International Journal of Innovative Studies in Sociology and Humanities

ISSN 2456-4931 | Open Access | Volume 7, Issue 11, 2022

DOI: https://doi.org/10.20431/2456-4931.071103

Study of the Effects of Dead-End Street Configuration on Pedestrian Hygrothermal Comfort Using an Advanced Simulation Method. Case study: Sahat El Houria District Biskra, Algeria

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Recieved: October 08, 2022 **Accepted**: October 27, 2022 **Published**: November 02, 2022

Abstarct

Urban street design plays an important role in creating the urban micro climate, as streets typically cover more than a quarter of urban areas. The old vernacular towns of southern Algeria are typical in their configurations in the predominance of streets in the form of dead ends. The purpose of this study is to assess the effects of dead-end street geometry on hygrothermal comfort and urban heat island risk in hot and arid regions. The measurements results of all the microclimate parameters; including (air temperature, air velocity and relative humidity) show a good correlation between heat island risk and street network typology. Besides this, we have chosen to calculate the human biometeorological parameters such as mean radiant temperature (T mrt) and the physiologically equivalent temperature (PET) comfort index using the ENVI-met Bio-Met program (licensed). Subsequently, a series of simulations have been performed using the ENVI-met software to assess the phenomenon. This study aims at finding the relationship between urban configurations and the subsequent comfort conditions in outdoor spaces in hot and arid regions. This requires the use of new means of research in order to develop guidelines and new strategies for a healthy and sustainable urban space. What helps us explain the reduction of the risk of urban heat island in the city of Biskra is the low solar exposure and street depth which creates a better hygrothermal conditions.

Key words: Hygrothermal comfort – dead end street geometry – urban heat island - ENVI-met – Height/Width ratio – Physiologically equivalent temperature (PET) index.

INTRODUCTION

We all agree that there has been a rapid urbanization in hot and dry regions. This has generated various environmental problems in urban areas. Consequently, the public authorities have not devoted priority to urban configuration and outdoor spaces comfort (Johansson. E, 2006). Street heat and high temperatures in urban areas affect the human health and well-bieng of urban dwellers (Douglas. I, James.P, 2014). Because of the climate change, these negative effects will worsen in the future in regions with extreme weather conditions (T, salim.S, Parapari.D, 2015). Urban street design plays an important role in creating the urban micro climate (Bourbia.F, Boucheriba.F, 2010), as streets typically cover more than a quarter of urban areas (Shashua-Bar.L, Hoffman.M.E, 2003). Streets in the form of dead ends are one of the features of towns in southern Algeria (Amraoui.K, & al, 2021).

The most important factor that influences urban street geometry is the aspect ratio of the height of buildings (H) to the distance between them (W). This aspect ratio associated with the environment parameters (air temperature, wind speed, relative humidity) is affecting the outdoor comfort (Ali Toudert.F, & al, 2005), (Bourbia.F. Awbi.H.B, 2004).

The present paper investigates first the effects of dead end street geometry on the urban heat island risk. Second, the assessment of outdoor spaces hygrothermal comfort in the Sahat El Houria district. The aim of this research is to deepen knowledge about the impact of urban geometry; specifically the height to width street aspect ratio (H/W) and the causes of heat stress must be reduced such as: urban heat island, energy consumption and anthropogenic heat. As a result of this, we can ensure outdoor hygrothermal comfort in regions with high temperatures.

Dead End Street Geometry (Aspect Ratio (H/W) and Street Shading)

A French term, cul-de-sac literally means "bottom of the sack. It is a road that has only one inlet and outlet, allowing cars to move in and out turning around and so on. The design of cul-de-sac dates back to Athenian and Roman times, It was developed as a defensive measure so as to trap foreign invaders. (https://www.designingbuildings.co.uk/wiki/Cul-de-sac).

What attracts our attention is that life in cul-de-sac streets is more enjoyable than in other streets types. In terms of social cohesion, we find that resident of cul-de-sac streets are more neighborly than those of dead end streets. Helpfulness and friendly relationships characterize life in dead end streets. In addition to this, it gives children the opportunity to play and amuse themselves.

However, such types of streets engender negative effects in terms of security and prevention of risks. They make it difficult for fire trucks and ambulances to reach their destinations in a fast manner. (Hochschild, T. R., 2015).

Moreover, the most important factor that influences urban street geometry is the aspect ratio of the height of buildings (H) to the distance between them (W). This aspect ratio is associated with the environment parameters (air temperature, wind speed, relative humidity). In hot climates, the outdoor comfort is highly dependent on the canyon aspect ratio and its orientation (Ali-Toudert.F, Mayer.H, 2006). The effects of shading in deep canyon streets are suitable for summer period and unsuitable for winter season and vice versa. (Jamei. E, & al, 2016; Thorsson.S, & al, 2011).

Street geometry and orientation are important in this context. They affect the solar access and the quantity of solar radiation received by the street surfaces, the facades and the indoor environment of the buildings. (Nasrollahi. N, & al, 2021). Besides, streets with different orientations have different conditions in terms of shading and the sun exposure during the day and throughout the year. (Fouda. Y, 2014; Knowles. R.L, 2003).

According to the street in northern latitudes, the north south (NS) street is shaded in summer during morning and afternoon while the west east (WE) street is exposed to the sun. Only a small part of this orientation is shaded. At noon, the street is completely under the sun exposure. (Nasrollahi. N, & al, 2021)

Parts of north west (NW) – south east (SE) and north east (NE) – south west (SW) are always shaded during the day for streets with an intermediate orientation. In the summer period, north south (NS) and intermediate streets have more shade during summer and less shade during the winter period in contrast to the east west (EW) streets (Fouda.Y, 2014). In several studies, the best orientation is NS and the worst is EW. Due to the lack of shading, streets are less comfortable (Boukhelkhal.I, Bourbia.F, 2016). In hot and dry regions, the east west (EW) streets are the worst orientation for achieving acceptable thermal comfort but north south (NS) is the best thermal condition (Ali-Toudert.F, Mayer.H, 2007) (Bourbia.F, Awbi.H.B, 2004).

Some studies demonstrate that east west (EW) is the best street orientation according to the results of physiological equivalent temperature (PET) evaluations (Abreu-Harbich.L.V,& al. 2014). A study in China shows that there is more shade and better thermal condition at an intermediate orientation street NW-SE (Zhang.Y, & al, 2017). In Freiburg, Germany, the lowest air temperature is observed at intermediate orientations north east (NE) - south west (SW). (Lee.H, & al, 2016).

