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Natural Daylighting in Traditional Architecture: A Case Study of Courtyard Houses in the Oasis City of M'chouneche, Algeria

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Abstarct

Oasis houses are known for their sensitive architectural response to the region's climatic conditions and socio-cultural norms. Courtyard is one of the invariants in oasis architectural forms that contributed in determining climatic, physical and psychological interior environment. Given its effectiveness as an interior micro climatic regulatory element, the daylight behavior of the courtyard in this type of houses is one of the most important passive strategies that can affect the nature of activities and the use of space in a daily manner, Without having to use the interior spaces to do various tasks. In this respect, this article presents an experimental study carried out to clarify the impact of the courtyard on visual efficiency of oasis houses located in the city of M'chouneche (Biskra), using simulation software on model of a real house. The simulation process was carried out at solstice days and spring equinox, taking into account the climatic data of the city of M'chouneche. The experimental results confirm that the obtained quantity of daylight in the most of interior spaces no matter it is not compatible with the required values, gives certain balance with the life style of occupant and the use of courtyard its self.

Key words : courtyard, natural daylight, oasis houses, visual performance.

INTRODUCTION

The luminous comfort of the buildings and especially in the habitat does not belong to the past, nor of the future, it is also a constant of the architecture. Thus the search for visual satisfaction in houses, which aims at the satisfaction of the physiological and psychological comfort of the occupants, is located at the hinge of a traditional historical knowledge, integrating traditional devices compatibles with the natural data of the site, which are found largely applied in oasis houses.

For many centuries and to the present day, the courtyard pattern has been used as one of the most characteristic forms of oasis houses in vernacular architecture (A. Muhaisen, M. Gadi, 2004), Which ensures by its direct relation to the outdoor environment many indoor climatic performances: thermal regulator, natural air conditioner, natural daylight-enhancing tools (A. Aldawoud, 2008). In addition to its environmental functions, the courtyard has a notable and crucial role in social life of its users by creating a point of interaction between family (Ahmed A. Freewan, 2011) and produce an extension of adjacent interior spaces (Fatma. A & al, 2016) where they can do their various daily activities such as gardening, cooking, working, playing, sleeping, or even in some cases as places to keep animals (Edwards & al., 2006).

In oasis area with hot and arid climate, the most field measurement and simulation based studies have been conducted regarding courtyard houses and their thermal performances (Hao. S, & al, 2019). But also the study of natural daylight performance of courtyard developed from the analytical formulae to the most recent research which uses computer simulation (I. Acosta & al, 2014). Those studies are carried out on many daylight factors (reflectance, contrast, luminance and illuminance, daylight factor...) (Wright et al, 1998), based on:

- The different characteristics of courtyard its self: form, size, orientation, (A. Abdulbasit & al, 2014), opening ratio, interior walls components and geometries (F. Elsiana et al, 2017).
- Climatic data of the site.

The overall objective of this article is to clarify the visual efficiency of the courtyard as a traditional device of natural daylight in oasis houses. More specifically, the goal is to know how the courtyard can contribute to achieve a satisfaction value of visual comfort compatible with different daily activities in the oasis houses. The results indicate the influence that the courtyard in oasis house plays as a complementary outdoor space that guarantees a quantity of natural daylight compatible with the different daily activities in the other adjacent interior spaces.

PRESENTATION OF CASE STUDY

Environmental Data

M'chouneche is a small oasis of 93,000 palm trees and more than 7000 inhabitants installed at more than 300 meters of altitude. The commune is located 30 km northeast of the city of Biskra (figure 1): one of the Saharan regions in the South East of Algeria. Typical of Sahara town, it is characterized by a hot and dry climate most of the year (table 1) with a short winter extending from December to February (Guedouh, M.S.; Zemmouri, N, 2017). The geographical features of the city are:

- The latitude = 34.48 N.
- The longitude = 5.44 N.
- The altitude which is equal to 128 m above sea level.

