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Thermal comfort and air movement preference in some classrooms in Cameroun

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Abstract - *The aim of this work is to study the relationship between air movement preference and thermal comfort in 30 naturally ventilates classrooms in 6 schools in the central region of Cameroon. This study was conducted during 2 seasons (the dry and the rainy seasons). An adaptive approach was employed, in accordance with ASHRAE 55/2004, ISO 7730 and ISO 10551. The questionnaires were given while wind speed, air temperature, relative humidity and CO_2 were measured simultaneously in rooms. A total of 1545 questionnaires were distributed in these different schools. Results show that 57.62% of voters found their environment tolerable. Results obtained after the analysis of questionnaires did not always match with results obtained through physical measure. Air preference varied according to each individual and place of study. Generally, during the two seasons, 75% of occupants wanted to have more air movement in their places. It was suggested that the increase in air velocity in schools is an essential phenomenon in obtaining thermal comfort environment.*

Résumé - *Le but de ce travail est d'étudier la relation entre le mouvement de l'air et préférence du confort thermique dans 30 salles de classe, naturellement ventilées et situées dans 6 écoles de la région centrale du Cameroun. Cette étude a été menée pendant deux saisons (saison sèche et saison de pluie). Une approche adaptative a été employée, conformément à la norme ASHRAE 55/2004, ISO 7730 et ISO 10551. Les questionnaires étaient distribués tandis que la vitesse du vent, température de l'air, l'humidité relative et taux de CO_2 étaient mesurés simultanément dans les chambres. Un total de 1545 questionnaires ont été distribués dans ces différentes écoles. Les résultats montrent que 57,62 % des électeurs ont trouvé leur environnement tolérable. Les résultats obtenus après l'analyse des questionnaires ne correspondent pas toujours avec les résultats obtenus avec des appareils de mesure. L'air varie en fonction de chaque individu et les lieux d'étude. En général, au cours des deux saisons, 75 % des occupants souhaitaient avoir plus de mouvement d'air pour leur milieu. Il a été suggéré que l'augmentation de la vitesse de l'air dans les écoles est un phénomène essentiel dans l'obtention d'un environnement confortable.*

Keywords: Classroom - Thermal comfort - Air preference.

1. INTRODUCTION

According to the international standards [1], thermal comfort is the situation in which an individual feels neither too much heat nor too much cold in a given

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environment [2]. Thermal comfort depends on subjective parameters such as: age, sex, health and geographical source. It also depends on objective parameters such as: air temperature, relative humidity, air speed, radiant temperature of the surrounding bodies etc. [3].

The study of thermal comfort is mainly done with two approaches of which one is rational and the other is adaptive. Standards such as ISO 7730 [4] and ASHRAE 55 [5] use certain research results carried by Fanger [6], the later defines thermal comfort as a mind state which expresses satisfaction with thermal environment.

These definitions are used well for the moderated climate for which it was developed [7]. Air movement has a direct impact on the feelings and thermal preferences inside buildings, offices, places of study and work places. The interval between air speed and preferences are specified in the international standards. Air comfort varies according to occupants of the environment.

For temperatures varying from 22 °C to 26 °C, air velocity adapted from comfortable after several standards is less than 0.25 m/s ($V_a < 0.25$ m/s). In areas with a warm climate, research on thermal comfort indicates that air velocity should vary from 0.2 m/s to 1.5 m/s. Air comfort is obtained from air velocities below 0.2 m/s in the standard ASHRAE 55 [5].

Work of Dear [8], Dear *et al.*, and Fountain [9], Kwok [10], Meyer [11], Wong *et al.*, [12], Nicol *et al.*, and Humphreys [13], Yamtraipat *et al.* [14], Hwang *et al.*, [15], Ogbonna *et al.* [16], specifies that air movement is one of the important elements that influence thermal comfort.

Qi Jie Kwong *et al.* [17] show that when air velocity varies from 0.1 m/s to 0.2 m/s, thermal sensation of occupants is significantly affected. Chow *et al.*, [18] found after study that inhabitants of Hong Kong city are largely sensitive to temperature and air movement.

Joseph *et al.*, [19], after a study in Thailand, assisted by 288 voters including 183 men and 105 women, showed the importance of the temperature (26 °C to 36 °C) and air speed (0.2 m/s to 3 m/s).

Surapong *et al.*, [20] advocated the importance of passive cooling for indoor temperatures between 30.9 °C to 38.2 °C, air velocity of 0.2 m/s to 1.42 m/s.