Physiologically Equivalent Temperature (PET) and Mean Radiant Temperature (Tmrt)

In urban open space, the thermal index physiological equivalent (PET) is a useful bioclimatic indicator. It is widely used to study and evaluate thermal comfort (Ketterer.C & Matzarakis.A 2016) (Jung.S, Yoon.S 2018). This index is based on human energy balance. It also considers the environment parameters (air temperature, relative humidity, mean radiant temperature (Tmrt) and air velocity). (H. Mayer, P. Höppe, 1987) (Muniz-Gäal. LP, & al, 2020).

PET is a function of the environmental parameters such as: air temperature, humidity, wind speed and mean radiant temperature. It includes the thermo-physiological processes of a human body in adjusting stressful thermal conditions. (Ali Toudert.F, & al, 2005)

The most important meteorological parameter affecting the human energy balance during sunny weather conditions is the mean radiant temperature (Tmrt). (Matzarakis & al. 2007).

In Isfahan, Iran, the mean radiant temperature (Tmrt) represents an equivalent temperature that summarizes the effect of all the different short and long wave radiation fluxes and the sky view factor (SVF). (Venhari, A.A, & al, 2019)

Moreover, PET results indicate a certain correlation between canyon geometries and outdoor thermal comfort. (Deng. JY, Wong. N.H, 2020). The PET values are used to characterize outdoor thermal comfort conditions for pedestrians. (Chatzidimitriou.A, Simos. Y, 2017) (Kumar.P, Sharma. A, 2020).

CASE STUDY DESCRIPTION (Sahat El houria district)

The city of Biskra, located in south east of Algeria has been chosen as a case study. It is characterized by a very hot and dry summer and a mild winter with a large diversity in urban configurations.

Meteorological data of Biskra shows that the average temperature ranges from maximum of +44, 9°C and a minimum value of−2.1°C with high insulation exceeding 3500h/year and intense direct sunlight which can reach 900 to 1100 W/ m^2 on a horizontal plane. Relative humidity values vary from 25% to 40% depending on the period of the year with rare and irregular rainfall. This city is characterized by violent seasonal sandstorms, figure 1.

Figure 1. Location of Biskra city. Source : https://fracademic.com/dic.nsf/frwiki/1733485.

Sahat El houria is located in the Star M'louk district which is at the city center. This district has been generated by the extension of the colonial checkerboard. Now, it is juxtaposed with the headquarters of the wilaya. Sahat El Houria district includes individual dwellings. It is limited by El Amir Abdelkeder Boulevard, Kherachi Ibrahim Street, Fertasse Saci Street and Badi Mohamed Street, as shown in figure 2 and 3.

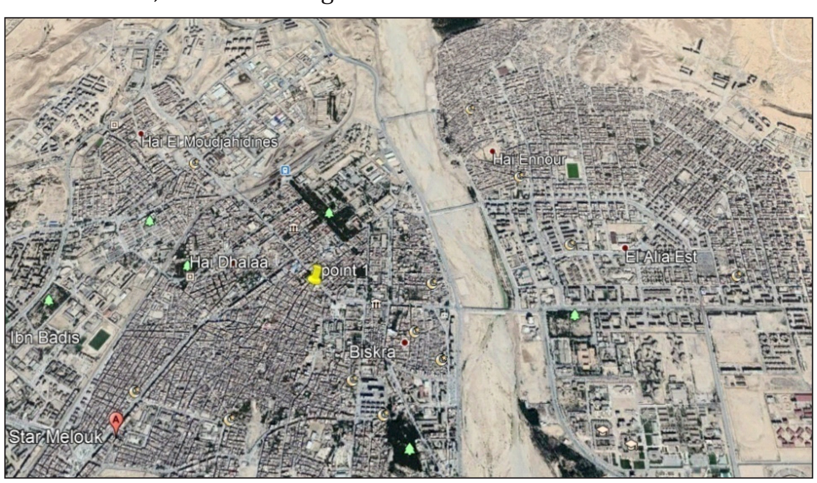


Figure 2. Location of Sahat El houria district in relation to the whole city of Biskra. Google Earth. Consulting date: 26th March 2019.

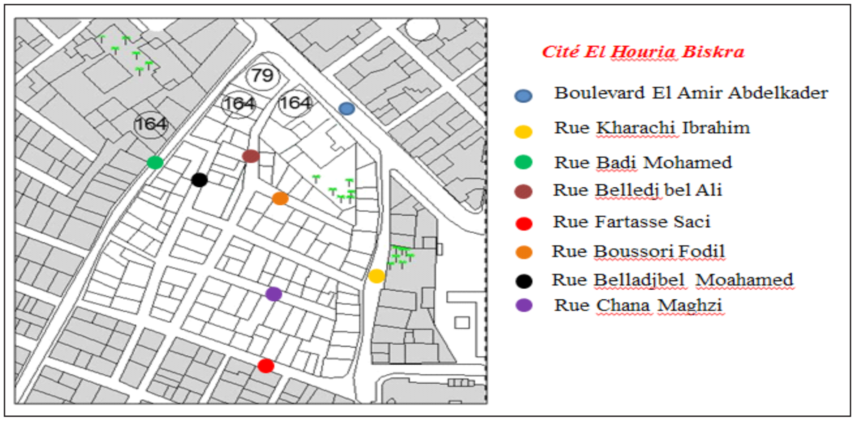


Figure 3. Borders of the Sahat El Houria district from master plan for development and urban planning of Biskra. (MPDUP).

The shape of the residential blocks is irregular. It is caused by the extension of the colonial checkerboard. The design of the district does not respect the regular layout of the city center.

The case study has been chosen according to the following criteria:

1- Overall dead end streets configurations characterize towns in hot and arid regions.

2- Canyon and dead end streets are another type of configuration.

3- A few studies on dead end streets have been carried out.

4- The lack of green spaces in the heart of the district and the absence of irrigation mean such as small canals, water jets and fountains are visible features.

The first dead end street (station 1) is Boussori Fodil Street. Its direction is East-West (E-W). The street (station 1) consists of individual dwellings with a maximum height of 12 m and a width of 8.00 m with an aspect ratio H/W= 1.2.

The second dead end street (station 2) is Chana Maghzi Street. Its direction is East-west (E-W). The street (station 2) consists of individual dwellings with a maximum height of 9 m and a width of 7.50 m with an aspect ratio H/W= 0.75. Dwellings in both streets (station 1) and (station 2) are built with concrete whereas streets are paved as shown in table 1 and figure 4.

