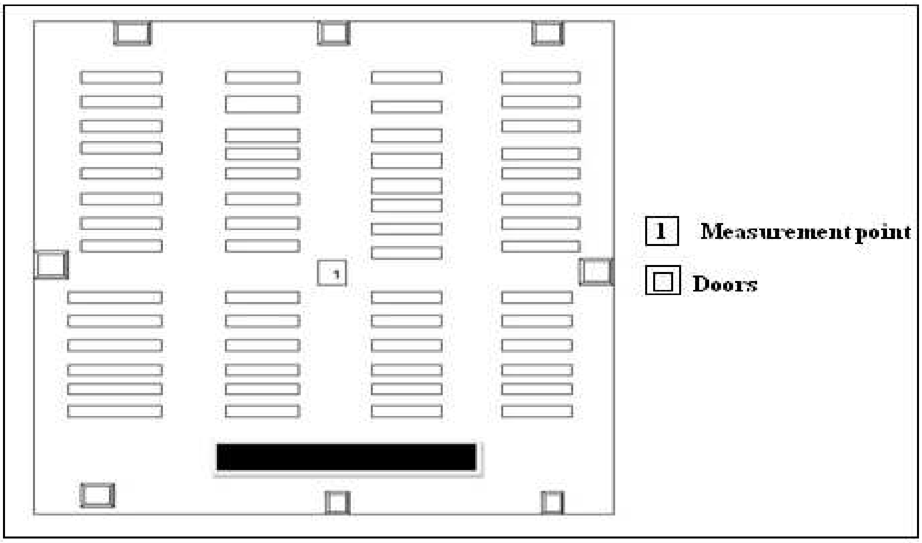


**Fig. 2**: Plan of the lecture hall A. 1002

Lecture hall A.150 of the teaching block (Virtual University of Central Africa): (03°51'26.6"N, 11°30'2.1"E) (figure 3)

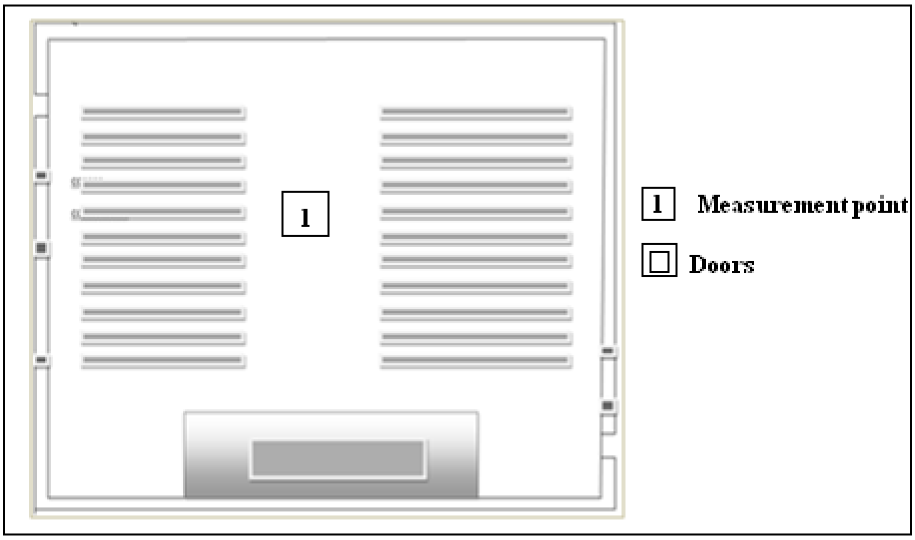


**Fig. 3**: Plan of the lecture hall A. 150

Lecture hall A.300, of the Faculty of Medicine and Biomedical Sciences (03°51'45.8"N, 11°29'44.8"E) (figure 4).

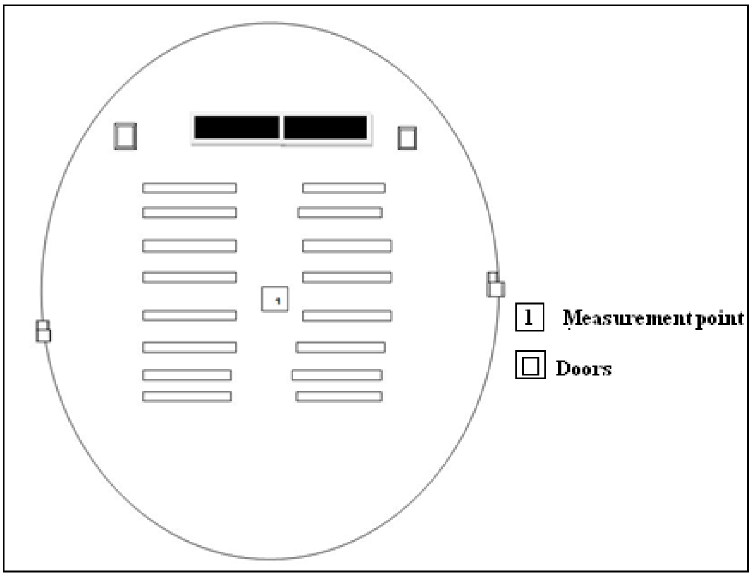


**Fig. 4:** Plan of the lecture hall A. 300

The choice of the various classrooms was based on the types (models) of classrooms on the site, the parameters that can influence thermal comfort (such as ventilating systems) and their carrying capacity. The measurements were taken every 30 minutes at approximately 1.5 m height from the ground level, between 8 am and 6 pm.

### *2.3 Methodology*

The measurement of the environmental parameters was done in conformity with the norms ( ISO7730,2006; ISO 10551,2002; ASHRAE Standard,2004) using the new adaptive approach. Even if some classrooms have ventilating systems, they were naturally ventilated during the study. Some characteristics of the classrooms are presented in tables 1, all the data were measured during the lessons' periods. A total of 2498 students expressed their thermal feelings during the campaign. The model of Wray, based on the uniform equivalent temperature ($T_{eu}$) and the uniform temperature ($T_u$) was used. $T_u$ is the temperature to seek to get optimal comfort conditions. The following equation, solved with the assumptions (L=0,Ta=Tu=Tmr) was also used(Buratti,2009).