Sub Saharan Africa is dominated by dense forest which influences the climate. One of the elements which affect the quality of indoor air is the wind speed. It directly acts on human health and productivity of occupants. During the design of buildings, architects do not always take into account the seasonal wind direction such as Harmattan *et al.*

However, these elements affect the comfort. Air preference varies from one individual to another and depends on the micro climate of the place. This research aims at studying the existing relationship between thermal comfort and preference of air movement inside naturally ventilated buildings in Sub Saharan areas. In this vein, a questionnaire and physical measurements were used.

2. METHODOLOGY

2.1 Cities analyzed

Cameroon is divided into three climatic zones: the Sudanese region, the sudano–Sahelian region and the equatorial region. Cameroon is characterized by an equatorial climate with two main seasons of equal amplitudes. The study was conducted in the equatorial city of Yaounde.

Yaounde is the Cameroon political capital and is located approximately 300 km from the Atlantic coast and enjoys a sub-equatorial climate with four seasons; a large dry season from mid November to late March, a short rainy season from April to mid June, a short dry season from mid June to mid August and a long rainy season from mid August to mid November. Its altitude is between 600 - 800 m.

Yaounde city has relatively fresh climate. The maximum temperature is ranged between 30 °C and 35 °C and the minimum is 15 °C. Geographically, it is between 3°52' N latitude and 11°32' E longitude.

Its population was about 2.5 million of inhabitants in 2011 due to the early 90s rural exodus which increased its population with a growth rate estimated at 7 % per year. As a consequence of this fast exodus, several suburbs were created at the western and the north parts of the Yaounde city.

2.2 Measurement rooms

The experimental study was carried out in six schools in Yaounde, during two seasons. These schools are located in five districts of the political capital of Cameroon. Classrooms are chosen according to the number of person, the area and the volume. The type of ventilation imposed is natural. The main characteristics of the six classrooms selected in these schools are given in **Table 1**.

Table 1: Main characteristics of the analyzed of 6 room selected in 6 schools

Room	Coating	Lat.	Long.	Alt.	Area	Vol.	Height	Win. Expo.	Natural Ventil.
1	Stone	3.38-45N	11.48-44E	766±3	408	1632	4.2	NS-SE	yes
2	Plaster	3.81.11N	11.37-20E	765±8	96	393	4.1	SW-SE	yes
3	Paint	3.84-16N	11.18-45E	745±7	164	632	3.8	E-ES	yes
4	Paint	3.35-29N	11.24-17E	730±7	132	462	3.5	S-SW	yes
5	Earth	3.51-20N	11.50-13E	717±3	125	499	4.0	E-ES	yes
6	Wood	3.75-43N	11.34-32E	715±5	196	827	4.2	E-ES	yes

The choice of clothing is according to the schools; their average resistance was 0.9 clo during the rainy season against 0.5clo in dry season which is in accordance with the recommendations in thermal insulation ASHRAE 55 [5]. Sedentary activity varied (1met to 1.4et) .10 of 30 classrooms studied had a white ceiling. Windows, doors and curtains were half opened. Clothes and a model Room studied are shown in Figure 1.

2.3 Occupants

More than 800 people participated in this study during the two seasons. The experimental approach was used to make occupants massively participate in this study. He has been advised to persons to give anonymous responses, but elements concerning their sex, age, weight and size could be known.

It has been noticed that ages of occupants varied from 15 to 29 years. It was also possible to notice a large number of women among voters (63 %).

Fig. 1: Classroom and clothes

2.4 Measurement equipment

In this study, the indoor wind speed, indoor relative humidity and air temperature were measured respectively by a Thermo-anemometer (model C.A1226), $C0_2$ Monitor (model CO200) and probe thermometer. Some materials are shown in figure 2. The various values of outdoor temperatures were collected from the national weather station in Douala.

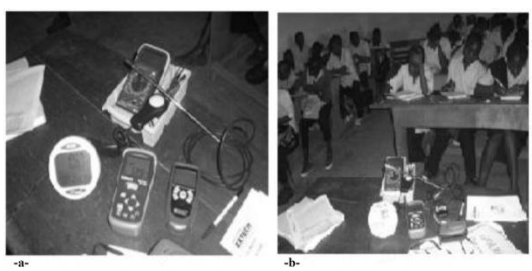

Fig. 2: a- Some physical materials b- Occupants and physical measure

The characteristics of the used measurements system are reported in **Table 2**. All these equipments were calibrated before used to ensure reliability and accuracy in readings during the field studies.