Table 1. Typological characterisctics of Bossori Fodil Street and Chana Maghzi Street**.**

Street name	Station	Street direction	Height (m)	Width (m)	H/W
Boussori Fodil	1	East west (E-W)	9	7.50	1.2
Chana maghzi	2	East west (E-W)	6	8	0.75

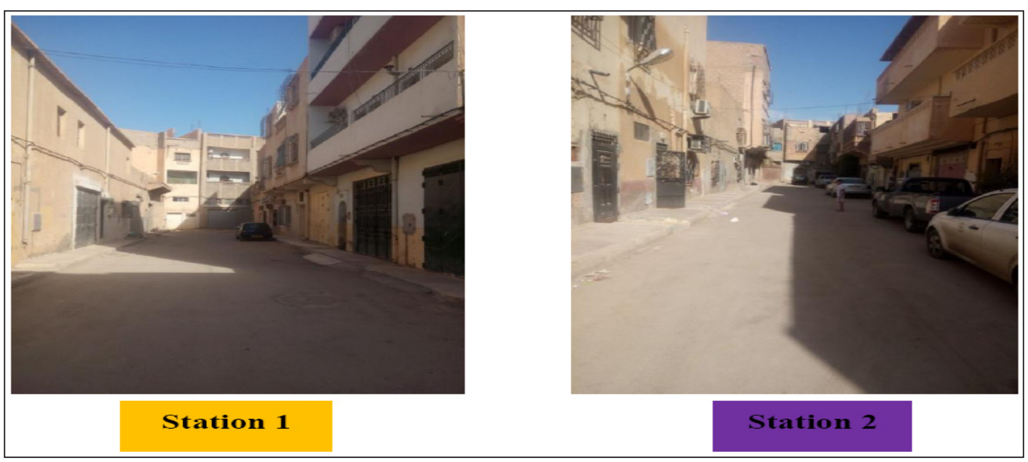


Figure 4. Dead end street 1 (station 1) and dead end street 2 (Station 2). Photos taken on 25th July 2021 by the author.

METHODOLOGY AND APPROACH

In Situ Measurements

The main aim of this study was to measure hygrothermal parameters that define the outdoor climatic conditions (air temperature, relative humidity and air velocity).

Measuring Instruments

The air temperature, relative humidity and air velocity were measured using the thermo hygrometer sensor « Testo 480 », figure 5.

Figure 5. The components of the Testo 480 handheld, one probe for measuring air velocity and one for easuring relative humidity. Source: www.testo.com

Measurements' Protocol

The year of 2005 represents the hottest year for the eleven past years (2005 - 2015). The air temperature reached 46, 5 °C. Several values of air temperature are given in table 2.

Table 2. Values of maximum air temperature (2005-2015). Source: www.infoclimat.fr.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
T(°C)	46.5	41.7	43.8	43.7	45.3	40.1	36.4	38	41	43.9	42.2

A simulation has been performed specially for the 25th July as it represents the hottest day (the design day is selected from 365 days in 2005).

Air temperature, relative humidity and air velocity were measured in the month of July, with a bi-hourly protocol starting from 8:00 a.m and finishing at 7 p.m. The measurements were collected from the case study during one day « July 25th » of summer 2017. The 25th July represents a typical day and 2017 is the year of measurements.

Simulation Protocol

We need to perform a series of simulations by using the ENVI-met version 4.4.6 code, monitoring campaigns and BioMet so that we can assess the effect of dead end streets configuration on the hygrothermal comfort level. We can also evaluate the urban heat island risk in Sahat El Houria district in Biskra and ensure the outdoor hygrothermal comfort.

In this research, PET was calculated through ENVI-met BioMet V 1.5. It is a post processing tool to calculate human thermal comfort indices which includes PMV/PPD, PET and UTCI…etc. Bio-Met directly interacts with the ENVI-met and performs calculation based on the simulation data output by ENVI-met. Basically, Bio-Met summarizes the impact of four variables on human thermal sensation: air temperature, radiative temperature, air velocity, relative humidity and mean radiant temperature (Tmrt).

ENVI-met is a holistic resolution microclimate modeling system. It has a CFD microclimatic model designed to simulate the interactions between the urban environment (urban surfaces, vegetation and atmosphere) in a virtual environment by reproducing the major atmospheric process (Matallah, 2020. Bruss), with a typical resolution of 0.5 to 10 m in space and 10 sec in time. The generated output contains the main four thermal comfort parameters: air temperature, relative humidity, air velocity and mean radiant temperature. It is a non-hydrostatic RANS model. In addition, it calculates the dynamics of microclimate during a diurnal cycle (24 to 48 hours) using the fundamental laws of fluid dynamics and thermodynamics. (Elnabawi, Mohamed H, & al, 2013).

Measurements and simulation data are conducted to validate the simulation tool ENVI-met 4.4.6. The measurements were conducted at Sahat El Houria district (two dead end streets) and consisted of recording exterior air temperature, relative humidity, and air velocity at 1.8 m at two stations (Boussori Fodil street and Chana Maghzi street) on one day. After the measurements, the geometry of Sahat El Houria district was modeled and simulated. The simulations were conducted using the weather data of the measurements day with the aim of investigating the accuracy of the model.

Moreover, ENVI-met has two basic steps before the simulation is run. The first is editing the input of the urban area to be tested. For this task, we need the horizontal and vertical dimensions of the architectural environment along with any specific design features such as open breezeways, overhangs, horizontal surface materials, ground cover, vegetation size and coverage… etc. (Elnabawi, Mohamed H, & al, 2013).

The second is modeling and editing the simulation parameters (microclimate data and built elements) by using the database of the plants and surface material in order to create the area input file (.INX) and the simulation file (.SIM). Finally, we can mention the assessment of the outcome files (.EDT/.EDX) which has to be imported into a visualization program LEONARDO 4.4.4. Each output file has a multitude of information which has to be translated into different layers in Leonardo. The following main layers are typically used to visualize the output data. (Chatzinikolaou, E., 2018) (Elnabawi, Mohamed H, & al, 2013).

After the simulation in ENVI-met, a subsequent analysis was conducted with BIO-MET for the calculation of the physiological equivalent temperature (PET). The PET is an index of thermal comfort that is based on a prognostic model of the human energetic balance. The latter includes calculations of the skin temperature, core temperature of the body and the sweat rate.

The study was centered on the air temperature, air velocity and relative humidity for the assessment of the outdoor hygrothermal comfort in dead end streets configuration.

Air temperature (°C): it evaluates the distribution of temperature in relation to the influence of building layout and shading effects, as well as the albedo of the materials used to pave Sahat El Houria district

• Air velocity (m/s): it evaluates the distribution of the wind or air.

•Relative humidity (RH) (%): evaluates the effect of the relative humidity and its temperature-related impact.