A questionnaire was distributed to the students in order to evaluate their thermal perception, while measurements were taken. The points of measurement were selected near positions of high students' concentrations. The questionnaire was divided into three different parts; namely: Personal data (age, sex); Thermal aspects : judgements of thermal environment and air movement, difference in temperature between the head and the ankle(José,2011) , activities done in the 10, 20, 30 and 60 past minutes, possible preference of the different conditions; Micro climatic control

$$\begin{aligned} L = M &- 0.41\left[43 - 0.052M1.92\phi\left(T_a - 273\right) + 25.3\phi\right] \\ &-0.490.86M - 50 + 0.0023M\left[44 + 1.92\phi\left(T_a - 273\right) + 25.3\phi\right] \\ &-0.0014M\left(307 - T_a\right) + 1.58.10^{-7} f_{cl}T_{av}^{3}\left(T_{cl} - T_{mr}\right) - f_{cl}h_c\left(T_{cl} - T_a\right) \end{aligned} \tag{1}$$

Values of $T_{cl}$, $f_{cl}$, $h_c$, PMV and PPD are determined through a computer programme. $T_{eu}$ is evaluated through (Buratti,2011):

$$T_{eu} = \frac{1}{1-S}T_{mr}^{*} + \frac{S}{S-1}T_{a}^{*} \qquad S = S\left(M, I_{cl}, f_{cl}, h_c, \phi\right) \tag{2}$$

The expression of the coefficient of convection $h_c$ was that proposed by (Colin,1967) :

$h_c = 2.7 + 8.7V^{0.67}$ for $0.15 < V < 1.5$ (3)

$h_c = 5.1$ for $0 < V < 0.15$ (4)

While the operative temperature was evaluated by(ASHRAE,2004) :

$T_o = AT_a + (1-A)T_r$ A=0.5 for $V < 0.2$ m/s (5)

A=0.6 for $0.2 < V < 0.6$ m/s

A=0.7 for $0.6 < V < 1$ m/s

**Table 1: Some characteristics of various Classrooms .**

| Classroom | A. 1002 | A.300 | A.150 |
|---|---|---|---|
| Localisation | Faculty of Science | Faculty of Medicine | Teaching block |
| Altitude (m) | 758 ± 8 | 766±3 | 781±5 |
| Precipitation (mm) | may : 220 | Oct. : 296 | Sep : 254 |
| Temperature | may : 25.3 | Sep : 23.1 | Jul. : 22.4 |
| Average (°C) | Jun : 23.3 | Oct. : 23.3 | – |
| Capacity (students) | 1002 | 300 | 150 |
| Doors | Anti-panics : 7 | Wood : 2 | Wood : 2 |
| (color) | brown | blue | yellow |
| windows | confined | Glaze | Glaze |
| Podium | yes | yes | yes |
| HVAC System | No | Air / water | No |
| Experimental periods | Little dry Season rainy seasons | rainy seasons - | Little dry Season rainy seasons |
| Number of experiments | 8 | 8 | 8 |
| Number of questionnaire | 847 | 757 | 894 |
| Type of luminary | Neon : 84 | Neon : 29 | Neon : 8 |
| Floor's area S ($m^2$) | 812.250 | 408.074 | 130.000 |
| Volume V ($m^3$) | 3655.125 | 1632.297 | 482.300 |
| Height (m) | 4.500 | 4.000 | 3.710 |
| Exposure windows | N-S-NE-NW | NW-SE | SW-SE |

**Table 2 :** Months of study.

| Experience number | A.1002 | A.300 | A.150 |
|---|---|---|---|
| 1 | May | June | June |
| 2 | June | June | July |
| 3 | September | September | September |
| 4 | September | September | September |
| 5 | October | September | September |
| 6 | October | October | September |
| 7 | October | October | September |
| 8 | October | October | October |

The questionnaires were distributed twice a day, 15 minutes after the beginning of the lesson to allow the students and the instruments to adapt to the environmental conditions.

The questionnaire also takes into consideration(Buratti,2009):

- thermal dissatisfaction index (TDI) [%], defined as the ratio dissatisfied persons/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''light annoyance, annoyance, heavy annoyance'' to the question ''what is your thermal sensation?'');

- thermal preference index (TPI) [%], defined as the ratio persons who want to change/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''much too cool, too cool, a little bit cool, a little bit warm, too warm, much too warm'', to the question '' how would you like to feel?'');

- thermal unacceptability index (TUI) [%], defined as the ratio persons who consider unacceptable/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''no, it is not acceptable'' to the question ''On the basis of your personal preferences, how would you consider the room temperature acceptable or unacceptable?'');
- thermal annoying index (TAI) [%], defined as the ratio persons who cannot tolerate it/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''slightly hard to tolerate, hard to tolerate, very hard to tolerate, intolerable'' to the question ''how do you consider this room?'');
- unacceptable air movement index (UAMI) [%], defined as the ratio persons who express a negative judgement/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''completely not acceptable, not acceptable, slightly not acceptable, slightly acceptable'' to the question ''how do you feel about the air flow in this moment?'');
- unacceptable vertical thermal gradient index (UVTGI) [%], defined as the ratio persons who express a negative judgement/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''completely not acceptable, not acceptable, slightly not acceptable, slightly acceptable'' to the question ''how you consider the temperature difference between head and ankle?'').
- preference vertical thermal gradient index (PVTGI) [%], defined as the ratio persons who wants to change/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''lower than now, higher than now'' to the question ''would you prefer a temperature difference of temperature between head and ankle'');
- environmental control dissatisfaction index (ECDI) [%], defined as the ratio persons who express a negative judgement/persons who express a judgement (it is evaluated as the percentage of persons who have answered ''very unsatisfied, not satisfied, slightly not satisfied, slightly satisfied'', to the question ''How do you feel about possibility of controlling thermal comfort?'').