Table 2: haracteristics of the measurement system

	Function	Range	Resolution	Accuracy
CO2 Monitor (mod. CO200)	CO_2	0 to 9999ppm	1ppm	±(5%rdg+50ppm)
	Temperature	-10 to 60°C	0.1°C	±0.6°C
		14 to 140°F	0.1°	±0.9°F
	Humidity	0.1 to 99,9%	0.1%	±3%(10 – 90%) ±5%'<10% or >90%'
Digital thermometer	Temperature	-20°C to 0°C	1°C	±5% of rdg ± 4 digits
		0°C to 400°C	1°C	±1% of rdg ± 3 digits
		400to1000°C	1°C	±2% of rdg

C.A 1226 Thermo-anemometer	Air velocity	0.15 to 3 m/s 3.1 to 30 m/s	0.01 m/s 0.1 m/s	±3% R + 0.1 m/s ±1% R + 0.2 m/s
	Temperature	-20 to +80°C	0.1°C	±0.3% R + 0.25°C
	Air flow	0 to 9999m^3/h	1 m^3/h	±3% R +0.03*surf.
Light meter IM-1308	Light meter	40.0lux to300 kLux	± 3%	±5% Reading ± 0.5% scale

2.5 Measurement process

Measurements were carried out every 15 minutes, probes were positioned at 1.1 meters height from the ground level, in strict accordance with the prescriptions ASHRAE Standard 55 [5], and ISO 7730 [4]. The devices were installed at 7:30 am so as to enable each probe to adapt to the environment and the data collection started at 8:00 am. All the data were collected regularly until 4:30 pm. These measurements provided four of the six parameters established by ISO 7730 [4] such as air velocity, relative humidity, ambient temperature and mean radiant temperature. These parameters were then used to calculate the PMV and PPD according to Fanger's model and ISO 7730 [4].

The mean radiant temperature (T_r) was estimated using the following regression model as function of the measured air temperature (T_a) proposed by Nagano [25]:

$$T_r = 0.99 \times T_a - 0.01, \quad R^2 = 0.99 \tag{1}$$

The operative temperature T_o, was determined from the measured air temperature T_a and the mean radiant temperature T_r by the following relationship [5]:

$$T_o = A \times T_a + (1 - A) \times T_r \tag{2}$$

Where the weighting factor (A) depends on air velocity (w).

A =0.5 for w <0.2 m/s; A =0.6 for 0.2< w <0.6 m/s; A =0.7 for 0.6< w < 1 m/s.

2.6 Subjective analysis through questionnaires

Perceptions and air movement preference of individuals were obtained by a careful analysis of the questionnaires. A specific questionnaire was developed according to UNI EN ISO 7730 [4] and UNI EN ISO 10551 [21]. Questionnaires were distributed twice a day including in the morning (from 8 to 12 AM) and in the afternoon (from 2 to 4:30 PM).

On Wednesday particularly, the questionnaires were distributed from 8 to 12 am. During the two seasons, a total of 1545 questionnaires were collected. The number of questionnaires filled depended on the number of occupants of the room. Figure3 shows some occupants of rooms and questionnaires.

Fig. 3: Occupants and questionnaires

As in other previous works, the questionnaire was developed by the authors [22-24]. It has been subdivided into three main parts:

• Part 1: Personal data (age, sex, height, weight, type of residence and construction age of the building).

• Part 2: Thermal Aspects (ruling on the thermal environment).

• Part 3: Personal micro climate control.

3. RESULTS AND DISCUSSIONS

3.1 Thermal sensation and thermal preference

For a relative humidity from 49 to 75 %, with an average value of 63.5 % and a standard deviation of 1.83, the operative temperature obtained in the different classes during the two seasons varied from 20.1°C to 30.0°C, with an average value of 25.4°C and a standard deviation of 0.95. According to Figure 4, thermal sensation is concentrated around 'Slightly warm'; 'Neutral' and 'warm', during the dry season (51.9%, 23.7 % and 21.2 %, respectively).