These data were obtained from the records of Biskra meteorological station on 25th July 2017. They were used as input into ENVI-met in an EPW weather file format (Energy plus Weather data) that contained data recorded every 2 hours between 8:00 a.m. to 7:00 p.m. The area of the model was composed of a 200 × 200 × 150 cell mesh (in an x, y, and z tridimensional reference system) with a cell size of a 10 × 10 × 2 m as shown in figure 6 and table 3. The materials chosen for the model consists of concrete pavement of buildings and asphalt in the zones for rolling traffic in white tiles.

Table 3. Input data of the study area "Sahat El Houria district "with element types of build environment and vegetation in ENVI-met v 4.4.6.

Simulation Input Data	
Simulation Model Size (m)	200 X 200 X 150
Model Area (Number of Grids) xyz-Grids	40 X 40 X 30
Size of grid cell (meters) dx,y,z	10 X 10 X2
Geographic location (Latitude, Longitude)	(34.48, 5.40)
Nesting grids	0
Reference time zone	CET/ UTC+1
Main model parameters	
Simulation Date	24th July 2017
Start & Duration of Simulation	20 :00, 24 hours
Wind speed measured in 10m height	

Wind direction	
Initial Temperature of atmosphere	
Min Temperature (simulation date)	
Max Temperature (simulation date)	
Relative Humidity in 2m height (%)	
Specific humidity at model top (2500m, g/kg)	Bi-hourly input was forced by data from Biskra meteorological station
Min humidity (simulation date	
Max humidity (simulation date	
Element typeand Albedo	
Asphalt road [ST]	0.2
Concrete wall [C5]	0.3
Palm large trunk, dense, small [PLDS]	**Height**= 5m, **crown's volume (m^3)** = 18, **number of palms**= 5.

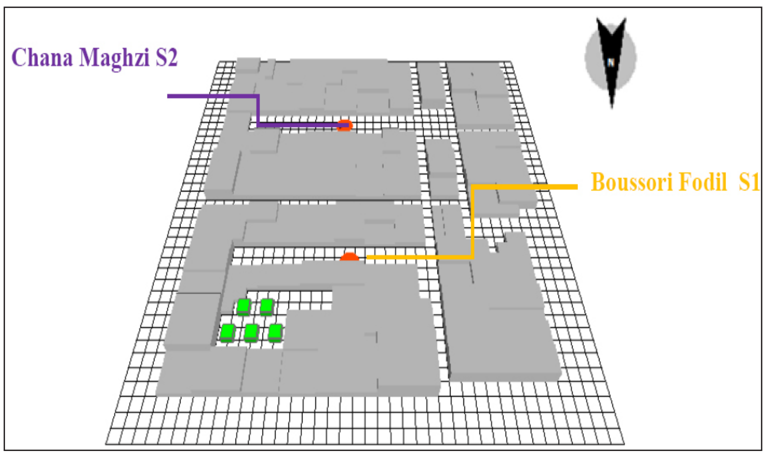


Figure 6. Generic model: Sahet El Houria district Biskra – Algeria via ENVI-met 4.4.6.

RESULTS AND DISCUSSION

From the results shown in figures 7 to 12 and table 4 to 6, it is clear that air temperature, air speed and relative humidity vary differently from (S1) and (S2). There is a convergence between the measured values and simulated ones in both streets. The values we have recorded in 25th July 2017 are not the same as the ones of Biskra meteorological station. They are higher. This difference between values can be explained by the impact of urban environment.

Air Temperature

The highest value of air temperature was observed in station 2 measured (Chana Maghzi street). It reaches 44.4 C° at 2 p.m. The value of air temperature simulated in station 2 showed the lowest value at 8 a.m. This increase can be explained by its physical environment (anthropogenic heat, energy consumption, air conditioning, albedo and thermal conductivity of materials.....etc). Air temperature values are listed in table 4 and are shown in figure 7, 8.

Table 4. Temperature trend of the air temperature values measured by the Testo 480, those of Biskra weather station data and simulated.

Air T (C°)	8 a.m	10 a.m	12 a.m	2 p.m	4 p.m	6 p.m	7 p.m
S1 measured	36.9	40.5	41.4	42.9	42.3	41.3	40.1
S2 measured	37.6	39.8	43	44.4	43.4	41.3	40.3
Meteo station	28.6	30	32	34.2	37	38	38
S1 simulated	34.7	39	40.5	41.2	42.25	41.2	40
S2 simulated	34.5	39.5	42	41.2	42.25	40.6	39.3

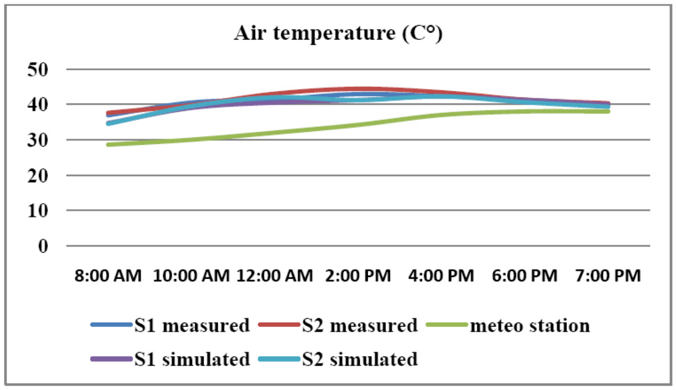
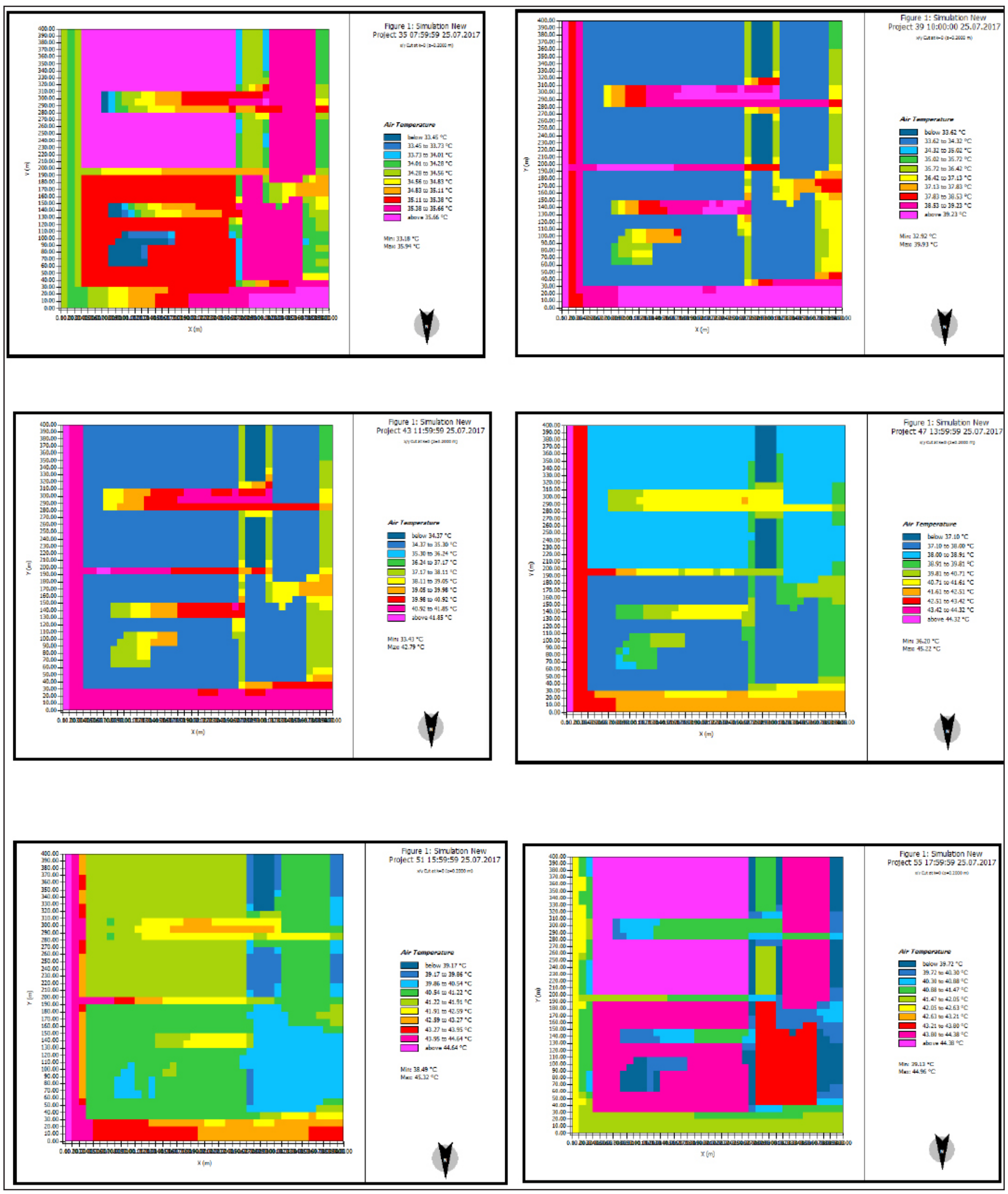


