LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
2017, VOL. 12, NO. 5, 1233 - 1247

Post-occupancy assessment of thermal environment in classrooms

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ABSTRACT

In this paper, we present our main results of the post occupancy evaluation of thermal comfort of two primary schools constructed following the same plane, situated in two different climate zones. The first stage of the work consisted on measurements using meteorological equipments. These measurements are used to quantify the physical parameters of the thermal atmosphere, such as temperature, rate of relative humidity and wind speed prevailing inside classrooms. The second step aims to support the results of the first stage; and it is a psychological investigation using inquiry with users.

KEYWORDS

evaluation, thermal comfort, psychological factors

ARTICLE HISTORY

Received 20 January 2017
Revised 28 March 2017
Accepted 9 April 2017

Introduction

The architecture of school building has the duty to facilitate the learning of all the pupils, besides the comfort which it has to get them, it must be flexible and it doesn't oppose the evolution of the pedagogies. The reflection on the school conception has to arouse the architects and the decision-makers, on the pupil as the user of a space of learning on one hand. On other hand, the possibility of offering to the teachers a favorable work environment. However, they are forced to answer one of the major questionings of the domain which is: «*how can the school architecture contribute to the success of the pupils?* » (MAZALTO M. 2005). The current tendency of the school construction favors the multidisciplinarity, judging that the only architects are incapable to answer this question without collaboration with the teachers, the doctors, the psychologists etc.

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Recently we attended the appearance of several works and researches which aim to estimate the school climate in its various aspects, which are psychological; social either physics (fig.1). This last aspect is considered as prevailing and the architect is the first responsible for the physical comfort level (thermal, lightning, sound) offer by the school building.

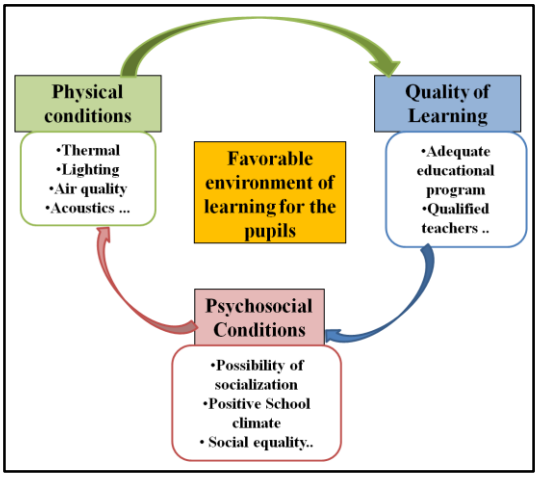

Figure 1: Conditions required for a favorable school environment.

In this work we shall be interested in one of the parameters of the physical conditions, namely the «thermal parameter ".

Objectives of the Research

The major objective of this research consists on an evaluation of the thermal comfort offered by a typical plan implanted in different climatic zones, and it also aims to:

- List the impacts of the internal thermal atmospheres on the health and the behavior of the pupils.

- List the parameters influencing the thermal comfort in a typical plan in two zones and for two seasons.

The Typical Plan of Primary Schools in Algeria

After the independence, Algeria knew a big mass construction of schools. As a matter of fact, the majority of the constructed primary schools since, obey to typical plan proposed by the Ministry of Education.

This typology is characterized by a simple architecture, ystem in portico, and classic and conventional building materials (concrete, brick). The building is conceived in the form of mono-orderly block, with a stairwell assuring the vertical circulation, and passageway serving as horizontal circulation.

Figure 2a: Example of school built according to the typical plan.

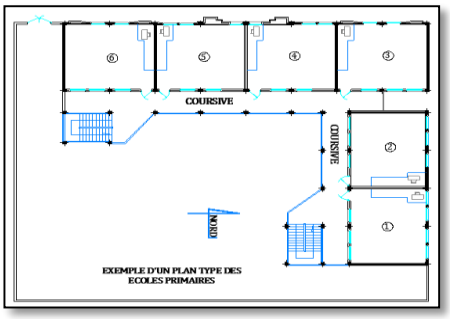

Figure 1b: Example of school built according to the typical plan.

This plan is reproduced since the seventies on the whole national territory, without considering weather conditions specific to every zone. This plan has not only neglected the climate but also the psychological needs of the children.