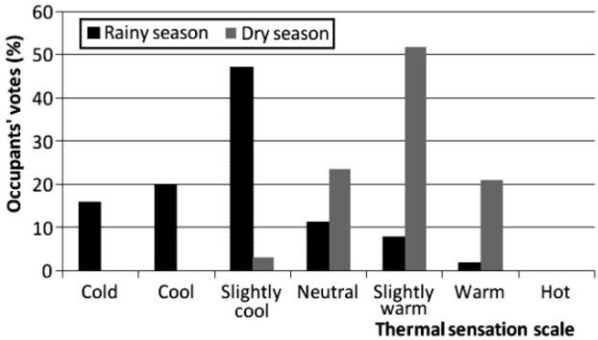

Fig. 4: Occupants' thermal sensation during two seasons

In the rainy season, thermal sensation is concentrated around 'Slightly cool', 'cool' and 'cold' (47.2 %, 19.9 % and 15.9 %, respectively). Only 11.3 % occupants indicated a 'neutral environment' during the rainy season, as the thermal sensation. During two seasons, no occupant found the environment 'hot'.

Figure 5 shows that 58 % of occupants found their place 'tolerable' and 42 % of voters found it 'intolerable' during the two seasons of study.

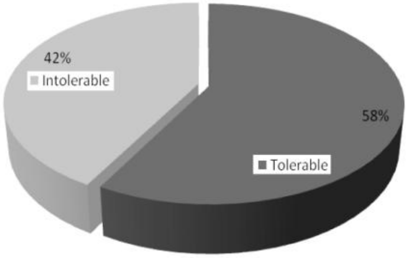

Fig. 5: Occupants' thermal consideration during two seasons

It was also possible to note that more voters found their environment 'comfortable' in the rainy season than in the dry season (69 % and 47 %, respectively). Freely, 54 %

of occupants prefer a medium, 'no change' and 27 % middle 'cooler'. These different values of thermal preferences obtained are consistent with the thermal sensation votes, when many occupants choose 'slightly warm' and 'warm' during dry season, (Fig. 6).

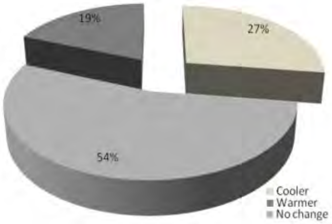

Fig. 6: Occupants' thermal preference during two seasons

Thermal preferences of the occupants in rooms highly depend on the air temperature. Figure 7 shows that from 18.0 °C to 24.0 °C, occupants wanted 'more heat' for their room. But beyond 24.0 °C, an average of 65.8 % occupants preferred a middle 'cooler'. At 30 °C, occupants felt more heat that is why 100 % of voters chose 'cooler' as thermal preference.

We also noticed that when the temperature varied from 24.0 °C to 26.0 °C, 54.8 % of voters wanted the medium unchanged. Generally, the results varied depending on the season. Thermal preference results indicate a strong relationship between occupants preference for 'No change' and also 'No change air velocity' (**Table 3**) during rainy season, whereas, in the dry season, a strong preference trend is observed for 'cooler' which corresponds to 'No change in air velocity'.

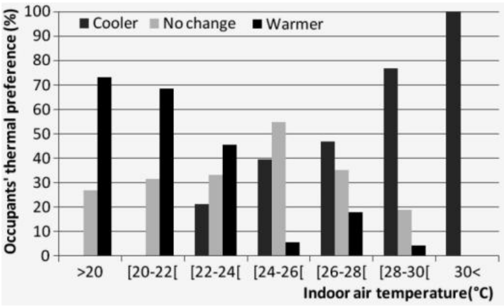

Fig. 7: Occupants' thermal preference binned for air temperature values

Table 3: Overall thermal and air velocity preferences

Season	Thermal Preference	Air velocity preference		
		more	No change	Less
Rainy season	Cooler	42.8%	32.2%	25.0%
	No change	25.3%	53.2%	21.5%
	warmer	17.1%	48.8%	34.1%
Dry season	Cooler	19.9%	60.4%	19.7%
	No change	10.4%	58.9%	30.7%
	warmer	42.8%	39.5%	17.7%

Among occupants who voted for 'cooler' as thermal preference in rainy season, 42.8% also reported 'more' as their air velocity preference. Among occupants who voted for 'warmer' as preference thermal in dry season, 42.8% also indicated 'more' as their air velocity preference.

Among occupants who voted for 'cooler', 'No change' and 'warmer' thermal preferences respectively, 25.0 %, 21.5 % and 34.1 % indicated as preference 'Less air velocity' in the rainy season, whereas for the same thermal preferences in dry season (19.9 %, 10.4 % and 42.8 %, respectively) indicated as preference 'more air velocity'. These results show that the climate of a place affects the quality of the indoor air.

3.2 Thermal sensation vs air velocity preference

Thermal sensation indices: -3 (cold), -2 (cool), -1 (slightly cool), 0 (neutral), +1 (slightly warm), +2 (warm), +3 (hot) are grouped by interval in the following figure 8 and 9. We noticed that in the dry and rainy seasons, the occupants in most cases indicated as preference 'no change air velocity'.