Figure 7. Air temperature trend values measured by the Testo 480, those of Biskra weather station data and simulated in station 1 and station 2 at 8:00 a.m to 7:00 p.m.



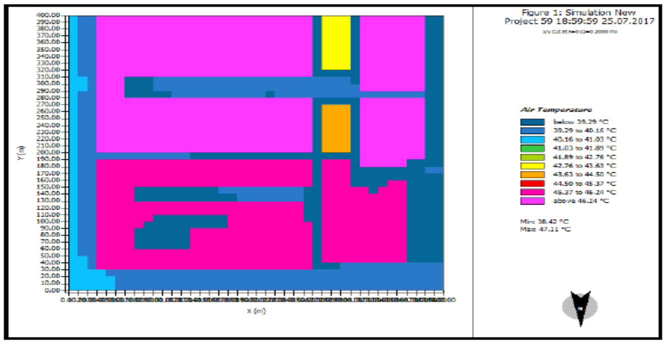


Figure 8. Air temperature profile results for Sahat El Houria district via ENVI-met LEONARDO 4.4.6.

From the comparison between the measured values of the air temperature in station 1 and station 2, an increase of 2° c is observed in the second dead end street. In S 1, the height of dwelling reaches 9 m with a width street of 7.50 m. The height of dwelling in S 2 reaches 6 m with a width street of 8 m.

The Effect of Urban Canopy

It is important to describe the fundamental impact of the urban canopy. The layer that has been simulated includes both closed volumes (buildings) and open volumes (streets).

According to the results of the simulation, Sahat El Houria district is characterized by a strong heterogeneity including the type of surfaces, the materials used and the heights of buildings as well as the length of roughness. The urban canopy layer consists of the rough urban element from the ground to the mid-level of the roofs. Several parameters (anthropogenic heat, energy consumption, air conditioning, albedo and thermal conductivity of materials.....etc.) added to the lack of urban vegetation lead to the formation of urban heat island in the district.

Air Velocity

As we have mentioned, the air velocity values are not the same in both situations. The lowest value of air velocity observed in station 1 was measured at 7 p.m. In conclusion, we note that the results of air velocity measured and simulated in station 1 and station 2 are close to each other. Air velocity values are listed in table 5 and shown in figure 9 and 10.

Table 5. Air velocity values measured by the Testo 480, those of Biskra weather station data and simulated.

V air (m/s)	8 a.m	10 a.m	12 a.m	2 p.m	4 p.m	6 p.m	7 p.m
S1 measured	0.5	0.7	1.2	0.6	1.3	1.2	0.4
S2 measured	0.9	1.0	0.6	0.5	1.5	1.2	0.5
Meteo station	7.22	5.27	5.55	1.94	12.22	6.11	3.61
S1 simulated	0.6	0.74	1.10	0.55	1.1	1.2	0.41
S2 simulated	0.65	0.7	1.3	0.85	1.45	1.4	0.63

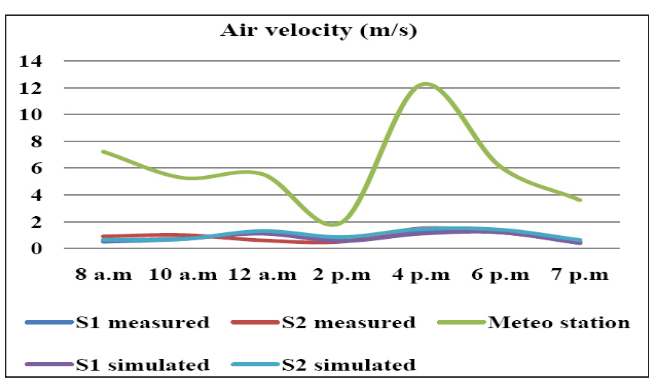


Figure 9. Air velocity values measured by the Testo 480, those of Biskra weather station data and simulated in station 1 and station 2 at 8:00 a.m to 7:00 p.m.