## 3.0 Results and Discussion:

**Table 3: Synthesis and analysis of the responses to the questionnaires**

| **Classroom** | **A. 1002** | **A. 300** | **A. 150** |
|---|---|---|---|
| **Total of questionnaires** | 847 | 757 | 894 |
| **Age (years)** | | | |
| Maximum | 24 | 22 | 23 |
| Minimum | 19 | 18 | 18 |
| Mean | 21.4 | 20.6 | 20.9 |
| Standard deviation | 2.42 | 0.98 | 1.23 |
| **TDI (%)** | | | |
| Maximum | 66.1 | 58.6 | 55.0 |
| Minimum | 15.4 | 12.9 | 15.9 |
| Mean | 39.0 | 34.8 | 31.5 |
| **TPI (%)** | | | |
| Maximum | 95.8 | 99.0 | 83.0 |
| Minimum | 46.7 | 58.0 | 44.6 |
| Mean | 65.0 | 74.2 | 62.7 |
| **TUI (%)** | | | |
| Maximum | 67.0 | 69.4 | 46.0 |
| Minimum | 10.5 | 9.7 | 10.3 |
| Mean | 32.6 | 42.5 | 24.7 |
| **TAI (%)** | | | |
| Maximum | 95.8 | 75.0 | 81.0 |
| Minimum | 31.2 | 7.0 | 18.5 |
| Mean | 51.8 | 44.9 | 54.8 |
| **UVTGI (%)** | | | |
| Maximum | 73.8 | 66.0 | 76.0 |
| Minimum | 15.4 | 16.1 | 17.2 |
| Mean | 43.7 | 35.5 | 44.6 |
| **PVTGI (%)** | | | |
| Maximum | 83.3 | 56.7 | 76.0 |
| Minimum | 19.7 | 30.1 | 37.6 |
| Mean | 51.6 | 42.8 | 53.9 |
| **ECDI (%)** | | | |
| Maximum | 43.2 | 83.1 | 89.0 |
| Minimum | 25.5 | 22.6 | 36.0 |
| Mean | 35.0 | 50.2 | 52.6 |

**Table 4 : Measured data**

| **Classroom** | **A. 1002** | **A. 300** | **A. 150** |
|---|---|---|---|
| **Outdoor temperature (°C)** | | | |
| Maximum | 24.0 | 24.6 | 24.6 |
| Minimum | 21.0 | 21.0 | 21.3 |
| Mean | 22.9 | 22.9 | 22.8 |
| Standard deviation | 0.96 | 1.32 | 0.84 |
| **Outdoor relative humidity (%)** | | | |
| Maximum | 92.0 | 84.5 | 91.5 |
| Minimum | 61.0 | 71.0 | 59.5 |

| | | | |
|---|---|---|---|
| Mean | 76.6 | 78.1 | 75.5 |
| Standard deviation | 2.16 | 3.12 | 1.59 |
| **Outdoor air velocity(m/s)** | | | |
| Maximum | 3.1 | 3.1 | 2.8 |
| Minimum | 1.1 | 0.7 | 0.8 |
| Mean | 2.0 | 1.7 | 1.5 |
| Standard deviation | 0.65 | 0.82 | 0.09 |
| **Mean indoor temperature (°C)** | | | |
| Maximum | 26.5 | 24.8 | 25.2 |
| Minimum | 23.8 | 23.1 | 24.1 |
| Mean | 25.4 | 24.1 | 24.6 |
| Standard deviation | 0.72 | 1.27 | 0.86 |
| **Mean indoor relative humidity (%)** | | | |
| Maximum | 56.0 | 53.1 | 53.3 |
| Minimum | 41.2 | 41.5 | 46.9 |
| Mean | 49.3 | 46.6 | 49.5 |
| Standard deviation | 2.55 | 1.70 | 2.35 |
| **Mean radiant temperature (°C)** | | | |
| Maximum | 26.3 | 24.6 | 24.9 |
| Minimum | 23.6 | 22.9 | 21.3 |
| Mean | 25.1 | 23.8 | 23.9 |
| Standard deviation | 0.70 | 1.24 | 1.28 |
| **Mean indoor air velocity (m/s)** | | | |
| Maximum | 0.14 | 0.16 | 0.17 |
| Minimum | 0.07 | 0.05 | 0.05 |
| Mean | 0.1 | 0.1 | 0.1 |
| Standard deviation | 0.02 | 0.04 | 0.01 |
| **M (W/m$^2$)** | | | |
| Maximum | 72.0 | 72.0 | 72.0 |
| Minimum | 67.0 | 58.0 | 58.0 |
| Mean | 69.5 | 68.5 | 69.0 |
| Standard deviation | 1.73 | 1.10 | 2.05 |
| **$I_{cl}$(clo) (M)** | | | |
| Maximum | 1.3 | 1.4 | 1.2 |
| Minimum | 0.5 | 0.6 | 0.5 |
| Mean | 0.9 | 0.8 | 0.9 |
| Standard deviation | 0.07 | 0.08 | 0.10 |

**Table 5: Synthesis of the average data**

| Class room | A. 1002 | A. 300 | A. 150 |
|---|---|---|---|
| **M(W/m$^2$) W** | | | |
| Maximum | 72.0 | 70.0 | 71.3 |
| Minimum | 69.0 | 68.0 | 69.0 |
| Mean | 69.1 | 69.2 | 69.0 |
| Standard deviation | 0.78 | 1.34 | 1.07 |
| **$I_{cl}$ (clo) (W)** | | | |
| Maximum | 1.2 | 1.2 | 1.2 |
| Minimum | 0.6 | 0.4 | 0.9 |
| Mean | 0.9 | 0.9 | 1.0 |
| **PMV (M)** | | | |
| Maximum | 0.0 | -0.9 | -0.5 |
| Minimum | -1.5 | -2.7 | -1.4 |
| Mean | -0.6 | -1.5 | -1.1 |
| **PMV (W)** | | | |
| Maximum | 0.1 | -1 | -0.7 |
| Minimum | -1.2 | -1.8 | -1.5 |
| Mean | -0.6 | -1.4 | -1.1 |
| **PPD (%) (M)** | | | |
| Maximum | 49.6 | 96.7 | 52.9 |
| Minimum | 5.0 | 24.2 | 11.2 |
| Mean | 18.3 | 53.2 | 33.5 |
| **PPD (%) (W)** | | | |
| Maximum | 37.7 | 67.2 | 50.2 |
| Minimum | 5.1 | 64.9 | 39.6 |
| Mean | 17.5 | 49.0 | 32.4 |

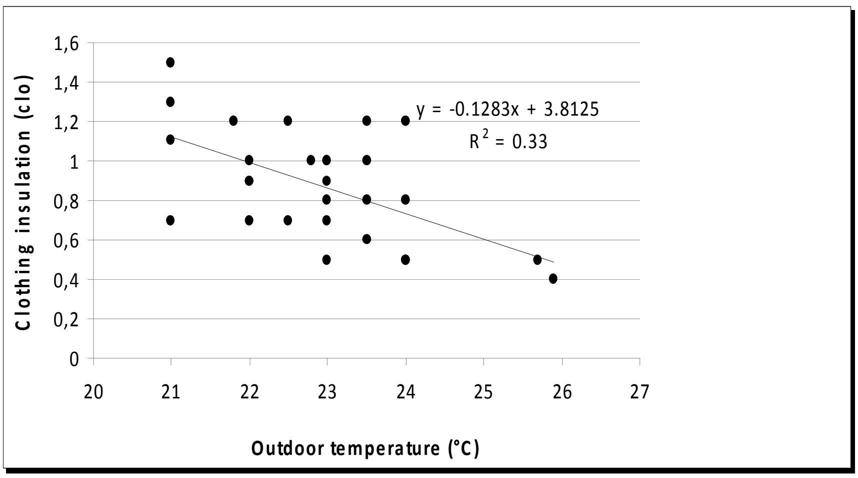


**Fig. 5**: Average clothing insulation **vs** outdoor temperatures during the period of study.

Figure 5 presents the variation of the average clothing insulation with outdoor temperature. It can be seen that the irradiation of insulation decreases with the temperature. The following correlation for outdoor temperatures between 21°C and 26 °C was obtained:

$$I_{cl} = -0.128T_{out} + 3.812\ ; \quad R^2 = 0.333 \quad (6)$$

It was observed that during the dry seasons, the irradiation of insulation is less than in the rainy seasons. This can be explained by the fact that during the dry seasons, with an increase in temperature, students prefer light clothes. the average clothing insulation obtained was 0.9clo . This average varied according to the age and sexe of students :for example in these different classrooms , the average clothing insulation was of 1clo for the studen or the age varied from 18 to 21years . For the students or them age was ranged from 22 to 24years, the average clothing insulation was of 0.8clo.In addition, the average clothing insulation at the male students was of 0.85clo ; it was 0.95clo at the women. These results are in conformity with those obtained by( Moujalled,2008) who found a strong dependence of the thermal insulation on climatic seasons.

PMV and PPD were calculated from the experimental data. The representative points are presented in figures 6 and 7.

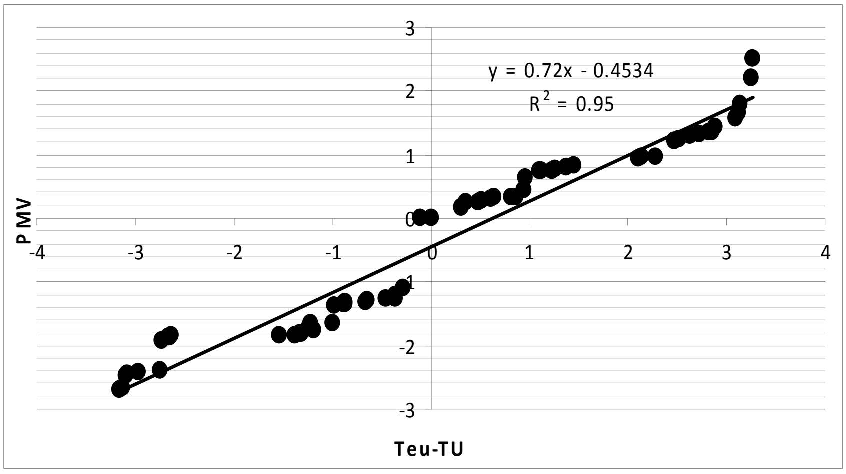


**Fig. 6** : PMV vs. Teu-Tu (°C)

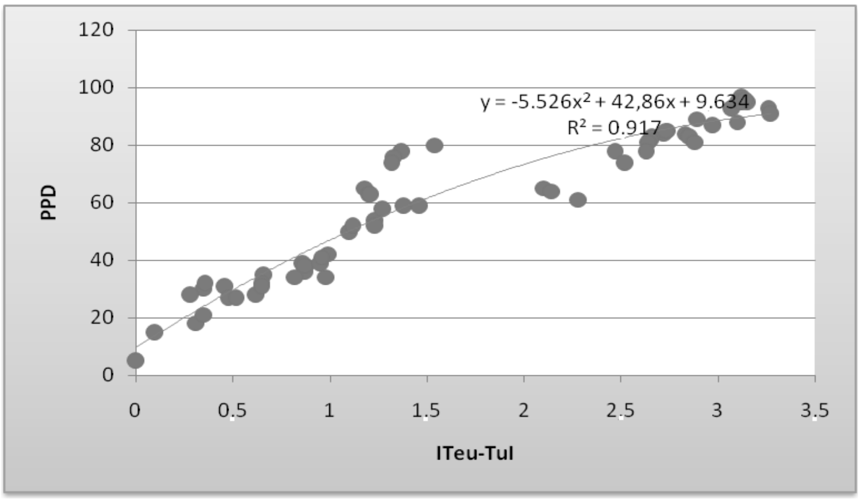


**Fig. 7** : PPD vs. $|T_{eu} - T_u|$ (°C)

Considering the range of clothing insulation, the following correlations were obtained:

- PMV vs Teu-Tu (°C) :

$$PMV = 0.72\left(T_{eu} - T_u\right) - 0.453\ ; \quad R^2 = 0.95 \quad (7)$$

- PMV vs $|T_{eu} - T_u|$ (°C)

$$PPD = -5.526\left(T_{eu} - T_u\right)^2 + 42.86\left|T_{eu} - T_u\right| + 9.634\ ; \quad R^2 = 0.92 \quad (8)$$

The values of the PMV and PPD for neutrality are obtained for Tu =Teu and PMV=0, we obtained respectively PPD=5.1 and PPD=5.02. Most of the values of Teu-Tu obtained were negative, showing that the studied environment was associated to a cool environment; this was confirmed by the various values of the PMV obtained, which were almost negative.

It arises from figure 8 the following correlation between the PMV and the operative temperature:

$$PMV = 0.448T_o - 11.96 \; ; \quad R^2 = 0.18 \qquad (9)$$

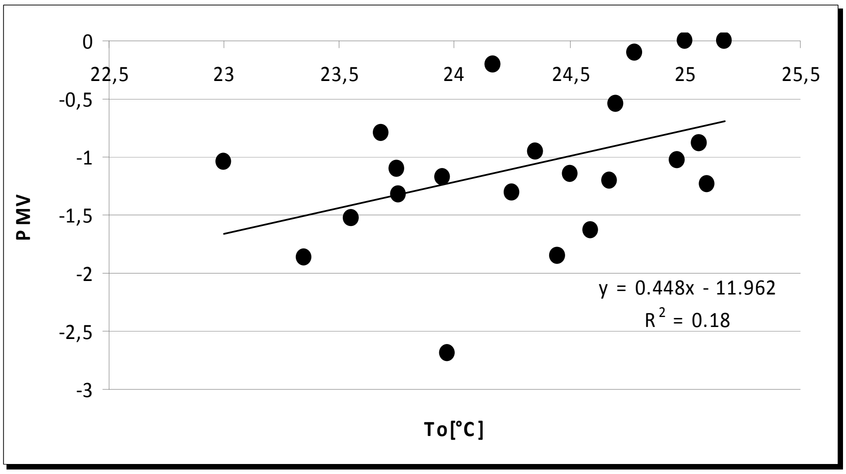


**Fig. 8**: PMV vs. Operative temperature

The mean PPD from the questionnaire is 16.97 % while that obtained from calculations is 33.98 %. The values of the PMV obtained are between -1.9 and 0.1 except for October 5, 2010 where the value of the PMV obtained was -2,69 . For 23.93 °C < T < 26.21 °C; 66.02 % of students found their environment comfortable. Some students voting for indices +2 (warm) during the dry season and -2 (cool) during the rainy season find their environment acceptable and preferable. From figure 9, it comes that: 10 % of students voted between +2 (warm) and +3 (hot) and 8 % of students voted between -3 (cold) and -2 (cool). In addition, these students found their environment not acceptable. It can also be seen from figure 9 that approximately 52 % of students who voted for indices (-1, 0, +1) found their environment acceptable.The proportion of the students who voted -2 and +2 is equitable, and the proportion of maximum acceptability is around 0 (neutral).

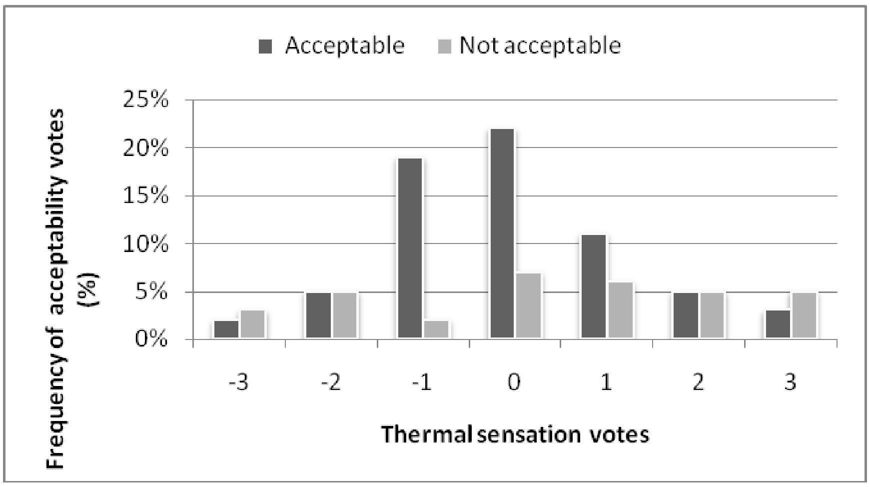


**Fig. 9**: Votes of thermal sensation during the little rainy season

It was found that in the various classrooms, the thermal preference was “want no change” during the dry seasons and “want warmer” during the rainy seasons. Indeed, more people voting for indices (-1,0,+1) considered their environment acceptable, while the people who voted for the index -3 , consider their environment not acceptable; this observation is checked very easily. On figures 10, one can observe that 24,83% of students find their environment not acceptable. Those who voted for -1 found it acceptable, while those who voted for -3 found their environment not acceptable. Among the 75.17 % of students who found their environment acceptable, nearly 31.4 % found it neutral. Thermal sensation varied according to the seasons and habitat type(Nematchoua,2014).

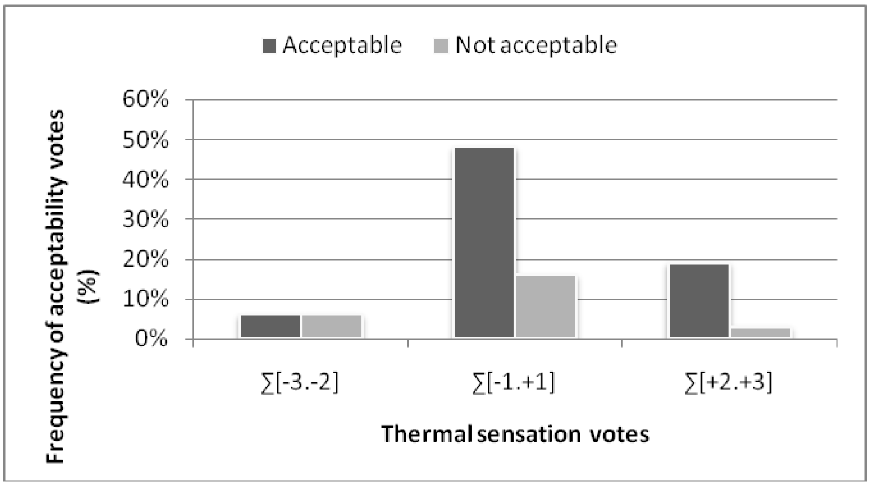


**Fig. 10** : Votes of thermal sensation grouped in (-3;-2), (-1;+1) and (+2;+3) during the little dry season.

From figure 11 , one can directly notes that during the great rainy season, where the temperature of neutrality varies between [23.41 °C; 25.72 °C], approximately 67.27 % of students found their environment acceptable. Moreover, it arises that among the 34.71 % of students who voted for the indices (+2 ; +3) and (-2 ; -3), approximately 20.59 % found their environment not acceptable, while the 53.15 % people voting for the indices (-1 ; 0 ; +1) found it acceptable.

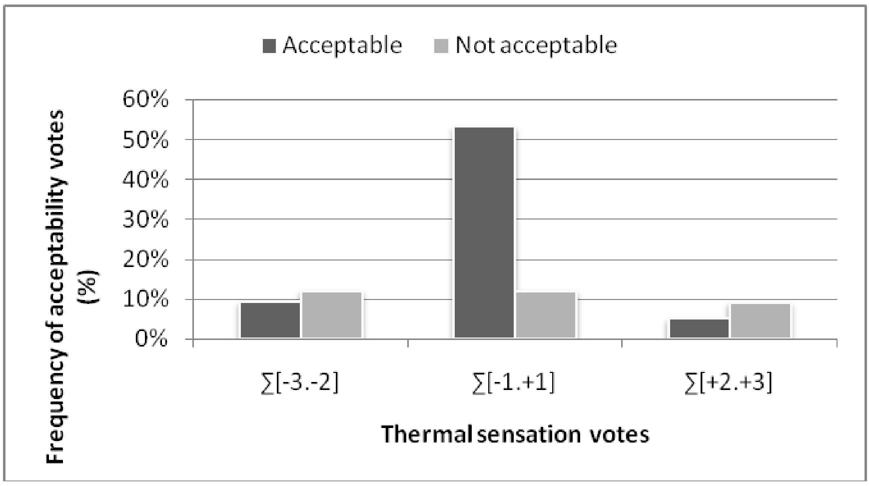


**Figure 11**: Votes of thermal sensation grouped in (-3;-2) (-1;+1), and (+2;+3) during the great rainy season

It arises from figure 12 that, 47.1 % of students voted for "want warmer" while 15.4 % choose "want cooler", and 37.5% preferred "no change". Moreover, it arises that a great concentration of students who voted for indexes (-1, 0 ,+1) prefered an environment "with no change’’.

