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Study and characterization of thermal comfort in outdoor public spaces: case study "city of Annaba"

I.Dafri[1], D. Alkama[2]

[1]Laboratory of design and modeling of forms and architectural and urban environments (LACOMOFA), Faculty of sciences and technology
University of Mohamed Khider, Biskra, 07000 Biskra–Algeria
[2]University of 08 Mai 1945, Guelma, 24000 Guelma-Algeria

*Corresponding author: ibtissam.dafri@gmail.com; Tel: +213 6696070 13

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ABSTRACT/RESUME

Abstract: *The comfort issue touches several domains such as the psychic and the physical, like olfactory, visual, and thermal comfort. The latter has a strong relationship with the outdoor public space, because thermal well-being defines the quality of life of the user. In this perspective, our work is conducted to identify the impact of different thermal factors and conditions on the microclimate. Furthermore, it aims to study the difference between the microclimatic parameters influencing thermal comfort in outdoor public spaces, and those taken from the meteorological station. The method adopted for this research is based on the comparison between the climatic data recorded in the meteorological station of the airport "Rabah Bitat" of Annaba, that it is located in a low concentration urban environment, and the climatic measurements taken in various stations in the areas of studies (revolution course, square of el Houria, Boukhatouta Houcine garden), which are located right in the city center, using a thermal hygrometer, and a thermo-anemometer. These data represent the measurements of an average of 03 typical summer days in August. The results obtained confirm the difference between the thermal comfort in an urban environment and the thermal environment in a low urban environment.*

I. Introduction

Throughout time, man has tried to take advantage of the climate to have a certain comfort in his place [1].

Because the climate is the factor that defines the comfort quality of the individual, precisely the thermal comfort. The latter is the subject of much work and research, as it can be summarised as an interaction between activated metabolism (energy production), clothing (thermal insulation), air temperature, mean radiant temperature of the environment and air velocity (climatic data) [2]. Others perceive thermal comfort as a sensation that involves physical, physiological and psychological factors, so this explains the complexity of this topic as it depends on the subjective side of the users, which places the perception of each individual at the analysis [3].

However, in an urban context, thermal comfort is the main objective of the fundamental design of outdoor public spaces, because they are characterised by significant daily, seasonal and microclimatic variations, which are much more difficult to apprehend [4].

In this regard, the article highlights the difference between thermal comfort in an urban environment and that in an open area, through a comparative study between the microclimatic parameters in three outdoor public spaces located in the city centre (urban area), and the climatic data recorded by the meteorological station [5] situated in a low urban environment.

The climatic parameters studied in this research are air temperature, relative humidity and air velocity,

because they are the most responsible for the thermal comfort of the individual [6].

Presentation of the areas of investigation

The city of Annaba is located at 600 km from the capital Algiers, at the extreme East of the country which it shares with its neighbour el Tarf, open on the Mediterranean littoral on 80 km, it extends on 1412 km2 that is to say 0,06 % of the national territory.

Annaba is limited:To the North: by the Mediterranean coastline. to the East: by the plains of el Tarf. to the South: by the mountains of Nechemaya (Guelma). to the West: by the delkbir plains (Skikda).

Figure 1. *Situation of the investigation sites in Annaba [7].*

Annaba is characterised by a Mediterranean climate, with seasonal variations marked by a hot summer and a cold and humid winter with a rainy and temperate character [8]. The table below presents the measurement points in the investigation sites and their urban characteristics:

Table1.*Characteristics of the measurement points in the investigation sites [9].*

Revolution course		
Points	characteristics	Site
Point 1	Vegetation composed by grass, shrub, Araucaria, pine, and palm.	
Point 2	Discovered.	
Point 3	Dense vegetation.	
Point 4	Intersection of the ventilation corridor.	
Point 5	Move away by25 m from the S4.	
Point 6	Nearest point to the sea.	
El Houria square		
Point 1	Locate in intersection of several alleys, semi covered.	
Point 2	Large density of vegetation.	
Point 3	Low density of vegetation.	
Point 4	Discovered, locate in the playground.	
Boukhatouta Houcine garden		
Point 1	Large mass of vegetation.	
Point 2	Densest point in vegetation.	
Point 3	Discovered, locate in the playground.	