Table 1 : number of school built according to the plan [2].

Type	Characteristic	Number
Type A	3 classrooms	2 225
Type B	6 classrooms	4 460
Type C	9 classrooms	1 661
Type D	12 classrooms	2 953
Rate	64%	
Except type	/	6 554
Total	/	17 853

Weather Conditions of the Zones of Study

Weather conditions of Algiers

Algiers is characterized by Mediterranean climate (zone H1a - wintry classification, E1–summer classification, according to the classification of climatic zones in Algeria), cold and rainy in winter and hot and wet in summer.

Weather conditions of Biskra

According to the same classification, Biskra is situated in the zone H3a characterized by very cold winters with a very important gaps daily of temperature. The zone E3 is very hot and dry summers. (OULD-HENIA A. 2003)

Methodology of Research

The in situ measures

The in situ measures aimed to quantify the physical parameters of the thermal conditions in classrooms during the occupation over two periods of the year and in two different climatic zones. During the campaigns of measures, we used three meteorological mini stations, type HOBO 512K. Every mini station contains a data logger, who receives information collected by four different probes (fig.3). This instrument can be installed in outdoors as in closed spaces.

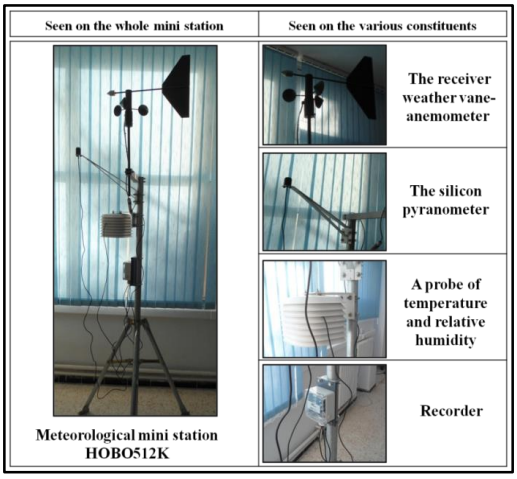

Figure 3 : The various probes of the mini station HOBO 512K.

The campaigns of measures took place in classrooms, as well as in outside space. The instrument is placed in the middle of classrooms at a height of 1.20 of the ground. (Fig.4)

Figure 4 : Location of the mini station in classrooms.

Winter campaign

In the presence of heating

This campaign allowed us to know the usual working conditions of the users, namely the air temperature, the rate of relative humidity, and the air speed inside classrooms. (The period of taking of measures is in February, March 2013)

In absence of heating

We measured the same parameters, in presence of only calorie intakes of the users. This work is made in order to know the comfort level that this typical building can offers without the contribution of heating. (The period of taking of measures is in February, March 2013)

Campaign of spring

This campaign had for objective to quantify the parameters of the thermal atmosphere in these schools during the hot period. (The period of taking of measures is in May, June, 2013)

Investigation by inquiry

We proceeded to an inquiry by questionnaire beside the teachers, which took place simultaneously with the campaigns of measures. Our sample of inquiry touched several primary schools having the same plan in the same region.

Treatment and analysis of data

To process the data collected during the experimental work we had turned to two software; the first one is Microsoft Office Excel, which we used to convert the registered values of mini stations of measure in graph. As for the results of inquiries was transformed into graph by means of a software of statistics even STATISTICA.

Discussion of campaign and inquiry results

Our results were obtained by the superimposing of the data of in situ measures on the data of inquiries.

Parameters of the thermal comfort on ALGIERS

During winter

- **Temperatures**

The registered values of temperature during the heated days in the presence of the pupils vary between 15°C and 22°C (fig.5).

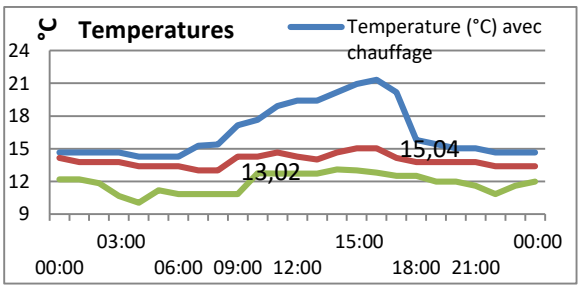

Figure 5: Fluctuation of the internal / outside temperature.