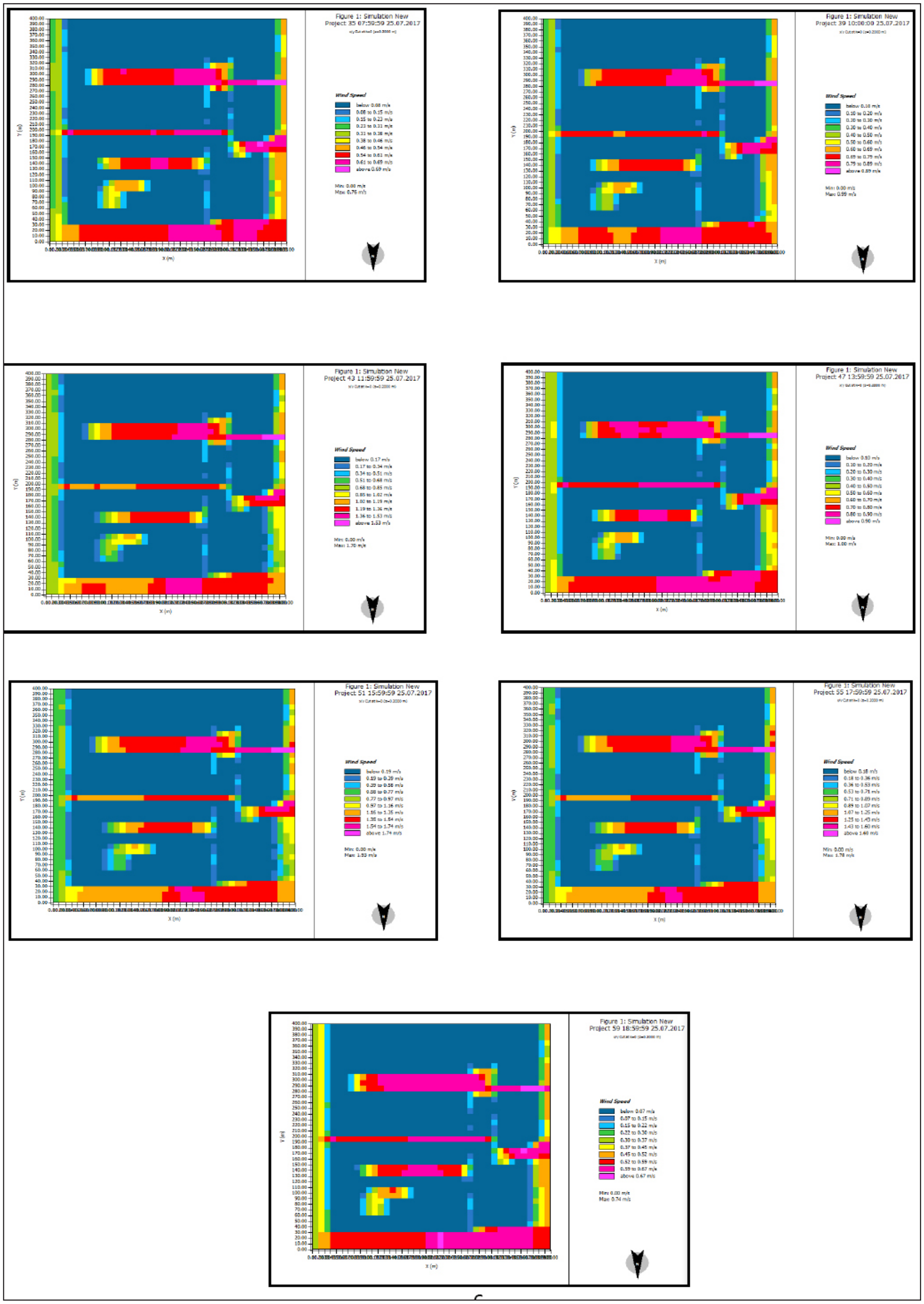


Figure 10. Air velocity profile results for Sahat El Houria district via ENVI-met LEONARDO 4.4.6.

The urban heat island phenomenon at Sahat El Houria district is due to the decrease in air velocity values. As we all know, this phenomenon results in an increase of air temperature and the decrease in air speed. It is caused by the storage of heat in surface materials through the day time. The produced warm is released at night.

Relative Humidity

It is noted that all the results (measured, simulated and those of Biskra meteorological station) are closer to each other. According to the relative humidity measured results, the lowest values at 4 p.m in station 1 is 12.8%. The highest value of relative humidity at S 2 measured and at the meteo station is the same. The value reaches 32 %. It can be explained by the lack of green and blue spaces in this study area. Relative humidity values are listed in table 6 and shown in figure 11 and 12.

Table 6. Relative humidity values measured by the Testo 480, those of Biskra weather station data and simulated.

HR (%)	8 a.m	10 a.m	12 a.m	2 p.m	4 p.m	6 p.m	7 p.m
S1 measured	31.2	28.6	23.2	17.5	13.9	14.7	15.5
S2 measured	**32**	27	20.5	15.2	**12.8**	14.7	15.6
Meteo station	**32**	25	23.4	19	13.9	14.7	15.5
S1 simulated	30.6	24.2	22.1	19.2	15.2	17.5	19.4
S2 simulated	**32**	26.1	23.6	19.2	14.5	17.5	20.1

