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Quantitative Assessment of the Thermal Environment of Urban District's Outdoor Space in an Arid Area

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***Abstract*—This research focuses on the open urban spaces quality related to the essential need of people to increase their social life in relation to a comfortable physical environment. The current emergence of environmental concerns involves several axes for new development possibilities; this environmental approach encourages research towards eco-urbanization. Improving the thermal quantities in an area's climate characterized by a very hot solar ray remains the main task. The assessment of the thermal comfort requires an analytical study of specific urban microclimates generated by the spaces morphology. To reach our objectives, the impact of different morpho-climatic indicators in urban areas will be tested to determine an optimization of adequate effects on the thermal environment of the open spaces of the studied districts. Three neighborhoods were selected for seasonal measurement campaigns, these urban tissues lend themselves easily to a chronological reading: traditional district, colonial district, and contemporary districts. The measurement tool used is a multifunction digital device (LM/FI 20) 3 in 1 (Anemo-Hygro-Thermometer). Mobile measurements monitoring are made in several timing of the day; the measurement times were chosen to measure the daily air temperature variations and to study the effect of solar radiation and shading in relation to the measurement stations. After the achievement of the measurement campaigns, we have proceeded to the calculation of the air temperature means on several levels in order to establish a thermal map of the studied districts. The results showed that each quarter represents a specific morphology that generates different thermal strata. The increase in air temperature values is mainly due to morphological and dimensional characteristics, solar exposure and the orientation of inter-district streets. It can also be deduced that the solar exposure of the external surfaces is due to: very low building heights, shadows of the constructive and natural elements, and coatings and textures of the different surfaces.**

Keywords—Thermal environment; Urban outdoor space; Onsite measurement campaign; Hot arid area

I. INTRODUCTION

This work aims to evaluate the urban thermal environment of the well being of users in the urban outdoor spaces for a sustainable urban development [3]. Conditions of an adequate ambient temperature require careful urban design that takes various quantitative and qualitative aspects, especially in hot and arid regions where a hot and an intensive sunlight characterize those areas [1].

A survey based on a monitoring assessment still the ideal tool designated to evaluate the thermal environment of outdoor urban space, to reveal adaptation degree related to the street's thermal ambience of the selected districts [7]. The selection of representative streets is based on the urban district morphological characteristics: building form, height/width ratios, orientations, colors and textures of the external vertical surfaces, and vegetation density [2]. The objective is to assess the impact of urban morphology on the thermal ambience in the study area, under specific clear sky condition throughout the year [5].

II. PRESENTATION OF THE CASE STUDY

A. Biskra downtown

Located in an arid area, the city of Biskra in Algeria is characterized by a cold climate in winter and a very hot dry summer with very intense solar radiation levels. In addition to: daily and annual temperature amplitude, little among of precipitation, and hot dusty winds especially during spring.

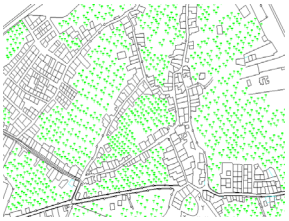
B. Urban morphology characterization

The urban morphology of Biskra is a product of more than three thousand years of history and an important multi-ethnic influx. Through history, Biskra was a place of civilizations crossing; different cultures and civilizations with a varying degrees of influence contributed to the nowadays form of the town. Four morphologies have been specified according to their urban morphology values and to investigate in their urban configuration: Traditional, Colonial, Contemporary 1 and 2.

C. District's presentation

The following housing districts have been identified as representative of Biskra urban morphology. The entire urban fabric was selected as a test sample for the monitoring and photography campaigns.