In figure 8, for occupants who voted indices (-3, -2), only 9.6 % of them mentioned 'Less air velocity'. In figure 9, all voters who mentioned (+2, +3), indicated 'more air velocity', as preference.

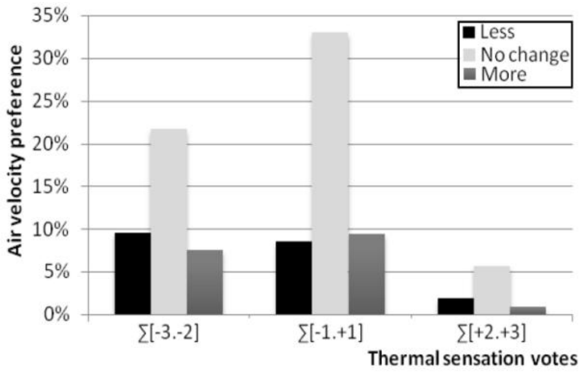

Fig. 8: Votes of thermal sensation vs air velocity preferency during dry season

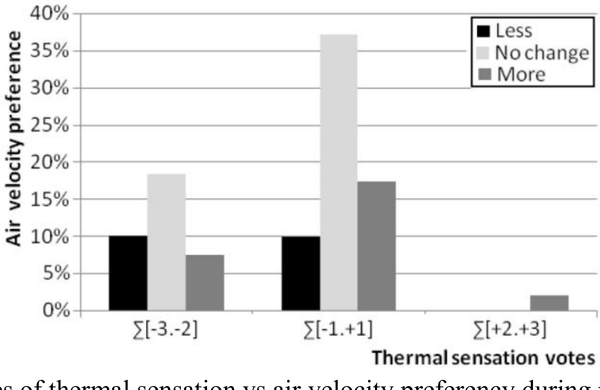

Fig. 9: Votes of thermal sensation vs air velocity preferency during rainy season

Table 4 shows air velocity preference according to operative temperature and main air velocity.

Table 4: Air velocity preference binned for operative temperatures and air velocity values

Operative temperature (°C)	Air velocity (m/s)	Air velocity preference More	No change	Less
20.0—22.5	0≤V<0.2	61.3%	38.7%	0.0%
	0.2≤V<0.6	3.4%	72.5%	24.1%
22.5—24.5	0≤V<0.2	83.2%	16.8%	0.0%
	0.2≤V<0.6	30.9%	58.7%	10.4%
24.5—26.5	0≤V<0.2	76.7%	23.1%	0.2
	0.2≤V<0.6	21.9%	34.5%	43.6%
26.5—28.5	0≤V<0.2	80.9%	19.1%	0.0%
	0.2≤V<0.6	31.3%	63.4%	5.3%
28.5—30.0	0≤V<0.2	100.0%	0.0%	0.0%
	0.2≤V<0.6	49.8%	47.1%	3.1%

We can observe from this table that the preference, 'more air velocity' decreases when the average air speed increases. When the operative temperature ranges from 22.5 °C to 24.5 ° C and the air speed from 0 to 0.2 m/s, 83.2% of occupants indicate as preference 'more air velocity'. Above 0.2 m/s, more voters indicate as preference 'No change air velocity' (58.7 %). The more the operative temperature increases, the more occupants indicated as preference 'more air velocity' in different rooms.

It is also important to note that hardly more than 40 % of voters indicated as preference 'Less air velocity', except when the operative temperature was ranged from 24.5 °C to 26.5 °C which corresponded to air speeds from 0.2 m/s to 0.6 m/s. In **Table 5**, we noticed that the more the medium was acceptable, the more occupants indicated as preference 'No change in air velocity'. During the rainy season, among voters who indicated that classrooms were 'unacceptable, 51.7 % of them preferred 'Less air velocity' and 48.3 % preferred 'more air velocity'. During dry season, as preference, 80.8 % of voters wanted 'more air velocity', when they found their environment 'Not acceptable'.

Table 5: Thermal acceptability and air velocity preferences

Season	Thermal Preference	Air velocity preference More	No change	Less
Rainy season	Acceptable	24.1%	60.2%	15.7%
	No acceptable	48.3%	0.0%	51.7%
Dry season	Acceptable	19.5%	65.2%	15.3%
	No acceptable	80.8%	1.8%	17.4%

The preferences of air speed can also vary according to the indoor air relative humidity.