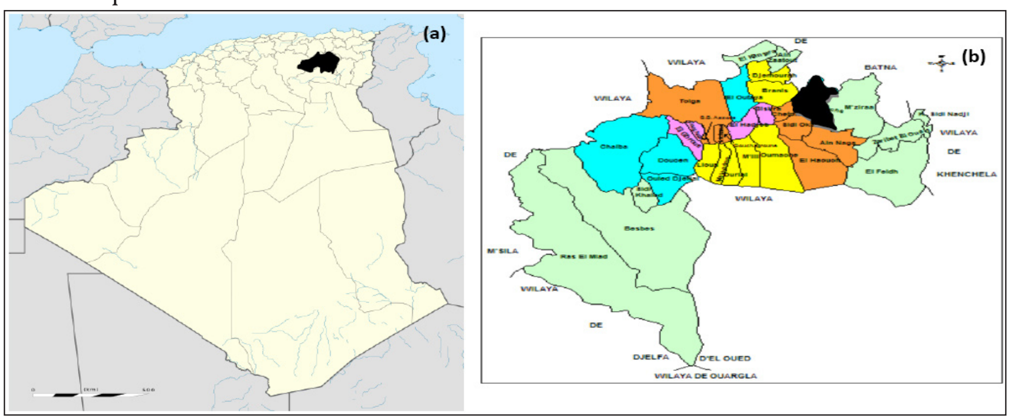


Figure 1. (a) location of the city of Biskra; (b) location of M'chouneche oasis. (Source: http://www.carte-algerie.com/carte-algerie-wilayas.html. consulted the 07/08/2019)

Table 1. Climatic Data of Biskra

Temperature	Relative Humidity	Precipitation
Max. Temp: 42 °C in July Min. Temp:7 °C in January Average annual Temp: 21.5 °C	Max. R.H: 50% in January Min. R.H:10% in July	Max: 200 mm per Year

Characterization of Oasis House Sample Case

Our choice of study was focused on one sample of the houses located in a Douar (Dachra) in the M'richi area north of the city of M'chouneche. The site is built on a hill that overlooks a vast palm grove on the edge of the valley of Ighzer amellal (figure 2).

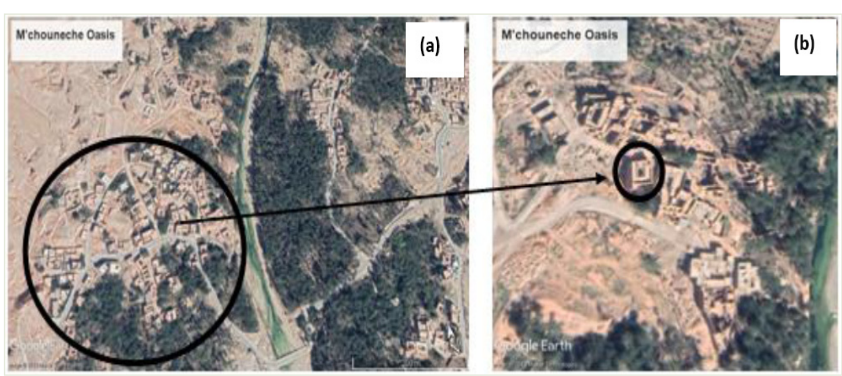


Figure 2. (a) Study area situation in the oasis; (b) location of courtyard oasis house sample case. (Source: author)

The chosen house is built with an introvert plan type with a surface of 165 m^2 (15*11m), opaque facades without exterior windows except one with very small opening ratio which is used for control reasons. It is built of local materials (mud, palm, and stone) with walls covered by plaster with a thickness of 50 cm.

With the presence of squifa at the main access of the house, all the other pieces (rooms, kitchen, and depot) are organized around a central courtyard, the contact between them is ensured by the doors or small windows in height with the exception of one room which has a window with a surface of 1.80 m^2 (figure 3).