TABLE I. TABLE STYLES CHARACTERISTICS OF THE SELECTED DISTRICTS

District	District's conditions	
	District's characteristics	*District's map*
Dist. 1	- Very compact urban district with narrow streets - low buildings heights - Houses are built with mud bricks (natural earth) - Very small openings on facades nearly blind without protection - Vegetation density: 65%	
Dist. 2	- Regular lot shape - Individual houses of one to two storeys - Large openings (Arabisance style) - Color of the facades: varied - Vegetation density: 19%	
Dist. 3	- A relatively well-structured plane - Houses of two to three levels - Facades are white - Trees planted all along the street - Vegetation density: 11%	
Dist. 4	- A regular plan - relatively high density - Height / width ratio: high - Colour of the facades: varied - Vegetation density: 3%	

[a.] District's map source: PDAU of Biskra 2018

As mentioned before many aspects of the selected urban streets: Building's architecture style, thermal characteristics, geometry, prospect, orientation, color, texture and vegetation.

D. The selected streets

The selected streets presented districts samples and depending to their districts representative degree. Monitoring campaigns realized in the selected streets of each district; the measurement stations were chosen to represent the daily, seasonal and annual air temperature variations between the beginning and the end of the day, between seasons and annual phase.

TABLE II. THE SELECTED STREETS

The selected streets (All districts)	
Traditional district	
	
	
Colonial district	
	
	
Contemporary districts 1 and 2	
	
	

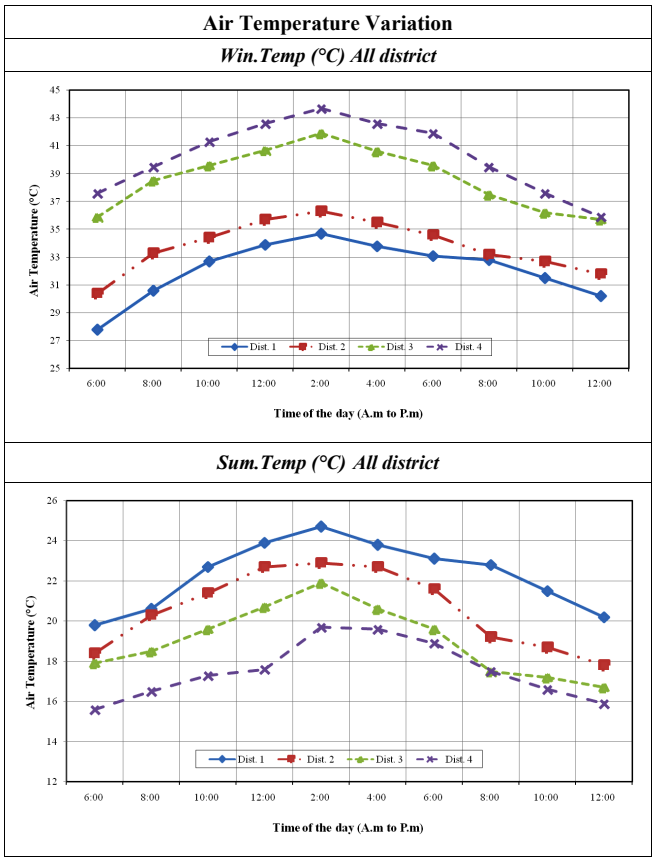
[b.] Photography Source: Author

III. MEASUREMENTS AND MONITORING CAMPAIGNS

The Measurement campaigns started in February 2018 and ended in July 2018 and took place during summer/winter

solstices which represent the extreme thermal conditions in term of heat degrees (Coldest days in winter and the hottest days of summer).

TABLE III. AIRTEMPERATURE (IN °C) VARIATIONS DURING SUM/WIN SEASONS IN THE URBAN DISTRICTS SELECTED



[c.] Measurement campaigns results (year: 2018)

From the results shown in table 2, the air temperatures vary between different morphologies; this is due to the morphological and dimensional characteristics of the district: H/W ratio, type and materials of surface coatings, vegetation density. Thereafter, realize that the districts Air temperatures variation according to:

A. *High/Width ratio (H/W.R)*

- The greatest is the H/W ratio the higher are the Air temperatures values due to the solar radiation exposure in the summer season [4].
- The monitoring campaign of the summer season shows that the traditional district represents the most adequate thermal environment in the studied area. The average H/W ratio in the traditional core can be limited between 1 < H/W R < 2.