The values between 18°C and 22°C are considered as comfortable, knowing that the first hour of occupation where the temperatures were between 15°C and 18°C was considered as uncomfortable (fig.6). The situation of comfort is exclusively gotten by the contributions of the heating (fig.7).

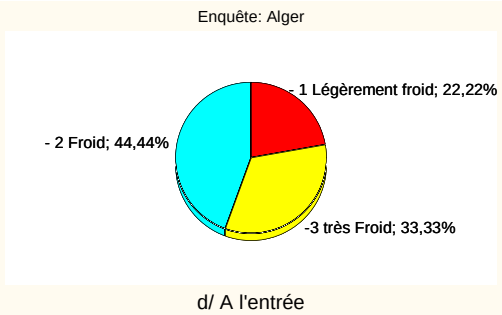

Figure 6: Evaluation of the thermal atmosphere in the entrance of classrooms.

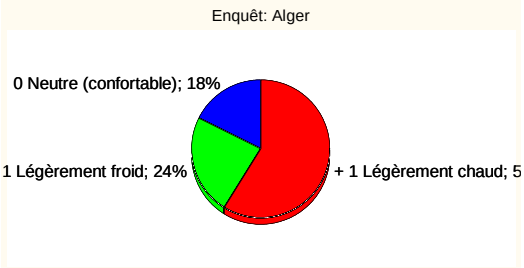

Figure 7: Evaluation of the thermal comfort during winter.

The not heated day testified of the incapacity of this type of building to insure a minimum comfort without the presence of the heating. The internal temperatures did not exceed 15.04°C during the occupation (fig.5). The registered thermal conditions show the bad thermal performance of classrooms thing owed on one hand, in building materials used even materials conventional (brick in double partition for walls, wood and simple glass 3mm for openings). Of other hand by, the important number of facades exposed to the outside climate (3 façades in the majority of classrooms).

In the face of these conditions, the North / South orientation of classrooms presented an atmosphere better than classrooms oriented East/West, but who remains all the same uncomfortable. (In absence of heating)

- **The rate of relative humidity**

The relative humidity is considered as an important element of the thermal comfort, its fluctuation influences the sensation of the comfort.

The values of the rate of humidity registered inside classrooms that turn the North / South either East/West varies between 68 % and 80 % (fig.8). This rate is considered by investigated raised and harms in the health of the pupils (fig.9). We dismiss these important rates of humidity to the shape of the building.

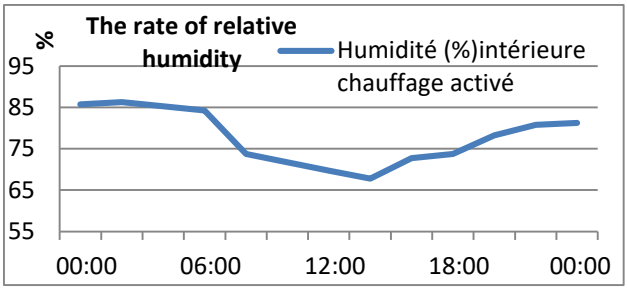

Figure 8: Fluctuation of the rate of relative humidity.

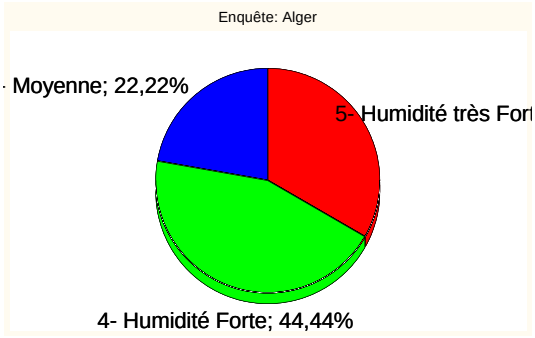

Figure 9: Evaluation of the rate of relative humidity.

➢ **The draft**

During winter, the presence of the draft is judged as useless even unwanted; set apart some investigated which require its presence to evacuate the burned gas (produced by gas heating). The values registered (the air speed was 0 m/s), shows this report.

These conditions make that the teachers of the investigated primary schools are satisfied by the thermal atmosphere of classrooms (in the presence of the elements of heating, thus important energy consumption). In spite of this satisfaction they give evidence all the same that these conditions have an incidence on the health of the pupils as well as their behavior.