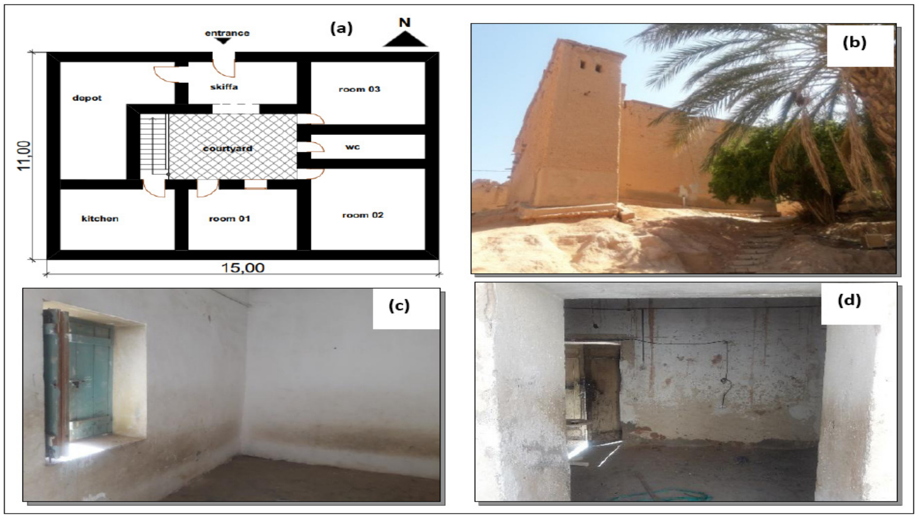


Figure 3. (a) plan of the house sample case; (b) the opaque façade; (c) room view; (d) skiffa. (Source: Author)

Courtyard's House Characterization

To characterize the courtyard of the chosen house geometrically, the method of Muhaisen and Gadi was used (A. Muhaisen, M. Gadi, 2006). This courtyard presents a simple cuboid with two different values of ratios: R1 indicate the depth of the form (R1= P/H) and R2 present the elongation of the form (R2= W/L) (table 2).the courtyard present similar materials as all spaces in the house. All the walls that surround it are painted in a light color with no shading or lighting devices (figure 4).

Table 2. Geometric data and ratio results for the courtyard

	Geometrical data		**Resulting ratios**
	Surface, S	17.15 m^2	
	Perimeter, P	16.80 m	R_1= 3.36= 3.40
	Height, H	5.00 m	R_2= 0.71= 0.70
courtyard	Width, W	3.50 m	
	Length, L	4.90 m	**Boxed type form**

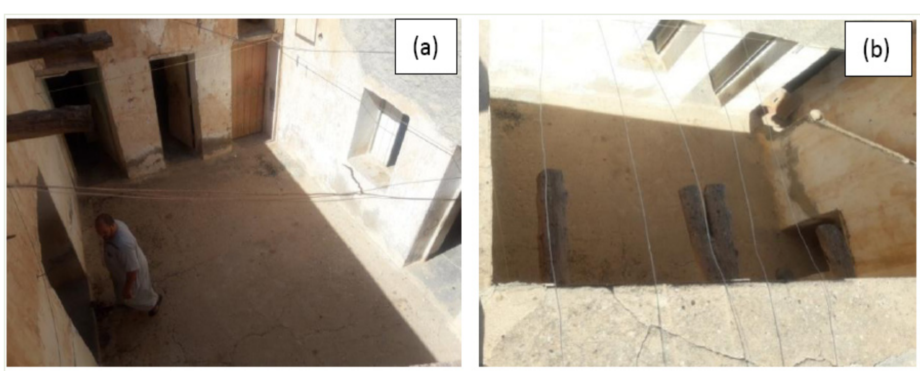


Figure 4. Courtyard views. (a) Shading effect of the courtyard; (b) view of the courtyard from the terrace. (Source: Author)

METHODOLOGY

To investigate the impact of the courtyard on daylight level in the adjacent interior spaces, and to see the extent of its efficiency as a support element for these areas to carry out various daily activities in a suitable and comfortable luminous environment, experiment with simulation as a tool was used as research method. A radiance-based computer simulation which had been validated in previous research was employed (Lim Y W & al, 2012).

Because of the complexity of the phenomenon of natural light, the study will be limited to studying the performance of a single physical parameter that is the illumination received on the horizontal surface in each simulated area.

The main steps of the experimental work are described as follows:

- The choice of simulated spaces in the chosen house:

To see how the courtyard influenced the lighting of the interior areas, two areas were selected in addition to the courtyard itself.

The selection of these two areas was based on the type and the surface of openings overlooking the courtyard: the first space is a room (room 1) oriented North with two openings (the door and a window with 1.8 m^2 of surface) (figure 5), the second (room 2) is also a room oriented West with a door and a very small window in height (0.35m^2) (figure 6).