The thermal preference was very solicited by students who voted for indices -3 (1.7 %), -2 (9.1 %), -1 (13.4 %), +1 (9 %) and +2 (7.1 %). Among the 28.6 % of students who voted for neutral (0), 21.9 % want “no change”. The proportion of those who want “no change” is weak for the indexes -1, +1, +2 with 3.2 %, 3 %, and 1.4 % respectively.

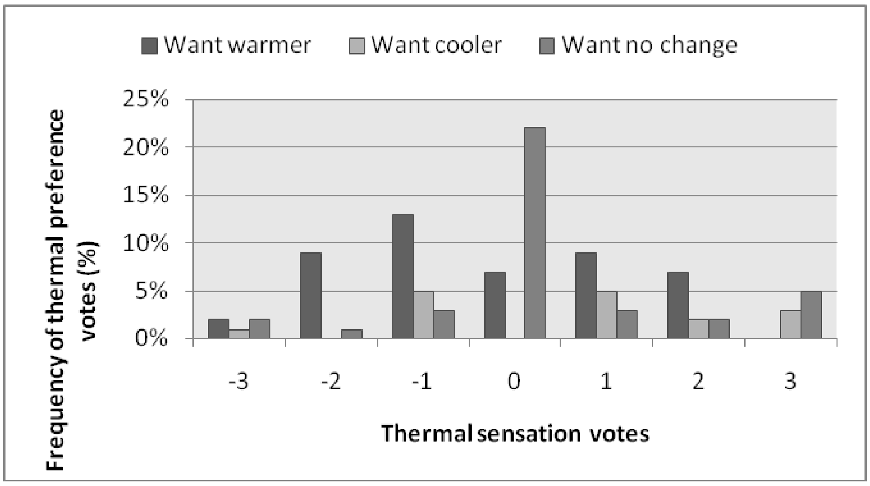


**Fig. 12** : Votes of thermal preference during the little rainy season

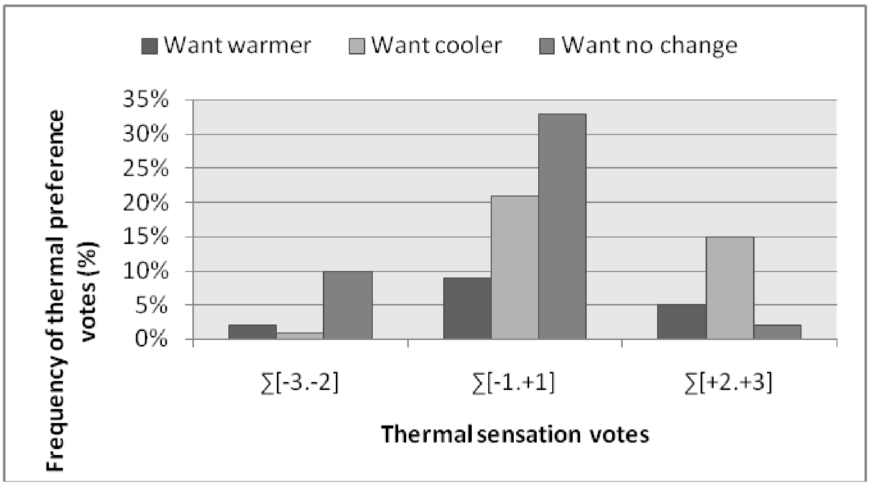


**Fig. 13**: Votes of thermal preference grouped in (-3; -2), (-1; +1) and (+2; +3) during the little dry season.

From figures 13, one can deduce that 14.6 % of learners who voted for the indices (+2, +3) prefer a “cooler” environment. However on figure 18, all those who voted for the index -2 choose an environment with “no change“. Moreover among the 63.53 % of students who voted for (-1, 0, +1), 33.05 % want “no change“.

One can see from figure 14 that during the great rainy season, with temperatures of comfort between [23.93°C - 26.21°C], approximately 66.14 % of students wished their environment to be changed, on the other hand 24.92 % of students voting for indices (-1; 0 ; +1) want no change. In general, 41.3 % of voters prefer "cooler" whereas 24.84% want their environment "warmer".