In **Table 6**, we deduced that when the humidity varied from 45 % to 55 %, at 20.83 °C as neutral temperature, 43.7 % occupants voted 'No change' as air velocity preference. At the same temperature, 31.5 % occupants voted for 'more air velocity'.

During this, whereas the humidity varied from 65 % to 75 %, and the air speed from 0.2 m/s to 0.4 m/s, all voters voted for 'more air velocity' as preference. The preference 'less air velocity' was the less desired by voters, despite the instability of the humidity and neutral temperature.

Table 6: Relations between PMV and indoor temperature, Air velocity preference according to neutral temperature for values of clothing thermal insulation of 0.3 clo to 1.3 clo and metabolism of 1 to 1.4 met

Relative Humidity (%)	Air velocity (m/s)	Air Temperature (°C)	PV equation	R^2	Neutral Temperature (°C)	Air more	Velocity No change	Preference Less
45%≤RH≤ 55%								
	0.0—0.2	18—22	$PMV = 0.195T_a - 4.061$	0.973	20.83	31.5%	43.7%	24.8%
	0.2—0.4	22—26	$PMV = 0.240T_a - 5.725$	0.935	23.85	52.7%	43.4%	3.9%
	0.4—0.6	26--30	$PMV = 0.211T_a - 5.618$	0.866	26.75	65.1%	34.9%	0.0%
55%≤RH≤ 65%								
	0.0—0.2	18—22	$PMV = 0.232T_a - 4.870$	0.985	20.99	17.6%	52.8%	29.6%
	0.2—0.4	22—26	$PMV = 0.170T_a - 4.120$	0.991	24.35	68.8%	21.2%	0.0%
	0.4—0.6	26--30	$PMV = 0.184T_a - 4.871$	0.994	26.47	89.7%	10.3%	0.0%
65%≤RH≤ 75%								
	0.0—0.2	18—22	$PMV = 0.245T_a - 5.220$	0.995	21.31	78.0%	14.6%	7.4%
	0.2—0.4	22—26	$PMV = 0.230T_a - 5.723$	0.981	24.88	100.0%	0.0%	0.0%
	0.4—0.6	26--30	$PMV = 0.179T_a - 4.817$	0.928	26.91	52.3%	21.4%	26.3%

These results are not surprising given the geographical position of Yaounde city for it is located on seven hills. Its climate is similar to that of several Sub-Saharan towns which change instantaneously. Yaounde is also located in dense forest and is regularly affected by humid and cold wind.

3.3 Study of climate micro

Figures 10 and 11 give the respective differences of temperatures and relative humidity between the internal and external medium.

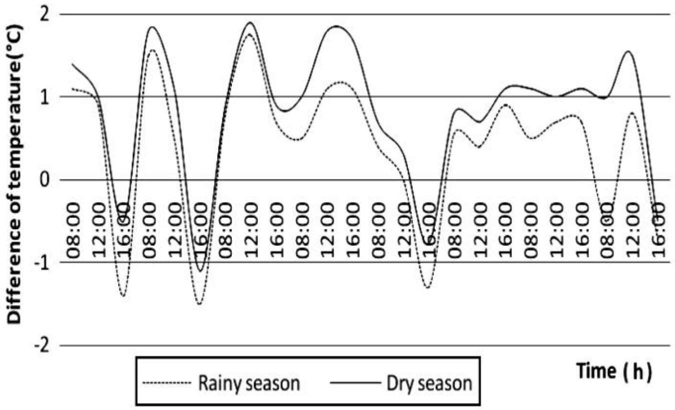

Fig. 10: Difference of temperature between outdoor and indoor in classrooms

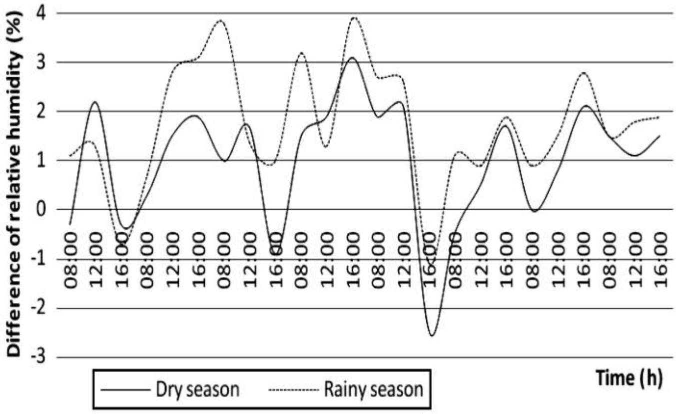

Fig. 11: Difference of relative humidity between outdoor and indoor

For internal temperatures from 18 °C to 31 °C and external from 21.5 to 32.5 °C, the differences varied from -1.5 to 1.9 °C, according to type of materials used for building. With values of moisture from 48.5 % to 75.2 %, the difference obtained varied from -2.5 % to 3.9 %.