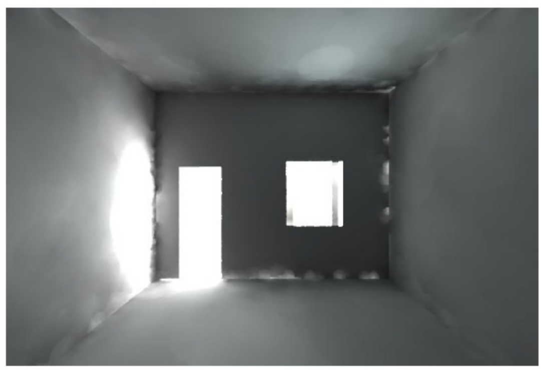


Figure 5. Room 1 simulated interior view by radiance Software in December 21 at 16 pm. (Source: Author)

Figure 6. Room 2 simulated interior view by radiance Software in December 21 at 16 pm. (Source: Author)

- Simulation tool:

The simulations for the study of the levels of illumination were carried out using the software Radiance 2.0 BETA.

- Simulation period:

All the models were simulated under inputs of the city's climate data of Biskra, to define their visual and thermal performance in this hot and arid region.

The period of the experiment is fixed at Solstice Days and Spring Equinox (December 21st, June 21st and March 21st)., and the hours of the illumination simulation are at 8h, at 12h and at 16h.

- After simulation, a Summary table of average illuminance areas in (%) was created (table 3), based on the Percentage illuminance zones and their indications in the visual comfort scales according to the amount of illuminance recommended by IESNA (Rea, M. S, 2000) to carry out various daily activities in each simulated area (table 4).

Table 3. Summary table of average illuminance areas in (%) for each month, hour.

Average illuminance areas in%	Indications in the visual comfort scales
% < 150 lux	Insufficient
150 lux < % <550 lux	Adequate
550 lux < % < 950 lux	Desirable
% > 950 lux	Uncomfortable

Table 4. Recommended illuminance levels from IESNA.

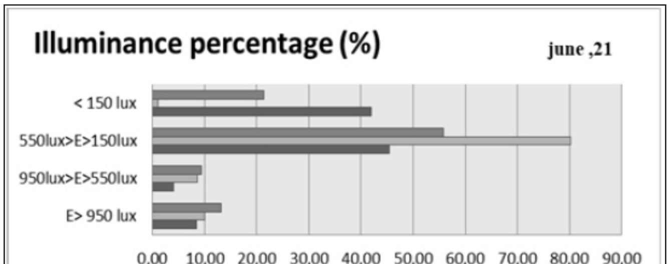
Room type	Recommended illuminance level
Bedroom	200-300 Lux
Kitchen	300-750 Lux
Living room	100-200 Lux
Corridor	100-200 Lux

RESULTS AND DISCUSSION

As mentioned before and in addition to the courtyard, two types of rooms in a oasis house were simulated to give a clear vision about the natural daylight performance of the courtyard, more exactly the level of illuminance received by surface in adjacent spaces and its relationship with this last. The results show that:

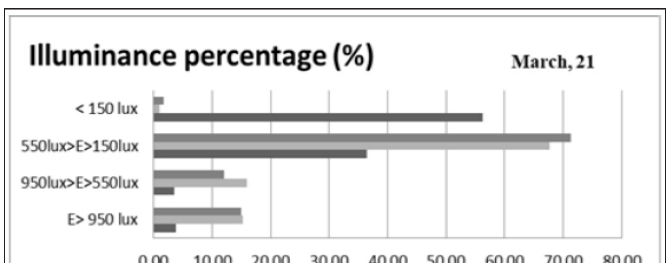
- *Room 1:*

The largest percentage of illuminance recorded by simulation results was adequate in visual comfort scale in all selected months with an average of 60. 55% of adequate illuminance in June (figure 7), 58.50% in March (figure 8) and 49.40% in December (figure 9). These percentages were caused by the amount of natural light provided by the window and the door overlooking the courtyard, which allows the users of the room to perform daily tasks that require sufficient light