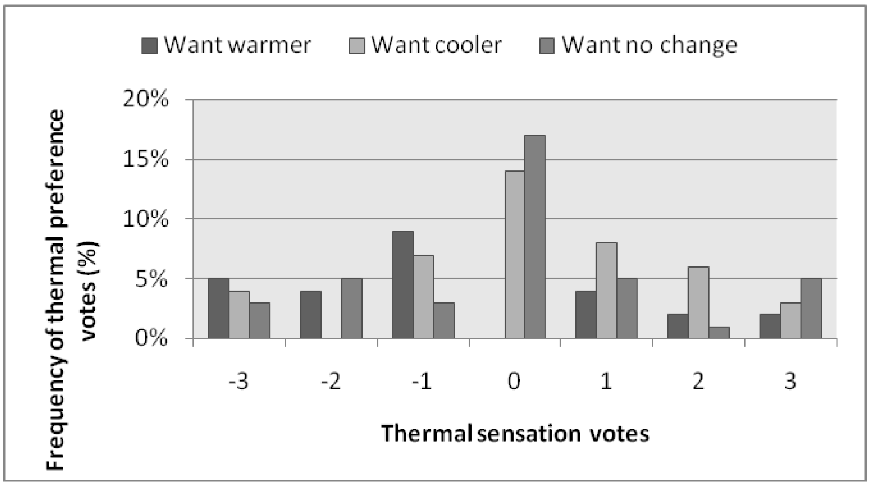


**Fig. 14** : Votes of thermal preference during the great rainy season.

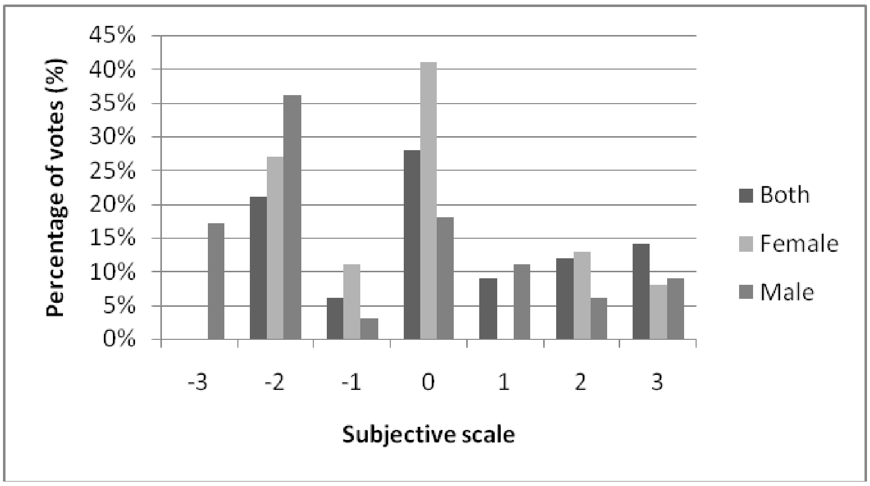


**Fig. 15**: Subjective responses about air movement during the little rainy season and the little dry season.

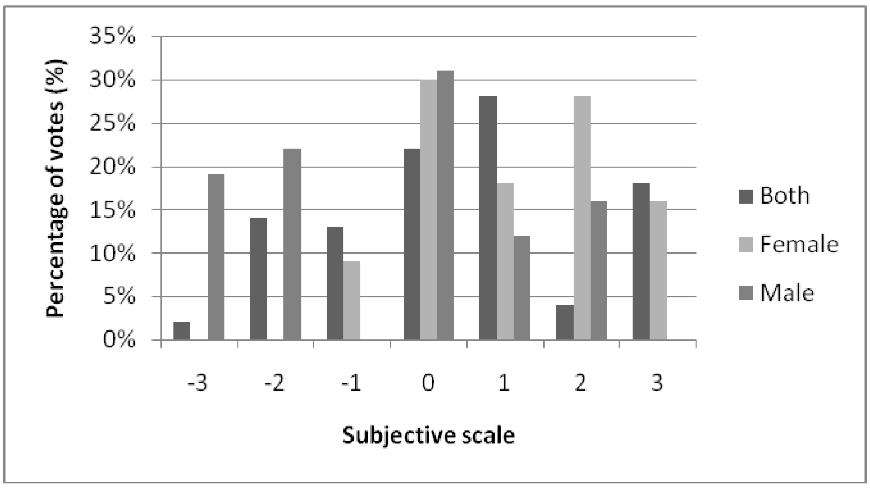


**Fig. 16** : Subjective responses about air movement during the great rainy season.

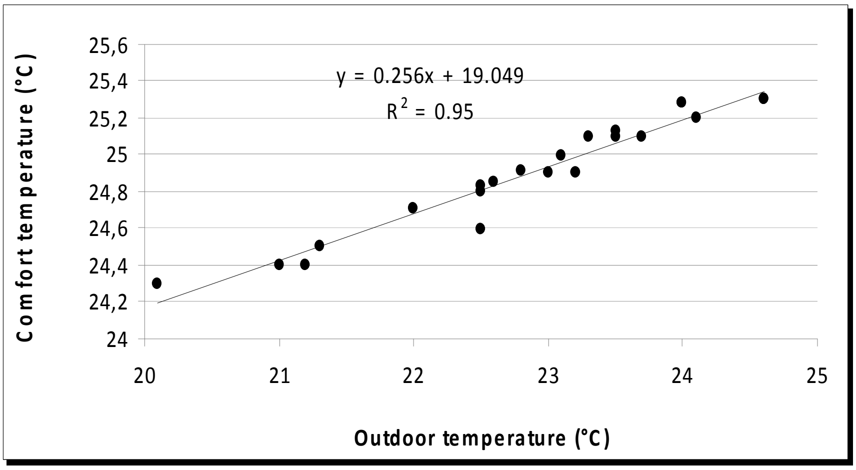


**Fig. 17** : Temperature of comfort vs. outdoor temperature.

It appears from figure 16 that: 56.1 % of women find the air flow in the various lecture halls acceptable while 57 % of men disagree. On the other hand, on figure 15 , 47 % of both find that the movement of air is not acceptable during the little dry and rainy seasons. On figure 17, a linear correlation was obtained between the temperature of comfort and the outdoor temperature:

$$T_c = 0.256T_{out} + 19.04\,; \quad R^2=0.95 \qquad (10)$$

The analysis of the air velocity in the three classrooms showed as presented on figure 18 that the average wind speed is 0.1 m/s. In general the wind speeds in the three classrooms were less than 0.18 m/s, this is probably due to the micro climate of Yaounde.