Aims of the research

Within the framework of making a comparison between the climatic data recorded by the meteorological station, and those required in the investigated public spaces (revolution course, square of el Houria, Boukhatouta Houcine garden), our study aims at :

- Identify the main elements that influence the microclimatic parameters, and then the outdoor thermal comfort.
- Confirm the difference between the thermal sensation in an urban environment and that in an open area.
- Identify the factors that impact the microclimatic change between the urban and low urban environment.
- To demonstrate the need for a study on outdoor thermal comfort, so as to have comfortable and practical outdoor public spaces in urban environment.

Based on a comparative study between the same urban public spaces (Revolution course, El Houria square and Boukhatouta Houcine garden), in order to confirm the variability of the thermal environment in an urban environment, whose microclimatic parameters (air temperature, relative humidity and air velocity) differ from one measuring point to another and from one urban public space to another, which is due to the characteristics of the measuring stations in each study space [10].

II. Materials and methods

The method adopted for this research is a comparative method between an urban environment and an open area, it is made between the climatic data (air temperature, relative humidity and air velocity) required in the meteorological station of the airport "Rabah Bitat" of Annaba, and the climatic measurements taken by the author in the revolution course, el Houria square and

Boukhatouta Houcine garden, these measurements are already presented in a previous article. The measurement campaign of air temperature, relative humidity and wind velocity is made during three successive days, on 03, 04 and 05 August 2016, in the public spaces studied, which are located in the city centre, which makes it easier to get around because of their proximity. The path was punctuated by 13 stations distributed in the study public spaces, of which 06 points were fixed during revolution course, 04 stations in el Houria square, and 03 stations in Boukhatouta Houcine garden, their distribution is made according to the shade (protection from solar radiation), of presence or absence of vegetation and water, of ventilation corridor, and of frequented spaces. The climatic measurements were taken at a height of 1.20 m, and were taken every 02 hours. The days of the investigation were considered to be very hot days, with clear and open skies. The air temperature and relative humidity are taken by a thermal hygrometer, the air velocity is taken by a thermo-anemometer. The thermo-hygrometer consists of a probe and an electronic sensor, with a display that shows the units of measurement (C°, F, %), the minimum and maximum values of temperature are (0°-60°C) and humidity are (20-95%). The thermo-anemometer is characterised by a high-precision telescopic probe, which can be stretched to a length of up to 1 m, and the devices allow the units of measurement to be changed [11].

The studied climatic parameters are recorded in the meteorological station every 03 hours of time, during the same days of the investigation, these data are collected and translated in the form of diagrams with the results obtained by the author, in order to make a comparison.

Figure2. *Measuring instruments, left thermal hygrometer [12], and right thermo-anemometer [13].*

III. Results and Discussion

III.1. Revolution course

Air temperature

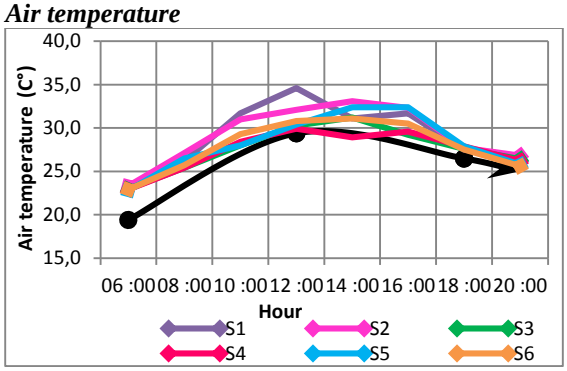

Figure 3. *Comparison between air temperatures measured in the revolution course and those recorded in the meteorological station.*

For a first observation, air temperature of the meteorological station is lower than that of revolution course almost during the whole day, wich due to the urban heat island effect, because the course is located in an urban environment, but the meteorological station is situated in an open area, with low urbanity. At 06:00 in the morning, a temperature difference of 3.6°C is recorded, which decreases to 1.95°C at noon, because the air temperature has reached its peak in the meteorological station at this time. During the afternoon, the air temperature of the meteorological station becomes a little higher than that of the station 04 in the revolution course, because the effect of the solar radiation is stronger in the areas with low urbanisation (meteorological station), with the absence of shade and solar masks, in contrast to the station 04 in the area investigated, which was well protected by buildings and a large mass of vegetation. From 16:00 onwards the temperatures start to decrease, and the situation is reversed, the temperature of the weather station is still lower than that of the course, with a difference of 1.18°C at 18:00.