Impact of the internal thermal winter atmospheres on the pupils

During spring

Table 2: Behavior of the pupils according to their teachers.

Behavior	Rate	Causes
Absence	80%	The frequency of the diseases during the period wintry (see board 3).
Laziness	56%	The used heaters (gas heating) reject (CO) which concentrates inside classrooms as well as rate of relative humidity raised cause the laziness of the pupils.

Table 3: The frequent diseases according to their teachers

Diseases	Rate	Causes
Grippe/ Rheum	82%	Every year the schools of the North record during winter significant number of pupils affected by the rheum. This situation is due to the thermal shocks (absence of intermediate spaces between the inside and the outside).
Allergy	65%	It is caused by molds which appear on the walls of classrooms; which are caused in their turn by the high rate of humidity.

➢ **Temperatures**

The day of the investigation was considered as comfortable by approximately 70 % of the investigated. The temperatures of this day were between 24°C and 27°C in the presence of the pupils (fig.10), these temperatures are not constant during the season.

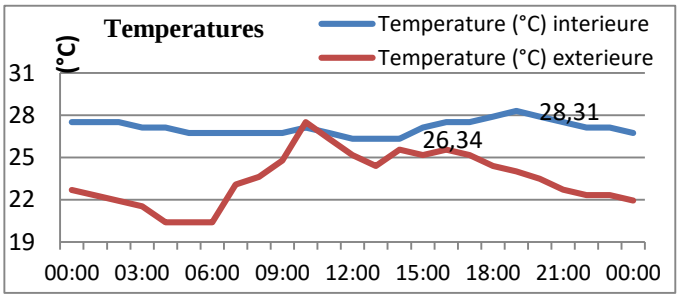

Figure 10: Fluctuation of the internal and outside temperatures.

The dominant thermal atmosphere on the whole season is considered as uncomfortable, thus hot, for approximately 60 % of the respondents of our investigation (fig11), with the presence of a nuance between the orientations in favor of the North / South orientation.

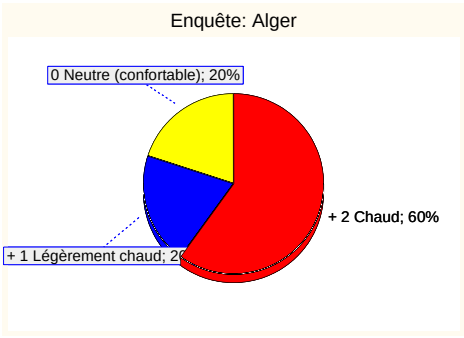

Figure 11: Evaluation of the thermal comfort during spring.

We note here, the absence of means of cooling except for the exercised control over the openings which serves sometime to create a comfortable climate inside classrooms.

➢ **The rate of relative humidity**

During spring the rate of humidity is considered, by the investigated, average, and the registered values confirm this appreciation, these values do not exceed the 60 % during the occupation of the classroom (fig.12-13). This why we judge that the humidity does not cause nuisance as in winter.

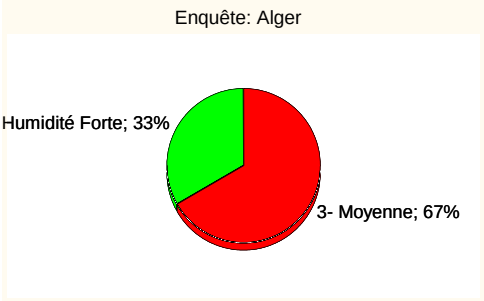

Figure 13: Evaluation of the rate of humidity.

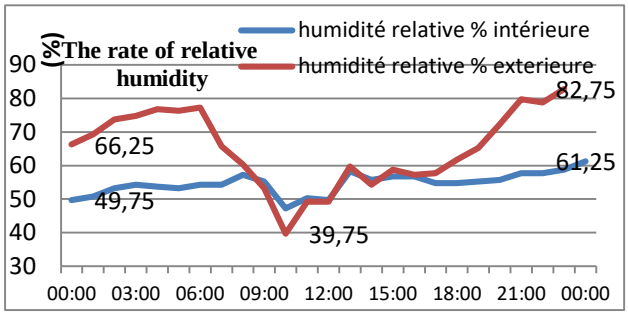

Figure 13: Fluctuation in the rate of relative humidity.