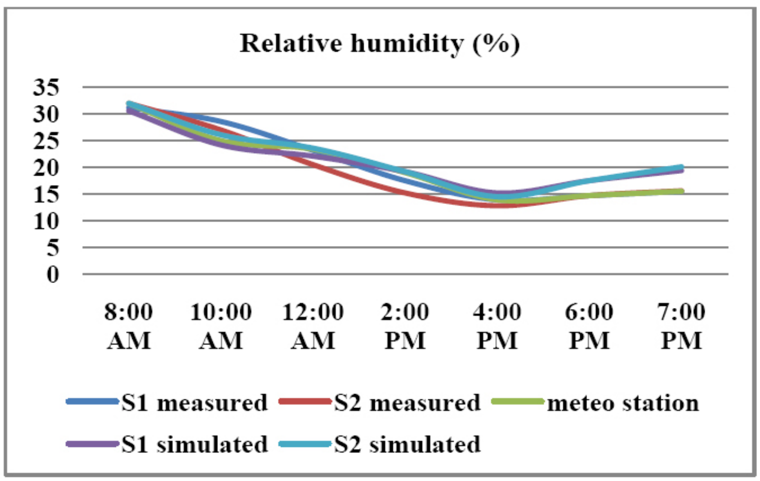
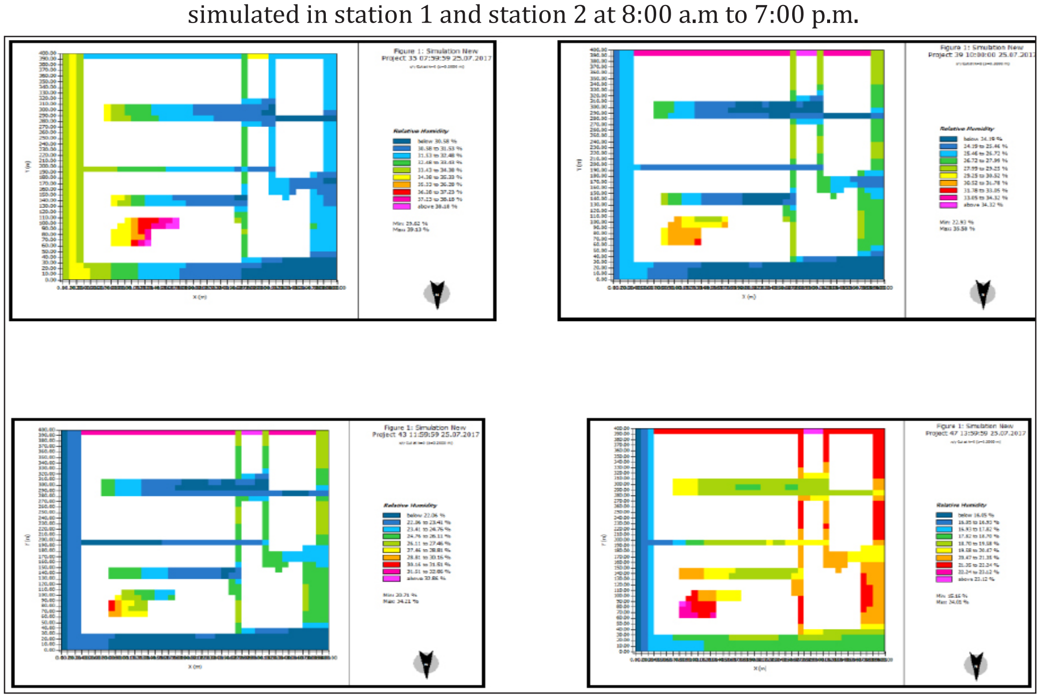


Figure 11. Relative humidity values measured by the Testo 480, those of the Biskra weather station data and simulated in station 1 and station 2 at 8:00 a.m to 7:00 p.m.



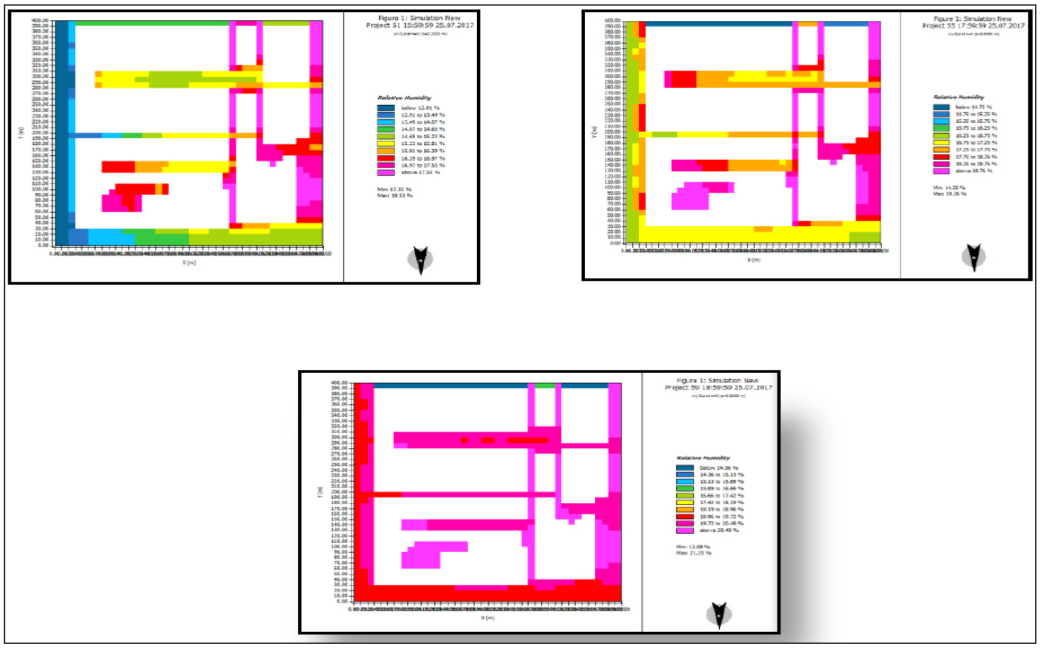


Figure 12. Relative humidity profile results for Sahat El Houria district via ENVI-met LEONARDO 4.4.6.

The slight increase in relative humidity in the second cul-de sac (S2) is due: firstly, to the width of the street, through air fluidity (the air is not stagnant) with a sharp drop in air temperature. Secondly, it is due to the shadow provided by the height of buildings. At last, we note that the shadow gives some cooling in the street (S2) which is wetter than street (S1).

Mean Radiant Temperature (Tmrt) Values

From the results shown in table 7 and figure 13, it is clear that Tmrt vary differently from the simulated model.

Table 7. The different mean radiant temperature values in station 1 and station 2 at 8 :00 a.m to 7 :00 p.m.

Tmrt	8 a.m	10 a.m	12 a.m	2 p.m	4 p.m	6 p.m	7 p.m
S1	63.57	74.3	73	76.8	81.4	72.58	40
S2	63.41	74.11	74.8	77	81.18	72.58	40

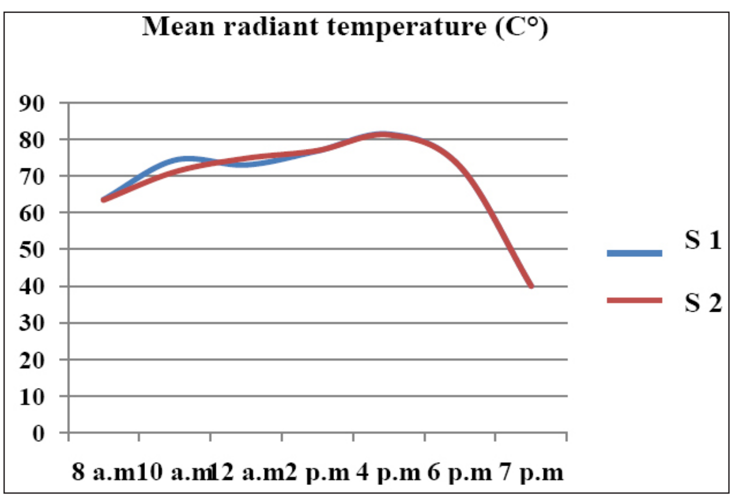


Figure 13. Mean radiant temperature values in station 1 and station 2 at 8:00 a.m to 7:00 p.m.