Relative humidity

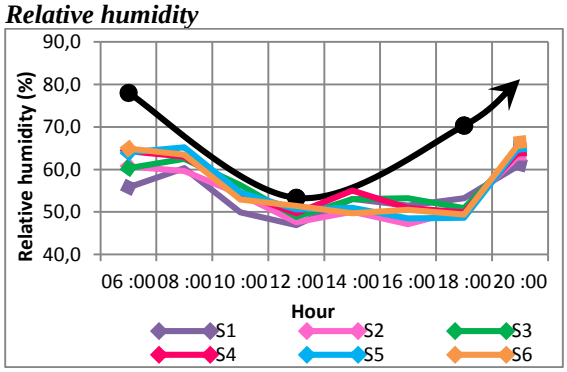

Figure 4. *Comparison between relative humidities measured in the revolution course and that recorded in the meteorological station.*

During the whole day, the relative humidity rate recorded in the meteorological station is higher than the one taken in the investigation site, due to the proximity of the sea, located a few meters away from the weather station. At 06:00 in the morning, the meteorological station records a maximum relative humidity, with a value of 78.0%, the ΔHR= 61.7%, then the difference was 16.3%, the latter starts to decrease to 4.12% at noon. The cause of this change is related to solar radiation, because the sun is perpendicular, which is followed by the rise in temperatures, so humidities naturally decrease. In the afternoon, the humidity levels rise again for all stations, the difference becomes the greatest during the whole day with a value of 19.9% at 6 pm, because the air temperature falls, this is due to the effect of evaporation from the sea in the meteorological station, so the presence of a large amount of water in the air causes the relative humidity level to rise rapidly.

Air velocity

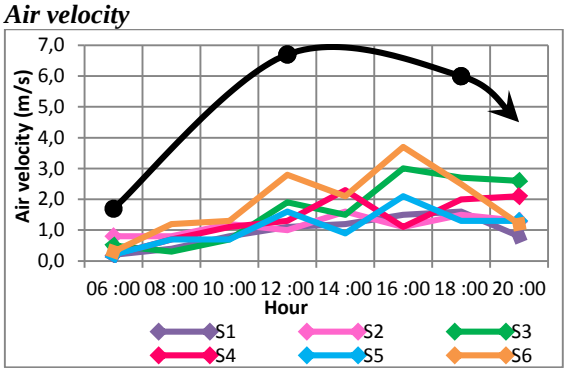

Figure 5. *Comparison between air velocities measured in the revolution course and those recorded in the meteorological station.*

The values retained in the site of investigation are disturbed and comprised between 0.2 m/s and 3.7 m/s, however, the meteorological station takes strong velocities during all the day, one can divide these velocities into two periods:

First period: Air velocities recorded by the meteorological station became increasingly strong from 06h until 12h, these are fresh air during the morning, and warm and dry winds at noon, the difference between the values at 06h and 12h is 1.3 m/s and 5.1 m/s per hour order.

Second period: Air velocities decrease progressively in the afternoon, until a value of 06 m/s at 18h, with a difference of 4.1 m/s, which allows the temperatures to decrease, so the air is calm and humid.

The air velocity is higher in the meteorological station than in the course of the revolution, because of the urban roughness and the surrounding buildings, which makes slowing down the wind velocities.

III.2. Square of el Houria

Air temperature

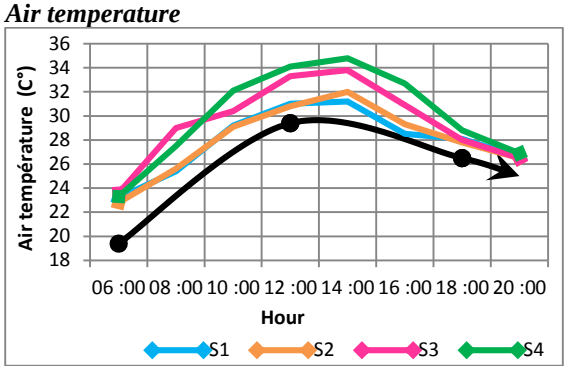

Figure 6. *Comparison between the air temperatures measured in el Houria Square and those recorded in the meteorological station.*

Overall, the temperature taken at the square is significant compared to that recorded in the meteorological station, at 06h, the difference between the temperatures was 3.8°C. During the morning, a progression of heat is made under the effect of solar radiation, at noon the difference became 2.9°C, the meteorological station required its maximum temperature, and however, the measuring points at the site recorded their daily maximum at 14h. At 6pm the temperatures dropped, the difference became 1.7°C, which brings the values of the square and the meteorological station closer together, as the latter is exposed to solar radiation, which allows the temperature to be stored for a long time, while the square is protected by the shade of vegetation.