➢ **The draft**

The presence of the draft in classrooms is desirable even essential to decrease the temperatures and evacuate the vitiated air inside the classroom.

On Algiers fresh wind in summer blow of the North and the North / West, of this fact the North / South oriented classrooms benefit from a draft better than East/west oriented classrooms, what explains the results of evaluation which are in favor of the North / South orientation (fig.14).

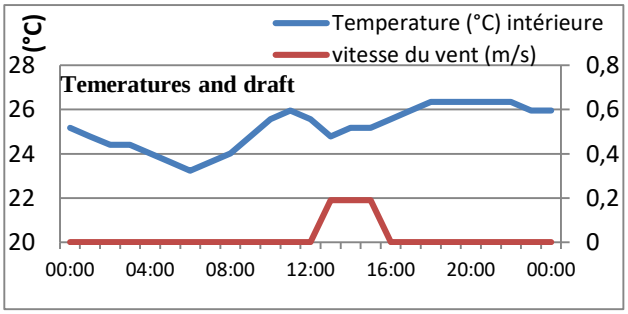

Figure 14: Fluctuation of the temperature according to the draft in classrooms oriented North/South

The thermal atmospheres offered by the plan proposed by the Ministry of Education are proved uncomfortable during the hot period. The led investigation revealed the bad quality of the working environment of the teachers and the impact of this latter on the health and the behavior of the pupils.

Impact of indoor thermal environments during spring on students in Algiers (north)

The following tables boards summarize the diseases and behaviors the most wide-spread according to the investigated of the Northern region during the hot period.

Table 4: The behavior of the pupils in classrooms.

Behavior	Rate	Causes
Loss of concentration	83%	The teachers consider that the pupils concentrate badly when the temperatures are raised, what explains their hanging laziness during the afternoon, when the temperatures are higher than the morning.
Laziness	72%	

Table 5: The most frequent diseases in classrooms.

Diseases	Rate	Causes
Irritation of the skin	72%	It is provoked by the excessive sweating due to the temperatures raised with the presence of the dust
Headaches	61%	The prolonged exposure of the pupils in the heat entrains headaches at the child according to the teachers.

The parameters of the thermal comfort in Biskra

During Winter

- **Temperatures**

We often think that the south region of the country is hot during practically all the year; therefore, the presence of heating is not essential. This study, thus took the care to demonstrate the opposite, such almost all of questioned teachers shows the necessity of the heating during the wintry period (fig.15) - This evaluation concerns all the investigated schools of the region and not only the school object of study.

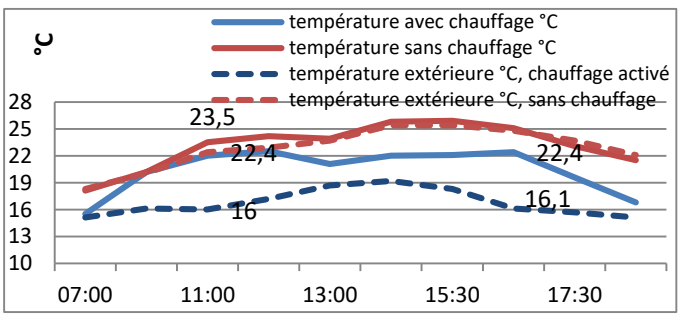

Figure 15: Fluctuations of the temperatures.

The internal / outside temperature difference, of the not heated day which does not exceed 0.9°C (fig.16) - The day programmed for the taking of measures without heating was characterized by a moderate climate, what falsified our results, demonstrates the bad thermal behavior of the walls of classrooms. The important thermal losses are due to the significant number of facades exposed to the outside climate and the used material of construction. In Biskra as in Algiers, the North / South orientation of classrooms is more favorable than the orientation East/west.

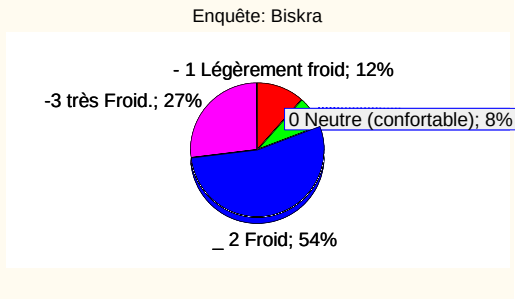

Figure 16: Evaluation of the wintry thermal comfort.