Generally, we note that the results are closer to each other in station 1 and station 2. Tmrt values increase in the daytime (8 a.m to 4 p.m). But they decrease at 6 p.m to 7 p.m.

We note that the highest values of Tmrt at Boussori Fodil street (station 1) and Chana Maghzi street (station 2) at 6 p.m are not similar: Tmrt S1=81.4 C° and Tmrt S2 = 81.18 C°.

The same lowest value of Tmrt was observed at Boussori Fodil Street (station 1) and Chana Maghzi Street (station 2) at 7 p.m. They reach 40°C in both Tmrt S1 and Tmrt S2.

Physiogical Equivalent Temperature (PET)

The outdoor hygrothermal comfort is influenced by both climatic and non-climatic conditions. The main climatic parameters that are used to represent the hygrothermal comfort of outdoor spaces are air temperature (Ta), air velocity (Va), relative humidity (RH) and mean radiant temperature (Tmrt) in addition to personal characteristics such as: age, sex, activity levels and clothing (CLO).

PET is defined as "*the air temperature at which, in a typical in-door setting (without wind and solar radiation), the energy budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed*" (H¨oppe, 1999).

In this research, PET is expressed in Celsius and assumes clothing (CLO) values is 0.44 (with summer clothes) and a metabolic rate of 110 W for a man who is walking. His age is 35 years. He has a weight of 75 kg and a height of 1.75 m. These parameters are the average site users**.**

In this investigation PET index is simulated through the ENVI-met BioMet version 1.5 in two dead end streets: the first one is Boussori Fodil Street (station 1) and the second one is street Chana Maghzi (station 2).

From the results shown in table 8 and figure 14, it is clear that PET vary differently from the simulated model.

Table 8. PET values in station 1 and station 2 at 8:00 a.m to 7:00 p.m.

PET(C°)	8 a.m	10 a.m	12 a.m	2 p.m	4 p.m	6 p.m	7 p.m
S1	47,4	50,5	48,7	51,6	50,1	49,9	49,2
S2	**47,2**	48,9	50,4	**52,2**	49,5	49,9	49,2

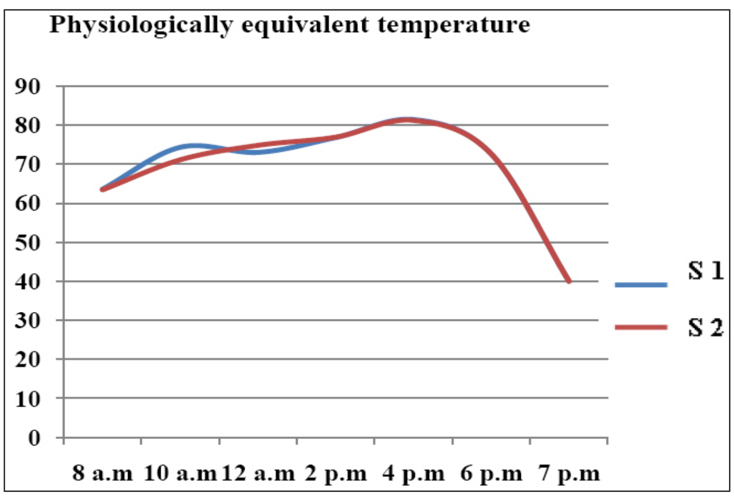


Figure 14. Physiologically equivalent temperature values in station 1 and station 2 at 8:00 a.m to 7:00 p.m**.**

At the same street (Chana Maghzi) station 2, we noted that the highest PET value at 2:00 p.m is 52.20 C° whereas the lowest PET is 47.20 C° at 8:00 a.m.

In order to assess the pedestrian outdoor hygrothermal comfort, PET scale is shown in both research (Matallah, 2020) and (Beer sheva, 2019). It is listed in table 9.

Table 9. The adjusted PET scale for Beer Sheva in Israel (BWh). Sources: (Cohen. P, et al, 2019) (Matallah. M.E, et al, 2020).

<table>
<tr><td>Matallah, 2020</td><td>Thermal comfort stress level</td><td>17–26
Neutral no stress</td><td>26–28
Neutral no Stress
Slight heat stress</td><td>28–37
Warm
Moderate heat stress</td><td>37–42
Hot
Strong heat stress</td><td>>42
Very hot
Extreme heat stress</td></tr>
<tr><td rowspan="2">Cohen, 2019</td><td rowspan="2">(BWh)
Thermal sensation</td><td>< 6 Very cold</td><td>6- 8cold</td><td>8 -13cool</td><td>13 - 17
Slightly cool</td><td>17 -26
Neutra</td></tr>
<tr><td>26 -28
Slight warm</td><td>28 – 37
Warm</td><td>37 - 42
Hot</td><td colspan="2">>42
Very hot</td></tr>
</table>

All PET values obtained from this study are higher than the greatest values in the adjusted PET scale.

CONCLUSION

Thanks to this research we have carried out, we highlighted the effects of dead end streets configuration on the urban heat island risk at Sahat El Houria district in Biskra. We also studied its effects on hygrothermal comfort level with the impact of cul-de-sac streets configuration. It remains that the main purpose of our research is to ensure the pedestrian outdoor hygrothermal comfort by using advanced simulation method.

The measured and simulated results confirm the presence of urban heat island in Sahat El Houria district. The difference in the recorded air temperature was 2°C. The results we obtained for relative humidity are close to each other. However, we noted that a great difference in the values of air velocity between Biskra meteorological station and those we have measured and simulated. This are due to several reasons including:

- Reduced green spaces and urban vegetation creates a reduced shading street and low evapotranspiration resulting in high air temperature and low relative humidity in the district.
- High H/W ratio and high albedo (emissivity of materials) creates a great heat absorption which causes an increase of temperature at night time in dead end streets.
- Reduced air velocity is due to urban surfaces roughness.
- High anthropogenic heat that is rejected from air conditioned dwellers, buildings energy and traffic road at Boussori Fodil Street and Chana Maghzi Street.

The results demonstrate that the outdoor hygrothermal comfort of pedestrians in Sahat El Houria district can be changed significantly with the width of the street (dead end street) and the shade provided by the height of buildings. It can be also changed by the physical environment (anthropogenic heat, energy consumption, air conditioning, albedo and thermal conductivity of materials, etc.).

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Competing of interests

The author(s) declare that they have no competing interests.

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Citation: **Zahra Ferhat, Noureddine Zemmouri***. Study of the Effects of Dead-End Street Configuration on Pedestrian Hygrothermal Comfort Using an Advanced Simulation Method. Case study: Sahat El Houria Biskra, Algeria. Int J Innov Stud Sociol Humanities. 2022;7(11): 26-41. DOI: https://doi.org/10.20431/2456-4931.071103.*