These results show that the microclimate of the medium has a great influence on the preferences of the occupants in their habitat. Indoor climate varied according to the activity of students. With an activity below 81.2 W/m^2, the internal climate was no longer favorable for the study. From the relationship established by Persily [26], it was possible to calculate the carbon dioxide rate consumed by each student. This very low rate varied from de 0.0098 cfm to 0.0169 cfm inside rooms.

Air consumed by each students depended not only on the activity, size and weight as mentioned in [26], but also on age and the health state occupants. During the two seasons, the average density of air speed was ranged between 297 m^3/h and 780 m^3/h. At the same time, an exegetic analysis was realized in the different study sites.

In fact, the exergetic analysis has been used for the first time in the optimization of thermal process in hydroelectric power and industrial plans. Meanwhile, energetic systems in building are designed only from the principle of exergy conservation. This principle alone cannot provide a full understanding of important aspects of energy consumption in buildings [26]. Formerly, the term exergy was used by some scientists within the context of sustainable development [27, 28].

Existing statistics of the building sector just show how energy is provided but it do not show where energy is consumed and with what rhythm. Consequently, it is important to know the energy rate consumed by parties of a system. Exergetic analysis allows us to design ventilation systems which provide internal thermal comfort and the rational use of the energy of the building [30, 31].

Dovjak *et al.* [32] compared results of exergetic and energetic analysis of the whole heating system in Slovenian building and defined the best solutions for the use of building with less energy. The general form of the exergetic balance equation for human body is expressed according to the expression given in [33]:

$$[\text{Exergy stored}] + [\text{Exergy output}] + [\text{Exergy consumption}] = [\text{Exergy input}]$$

The exergy input consists of five components: 1- Warm exergy generated by metabolism; 2- Warm/cool and wet/dry exergies of the inhaled humid air; 3- Warm and wet exergies of the liquid water generated in the core by metabolism; 4- Warm/cool and wet/dry exergies of the sum of liquid water generated in the shell by metabolism and dry air to let the liquid water disperse; 5- Warm/cool radiant exergy absorbed by the whole skin and clothing surfaces[34].

The exergy output consists of four components: 1- Warm and wet exergy contained in the exhaled humid air; 2- Warm/cool and wet/dry exergy contained in resultant humid air containing the evaporated sweat; 3- Warm/cool radiant exergy discharged from the whole skin and clothing surfaces; and 4- Warm/cool exergy transferred by convection from the whole skin and clothing surfaces into the surrounding air [33].

When exploiting the different tables, equations and figures in [31-34], we obtained the exergy consumed by occupants in the different areas of (2.55 ± 25 %) W/m^2. it varies according to the micro climate of the area, the activity and thermal isolation.

From these results, we show that in Sub-Saharan area, particularly in Cameroon classrooms, occupants required highly ‘more air velocity’, in both seasons. It is therefore suggested that the increase in air velocity in buildings is an essential phenomenon in obtaining thermal comfort environment.

The Yaounde climate nowadays has considerably changed. Some time, indoor temperature reached 32.5 °C. It is difficult now to distinguish the beginning and the end of a season. Floods and disasters are increasing.

4. CONCLUSION

This paper presents the results of a study related to air movement preferences and thermal comfort in 30 rooms, naturally ventilated and located in six schools of Cameroun. This study was conducted in two seasons (dry season and rainy season), and the results show that 54 % of occupants preferred an environment ‘without change’ against 58 % of voters who found the environment ‘tolerable’.

In the dry season, 51.9 % of voters found their milieu ‘slightly warm’, while in the rainy season, the occupants in the majority preferred ‘more air velocity’, even sometimes when the operative temperature is below 20 °C. The different air velocities largely depended on the type of season, of the habitat structure, etc..., that is why these air preferences largely varied according to rooms.

In classes without ceiling and especially with local materials, most occupants preferred ‘less air velocity’. In these buildings, The CO_2 particles are less than 1000 ppm. This shows that areas of study were not pollutant enough because the ventilation was natural.