➢ **Rate of relative humidity**

The investigated teachers of the south region seem to be satisfied by the rate of humidity relative of their thermal atmospheres (fig.17), and the registered values confirm this report, which varied between 45 % and 60 % inside classrooms during the occupation (fig.18).

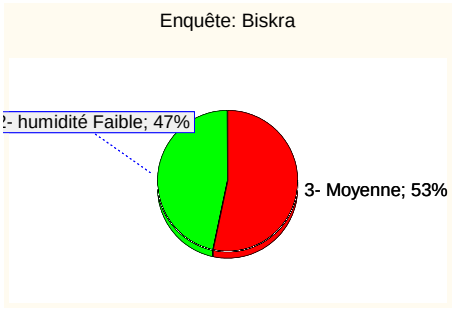

Figure 17: Evaluation of the rate of humidity

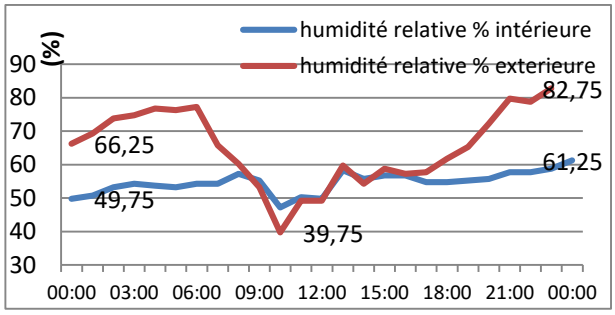

Figure 18: The values of the rate of relative humidity.

➢ **Draft**

The air speed inside classrooms is nil, however even the users do not show the need to have a draft inside classrooms.

On this region of the country, we were not able to reach all the expected results, but we revealed other problems. As a matter of fact, the working conditions in classrooms, in south region in winter, are very unfavorable.

Impact of the internal wintery thermal atmospheres on pupils in Biskra

As a matter of fact, the working conditions in classrooms, in south region in winter, are very unfavorable, and cause nuisances for the pupils and the teachers.

Table 6: The behavior of the pupils in classrooms.

Behavior	Rate	Causes
Hyperactivity	83%	The pupils try to get themselves a little of heat with the movements what explains their hyperactivity in classrooms.
Loss of concentration	79%	The cold limits the level of concentration of the pupils.
Desire to go out	67%	The investigated teachers show their dissatisfaction towards the repeated exits by the pupils who are due to the presence of the diseases (see board 7)

Table 7: The most frequent diseases in the school space in Biskra.

Diseases	Rate	Causes
Polyurie	80%	The permanent exhibition to the cold atmosphere cause at the child's of the diseases such as the polyurie which causes finally the desire to go out. As well as the grippe and rheum.
Grippe/ Rheum	58%	

During spring

➢ **Temperatures**

The internal temperatures of classrooms vary between 25°C and 37°C during the occupation (fig.19). This margin is considered uncomfortable by most part of the investigated. Therefore, they demand the presence of means of cooling to soften these conditions (fig.20).

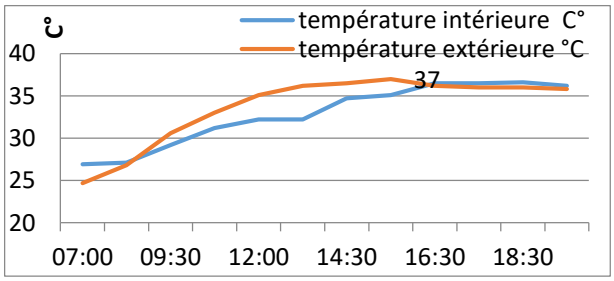

Figure 19: Fluctuations of the temperatures.

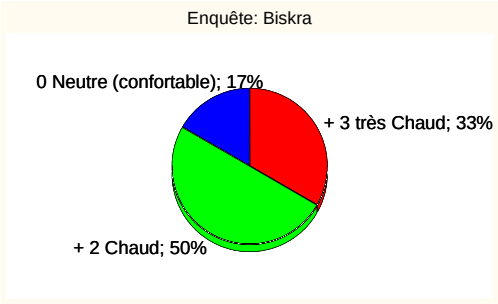

Figure 20: Evaluation of the thermal comfort.