Relative humidity

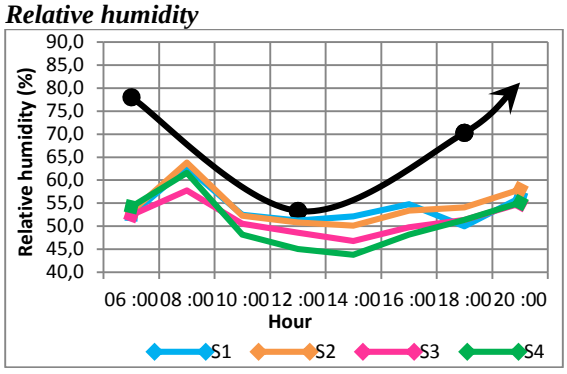

Figure 7. *Comparison between the relative humidities measured in el Houria Square and those recorded in the meteorological station.*

During the whole day, the humidity level recorded in the meteorological station is higher than that taken in the square, which is a big difference between the humidities in the two places. At 06:00 am, meteorological station records a maximum value, with a percentage of 78.0%, the difference between the humidity values of this station and the average of the measuring points in the square is 24.9%, at noon the difference weakens to 4.4%, due

to exposure to solar radiation at the time when the meteorological station records a maximum temperature, with a minimum humidity value of 53.3%. As air refreshing and temperature drops from the afternoon onwards, the relative humidity increases in both measuring ranges, and at 6 p.m. the difference rises to a value of 18.6%.

Air velocity

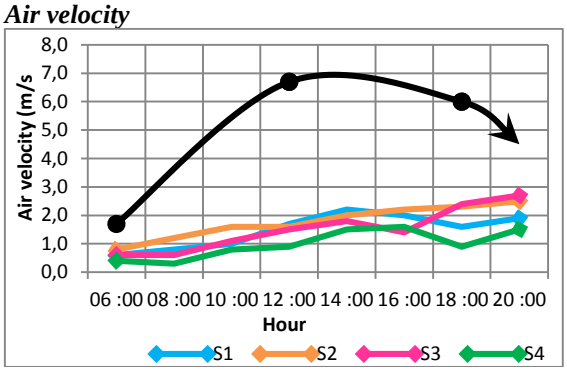

Figure 8. *Comparison between the air velocities measured in Houria Square and those recorded in the meteorological station.*

The air flow in the investigation site is calm during the whole day, the air velocity is between 0.3 m/s and 2.7 m/s, however, the meteorological station shows strong velocities, it registers its daily minimum at 06h in the morning, with a value of 1.7 m/s, the difference between the velocities of this station and that of the square is 1.1 m/s. At noon, the meteorological station reaches its maximum with a value of 6.7 m/s, at this time the difference increases in value, it is 5.3 m/s, this last one decreases to reach a value of 4.2 m/s at 18h. This change in velocity is mainly due to the position of each measuring point, because urban morphology and vegetation play a very important role in slowing down the velocity and freshing of the air.

III.3. Boukhatouta Houcine garden

Air temperature

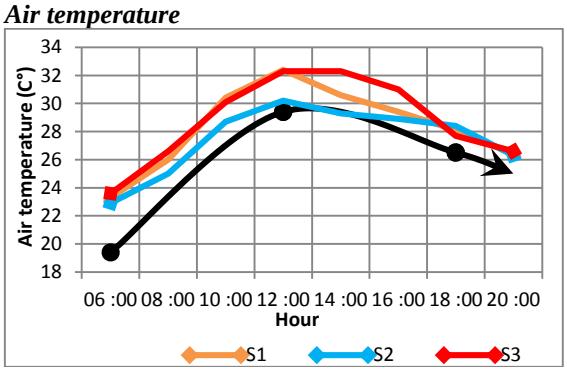

Figure 9. *Comparison between air temperatures measured in Boukhatouta Houcine garden and those recorded in the meteorological station.*

At 06:00 am, the measuring points in the garden and at the meteorological station present minimum temperatures, Tair (garden) = 23.3°C, and Tair (weather) =19.4°C, with a difference of 3.9°C, which is justified by the urban heat island (already mentioned).