These different results must be taken into account in the future by Architects in designing buildings in Cameroon in particular and also in all countries of the Central Africa and other Africa countries with the same type of climate.

A study of the environment and the choice of building materials represent a huge progress in the fight against the discomfort in Sub-Saharan area. Local materials (Wood, Soil, Stone) adapted to the climate should be privileged during construction. Walls with double layers are also recommended (outdoor with soil, and indoor with plaster, or outdoor with wood and indoor with glass).

APPENDIX

- Synthesis of the questionnaire -

Note: This questionnaire is anonymous; the results of the statistical evaluation, the analysis and conclusions will be published. Please carefully read each question before answering and don't discuss with your friend who also filled this questionnaire.

* Thanks you for your co-operation and the time you will have to devote to this questionnaire *

PART 1: PERSONAL DATA

(Please tick off the appropriate box)

Age-........... Sex- M ☐ F ☐ height-...........weight...........

What is the type of house you live in? – Modern ☐ Traditional ☐

Is it with- mud ☐ wood ☐ stone ☐ glass ☐

Is it plastered ☐ Paint ☐

How long did you live in the town?..

How long you live in your present house?...

How old is your house?...

What is the color of your house?...

How many rooms does it have?...

PART 2: THERMAL QUESTIONNAIRES (Please tick off the appropriate box)

1- How do you feel about the temperature in this moment?
Cold ☐ Cool ☐ Slightly cool ☐ Neutral ☐ Slightly warm ☐ Warm ☐ Hot ☐

2- How do you find it?
Acceptable ☐ Slightly acceptable ☐ Not acceptable ☐ Slightly not acceptable ☐

3- What is your thermal sensation?
Comfort ☐ Light annoyance ☐ Annoyance ☐ Heavy annoyance ☐

4- How would you like to feel?
Much too cool ☐ Too cool ☐ A little bit cool ☐ No change ☐
A little bit warm ☐ Too warm ☐ Much too warm ☐

5- On the basis of your personal preferences, how would you consider the room temperature?
Acceptable ☐ Not acceptable ☐

6- How do you consider this room?
Perfectly tolerable ☐ Slightly hard to tolerate ☐ Hard to tolerate ☐
Very hard to tolerate ☐ Intolerable ☐

7- How do you feel about the air flow in this moment?
Completely not acceptable ☐ Not acceptable ☐ Slightly not acceptable ☐
Slightly acceptable ☐ Acceptable ☐ Perfectly acceptable ☐

8- Would you like to have an air?
Smaller than now ☐ Exactly how it's now ☐ Greater than now ☐

9- How do you consider the temperature difference between head and ankle?
Completely not acceptable ☐ Not acceptable ☐ Slightly not acceptable ☐
Slightly acceptable ☐ Acceptable ☐ Perfectly acceptable ☐

Provide us indication regarding your clothing (e.g. Underwear, woman clothes, trousers, accessories, shirt, pullover etc.) **(Appendix)**

10- What was your occupation during last hour?

Occupation	Last 10 min	minutes ago	minutes ago	minutes ago
Doing office job	☐	☐	☐	☐
Walking in slope	☐	☐	☐	☐
Walking in flat land	☐	☐	☐	☐
Walking in ascent	☐	☐	☐	☐
Resting	☐	☐	☐	☐
Running	☐	☐	☐	☐
Seating	☐	☐	☐	☐
Taking a bath	☐	☐	☐	☐
Driving	☐	☐	☐	☐
Reading	☐	☐	☐	☐
Doing something else	☐	☐	☐	☐
eating	☐	☐	☐	☐
Washing dishes	☐	☐	☐	☐
Cooking	☐	☐	☐	☐

PART 3: PERSONAL MICROCLIMATIC CONTROL

(Please tick off the appropriate box)

1- How can you define the level of control of microclimatic conditions?

No control ☐ Light control ☐ Medium control ☐ High control ☐ Total control ☐

2- How do you feel about the possibility of controlling thermal comfort?

Satisfied ☐ Not satisfied ☐

3- Can you open/close the windows?

No ☐ Yes ☐

4- How often do you do this?

Never ☐ Rarely ☐ Sometimes ☐ Frequently ☐ Always ☐

5- Can you open/close the external doors?

No ☐ Yes ☐ There is no door ☐

6- Can you open/close the inner doors?

No ☐ Yes ☐ There is no door ☐

7- Can you regulate the thermostat?

No ☐ Yes ☐ There is no thermostat ☐

8- Can you regulate curtains / rolling shutters?

No ☐ Yes ☐ There is no thermostat ☐

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