- **The rate of relative humidity**

To Biskra, during the hot period the internal rate of relative humidity in classrooms does not exceed 29 % at the entrance of the pupils, to vacillate around 23 % along the day (fig.21). This atmosphere is considered as dry (fig.22).

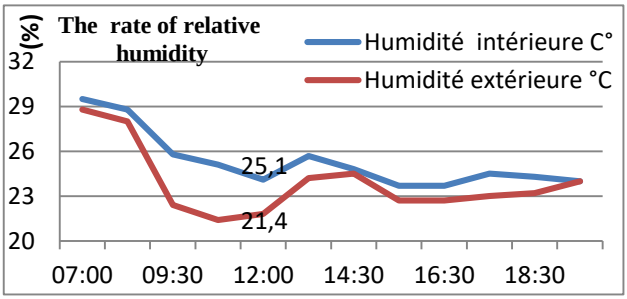

Figure 21: The values of the rate of relative humidity.

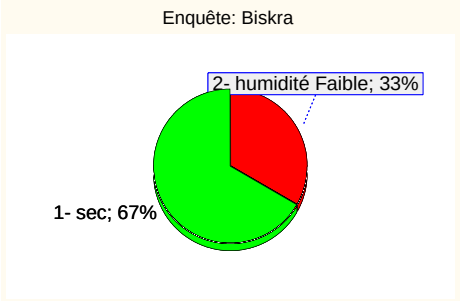

Figure 22: Evaluation of the rate of humidity.

The malaise expressed by the investigated towards the very low values of the humidity demonstrated that finally the above-mentioned temperatures could be comfortable if the rate of relative humidity was higher.

➢ **The draft**

The draft is an element dominant and looked for in spring to reach certain comfort, but the frequency of the storms of winds of sands makes that the users asks for it with limitation, knowing that winds summer are dry (sirocco).

Impact of the internal thermal atmospheres in spring on pupils in Biskra (south)

Table 8: The behavior of the pupils in classrooms.

Behavior	Rates	Causes
Loss of concentration	85%	The raised temperatures and the lowed rate of relative humidity provoke the loss of concentration and the laziness at the child inside classrooms.
Laziness	57%	

Table 9: The most frequent diseases in the school space.

Diseases	Rate	Causes
Irritation of the skin	78%	It is caused by the excessive sweating due to the raised temperatures with the presence of the dust
Headache	71%	The prolonged exposure of the pupils in the heat entrains headaches at the child.

This typical building, demonstrated its failure to offer a minimum of thermal comfort to the users, in the hot period. In absence of active solutions (ventilator or air conditioner), the manipulation of openings is proved not effective in this zone.

The schools of the south region suffer from a lack of equipment of heating and cooling, what returns the processes of teaching and learning more difficult. In this situation the architecture of the school building had to take into account these lacks. But in reality the conception of the school buildings is only adapting, according to the ground, the typical plan proposed by the Ministry of Education and makes no reference to the climatic data of the zone of setting-up.

Conclusion

This study allowed us to know the real quality of the internal thermal atmospheres offered by the typical plan of primary schools, in two different climatic zones and during two seasons.

The internal thermal atmospheres of classrooms are considered as bearable in winter in the schools of the North of the country. This situation is not bound to an adapted architecture, but rather to use of the active solutions basing on the energetic consumption. During spring the thermal conditions are acceptable more at least.

Whereas in the South, this study shows us the inadequacy of the internal thermal atmospheres in these schools during both seasons. On other hand, the lack of equipments which could remedy the failures of the architecture of the school building accented the sensation of discomfort.

We note that:

The influential factor of the wintry thermal comfort in the north is the rate of relative humidity, and in the South is the ambient temperature. The users of the schools of the South suggest temperatures higher than the users of the same space situated in the North.

During the hot period, the dominant factors in the North are the ambient temperature and the draft, in the South those are the rate of relative humidity as well as the draft.

These results confirm the necessity of considering the specific climatic parameters of every zone in the process of conception and realization of buildings.

Disclosure statement

The Authors reported that no competing financial interest.

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