The rise in temperature is noted as a result of the effect of solar radiation, which is all the stations record maximum values at 12 noon, with the difference decreasing to 2.2°C, during which time the garden has become unbearable. During the afternoon, temperatures in the garden and the meteorological station show a decrease in values, with the difference decreasing to 1.5°C at 6pm. The Boukhatouta houcine garden is like the other two investigation sites; they present important temperature values than those retained in the meteorological station during the whole day, because the last one station benefits from the fresh air caused by the sea, and to have important ventilation due to the absence of urban roughness.

Relative humidity

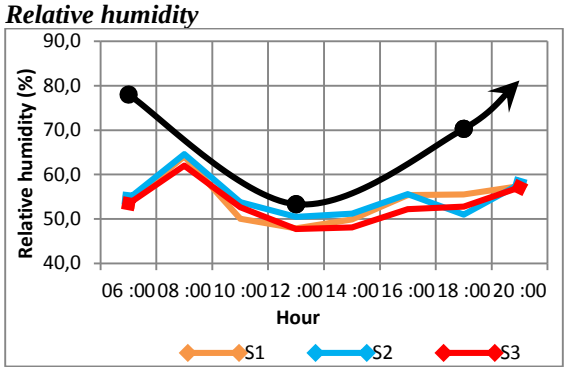

Figure 10. *Comparison between the relative humidities measured in the Boukhatouta Houcine garden and those recorded in the meteorological station.*

The relative humidity recorded in the meteorological station is higher than that taken in the garden throughout the day. At 06:00 the meteorological station records a maximum value of 78.0%, the difference between the humidities is 24.1%, with exposure to the sun, and decreases to 4.6% at noon. At this time the station records a minimum value of 53.3%, because the increase in temperature decreases the relative humidity. In the afternoon and evening the temperature values decrease, so the difference in relative humidity between the meteorological station and the garden became 17.2% at 6 pm. Thus the Boukhatouta Houcine garden has drier humidity values in the morning compared to the revolution course, and humid values in the evening.

Air velocity

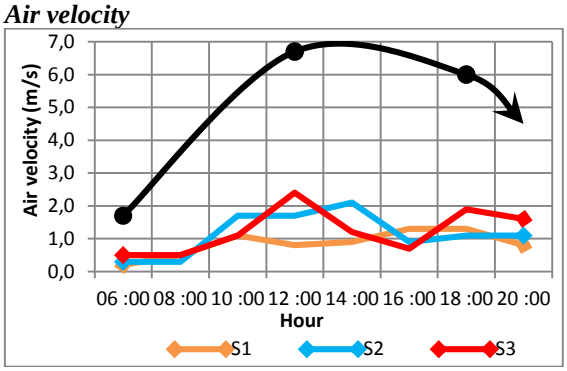

Figure 11. *Comparison between the air velocities measured in the Boukhatouta Houcine garden and those recorded in the meteorological station.*

The meteorological station always has higher wind velocities than the investigation site; the cause is always the effect of urban roughness in attenuating the winds. These velocities are characterised by fresh air in the morning, warm and dry winds in the afternoon and fresh and humid winds in the evening. At 06h, the difference between the meteorological station and the garden is 1.4 m/s, at noon the wind velocities accelerate in both measurement sites, and despite this increase, the difference increases to 5.1 m/s, and becomes 4.6 m/s at 18h. Thus, the Boukhatuta Houcine garden presents air velocities approximating those of the revolution course.

As conclusion, the urban structure has well protected the garden from the air currents that is the air flow is low in an urban site, compared to a low urbanised site.

IV. Conclusion

The revolution course, Square of el Houria and Boukhatouta Houcine garden have high temperature values compared to those taken in the meteorological station, due to the effect of the urban heat island, because the investigated areas are located in an urban environment but the meteorological station is located in an open, low urbanized area near the sea, which allows for rapid freshing of the air, and the gain of important ventilation due to the absence of the urban roughness.

The relative humidity rates recorded in the meteorological station are high, compared to those taken in our study area, due to the effect of evaporation from the sea (located near the meteorological station). This phenomenon provides a large amount of water in the air, which causes the relative humidity to rise rapidly.

The meteorological station samples high wind velocities, because it is located in a low urbanized area, but the investigation areas present lower values (compared to those recorded in the meteorological station). This is due to the urban roughness, vegetation and urban morphology that slow down the air flow, so the wind velocity is low in an urban site compared to a low urbanized site.

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