B. *Type and materials of surface coatings*

- In a hot arid zone, the earth cladding seems better type of coating for a thermal environment than other coating used in the district selected such as: concert, bitumen… etc.
- The surfaces coated with materials that increases the heat of a street with a higher albedo than that of earthen sods or surfaces.

C. *vegetation density*

- The vegetation density has an important impact on the thermal condition in an outdoor space of a district. In our case study, the results show that the vegetation density can reduce the maximum air temperature of 9°C between the traditional district (with palm grove of 65 % of the total district area) and the contemporary district 2 with a weak vegetation presence.
- Type of vegetation and it position between construction is important in the structure of a district. Traditional and colonial possess two different type and form of vegetation, but both enhance the thermal environment and the microclimate of the urban outdoor space [6].

IV. THERMAL CUMULUS

The calculation of average air temperatures in a district is based on the sum of the values of the temperatures measured at all the stations fixed for the whole campaign. At the end, a cumulus of seasonal and annual temperatures is calculated. During the analysis, we will attempt, as far as possible, to explain the thermal phenomena observed, as well as the causes of the sudden or unusual increases. The formula for calculating cumulus is:

$$\sum T_{district} = T_{street1} + T_{street2} \ldots + T_{streetN} \quad (1)$$

The graph below shows the results of the calculation of the cumulus of all the districts selected.

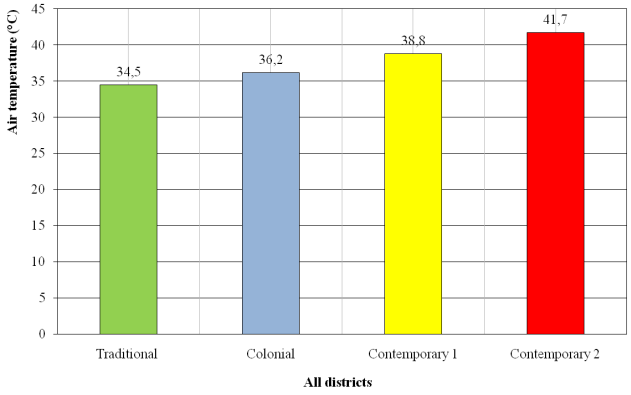


Fig. 1. Air temperature means in summer season (In °C) (All districts).

The lowest mean of air temperatures, measured during summer season, was found in the traditional district, while the highest air temperature value was found in the contemporary district 2, the traditional urban entities are very adapted to local thermal environment conditions in hot arid areas.

V. RESULTS INTERPRETATION

The experiment we conducted with different urban morphologies allows us to verify their impact on the thermal environment in the hot arid region. In order to enhance the thermal ambience to the inhabitants, we have investigated on indicators with an imminent effect of all the morphologies selected. The most relevant findings are:

1) An average H/W ratio is the most appropriate in an arid area.

2) The sunlight effect has a very low impact on the traditional tissu ; this is due to the gemetric caracteristiques and the material thermal qualities.

3) The presense of vegetation with a high density than costructions density inside the district.

4) The air temperature cumulus shows that contemporary districts are less adapted to an arid area thermal conditions.

5) The traditonal tissu caracteristics reveals a high thermal enhancement by decreasing the intense heat of the desert region.

VI. CONCLUSION

We conclude that in order to enhance the thermal conditions of the district in hot arid area; we have to associated the morphological characteristics of the urban compositions with thermal environment intention to minimize the maximum heat in the outdoor space, the traditional tissue shows a better thermal results than other contemporary districts; with lower air temperature quantities due essentially to several morpho-climatic parameters such as: form and surface qualities, an average H/W ratio, material coating, texture, color, presence and density of vegetations. These must be chosen with urban intentions and with morphological and aesthetic values of the thermals phenomenon to successfully provide the most appropriate ambience to a specific context for a better user comfort.

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