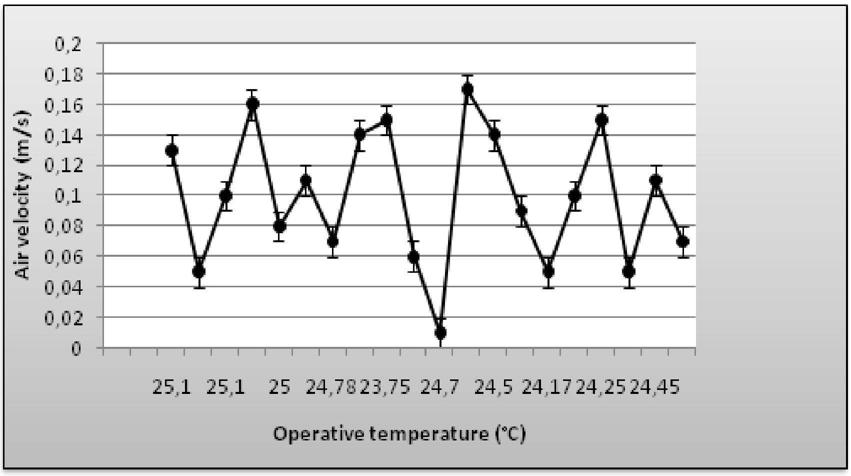


**Fig. 18** : Air velocities vs. Operative temperature

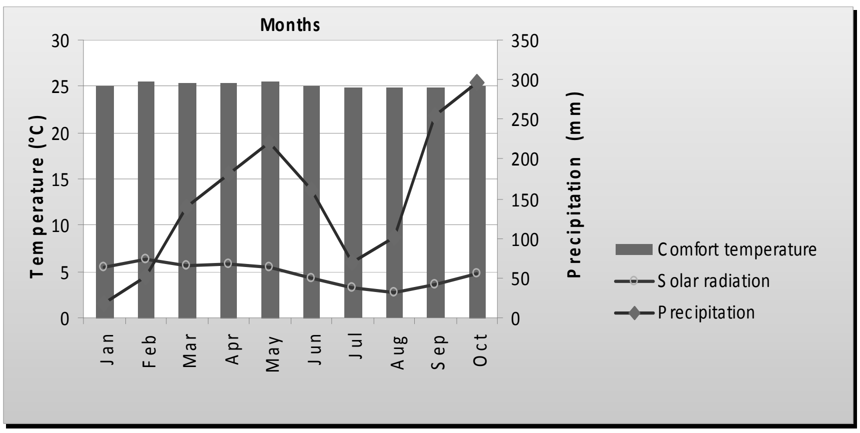


**Fig. 19** : Temperature according to precipitation

From figure 19, one can observe that a peak of precipitation was recorded in May 2010 (220 mm) corresponding to a temperature of comfort of 25.5°C and with a solar irradiation of 5.4 W/m$^2$. The least rainy month is January (17 mm; 25.11 °C; 5.5 W/m$^{2)}$. Then it is thus significant to conclude that precipitations just like the solar irradiation can influence the students' feelings. On figure 20, we summarily represented the temperatures and the relative humidity measured. The indoor average temperature is between 23.1 °C and 26.5 °C with an indoor relative humidity between 41.2 % and 57.8 %. It thus rises that for the three classrooms, the values of temperature and of relative humidity obtained are between the range recommended by the standards for comfort
.

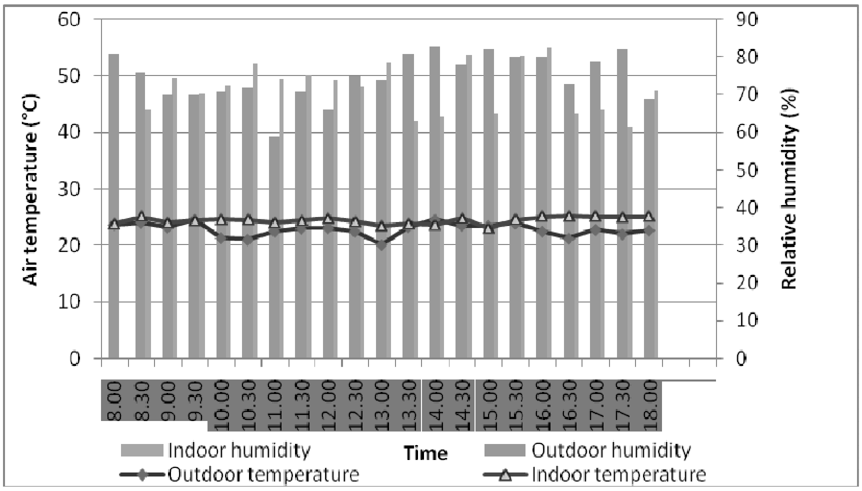


**Fig. 20** : Temperature and relative humidity

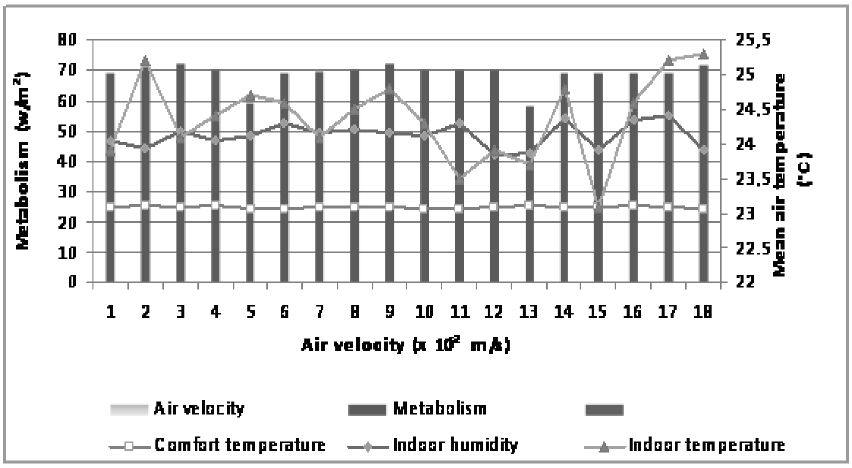


**Fig. 21**: parameters influencing thermal comfort

Some parameters influencing thermal comfort in a classroom are gathered on figure 21. One can observe linear correlation between various values of temperatures of comfort, with a range of metabolism between 58 $W/m^2$ and 72 $W/m^2$. The various values of wind speeds are less than 0.18 m/s. For considerable values of the metabolism, indoor moisture and wind speed, an increase in mean indoor temperature is observed. The results obtained enable to release that the parameter on which it is necessary to act firstly to get comfort in a classroom is the indoor air temperature: it is thus necessary to limit the contributions of heat through the walls and the roof of the dwellings. But from a given outdoor temperature, the use of an average cooling (water evaporation and air-conditioning) will be necessary in some hours of the day. The use of a ventilator to increase the air velocity reduces the thermal stress without making it possible to reach comfort if the temperature is greater than 30 °C. The increase in the moisture of the air leads to an increased discomfort, which is much more sensitive during rainy season and sometimes in dry season.

## 4.0 Conclusion:

A study of thermal comfort was conducted during three seasons in three classrooms of the University of Yaounde 1. An experimental protocol in conformity with the standards ISO 7730 and ISO 10551 permitted to determine the indices of Fanger and that of Wray. The PMV obtained were mostly between -2.7 and 0.1. Hygrometrical comfort obtained was optimal for PMV = 0, that corresponds to Teu = Tu, PPD = 5.1 %, and 5.02 %. It comes out from the study that the range of comfort temperature is between 23.9 °C and 26.3 °C and the temperature of neutrality is between 23.4 °C and 25.8 °C. It was noted that the solar irradiation is one of the principal sources of classrooms' heating; when the solar radiation is transmitted directly to the classroom, an immediate increase in the indoor temperature is observed. So, it is thus necessary to protect exposed surfaces. The analysis of the solar trajectories reveals the need to build east-west lengthened classrooms. In the equatorial Africa, and more precisely in Cameroon, the considerable increase in the ambient temperature constitutes the principal source of discomfort, from where need for thinking of the cooling of the amphitheatres as of their design. The passive techniques make possible to approach the conditions of comfort.

## 5.0 Acknowledgements:

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