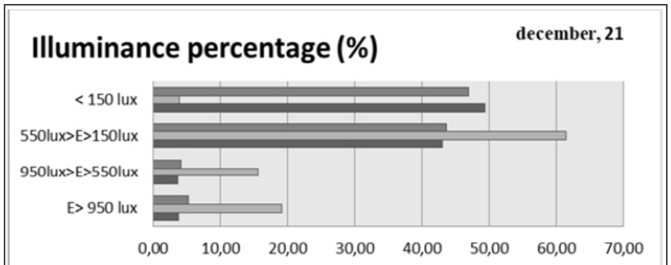
	E> 950 lux	950lux>E>550lux	550lux>E>150lux	< 150 lux
16 p.m	13,25	9,45	55,90	21,40
12 a.m	10,05	8,70	80,25	1,00
8 a.m	8,50	4,00	45,50	42,00

Figure 7. Illuminance percentage average (%) for room 1 in summer solstice. (Source: Author)



	E> 950 lux	950lux>E>550lux	550lux>E>150lux	< 150 lux
16 p.m	15,00	12,00	71,25	1,75
12 a.m	15,25	16,00	67,75	1,00
8 a.m	3,75	3,50	36,50	56,25

Figure 8. Illuminance percentage average (%) for room 1 in spring equinox. (Source: Author)

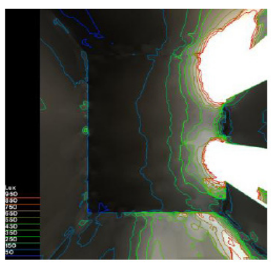
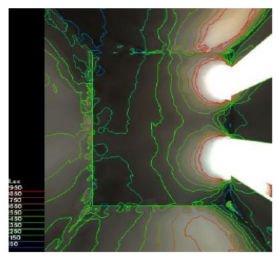
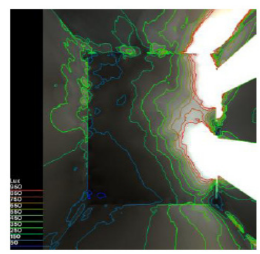
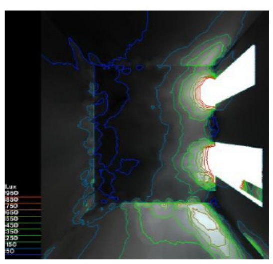
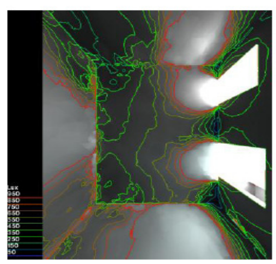
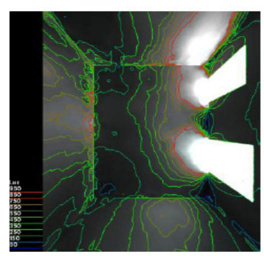
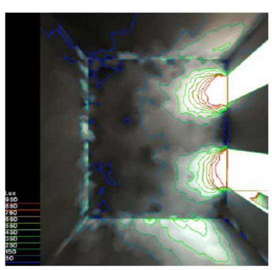
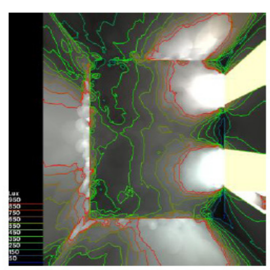
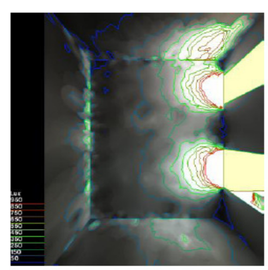


	E> 950 lux	950lux>E>550lux	550lux>E>150lux	< 150 lux
16 p.m	5,25	4,10	43,65	47,00
12 a.m	19,15	15,55	61,45	3,85
8 a.m	3,80	3,65	43,10	49,45

Figure 9. Illuminance percentage average (%) for room 1 in winter solstice. (Source: Author)

At summer Solstice (21 June), the results indicate that there is a remarquable percentage of insufficient illuminance in the depth zone of the room (table 5) at the earliest and the latest hours of the day (42.00% at 8.00 am and 21.40% at 16.00 pm) (figure 7), caused by the sun's course which is the highest in this solstice which did not allow light rays to enter.

Table 5. Isolux plot of room 1 illuminance simulation.

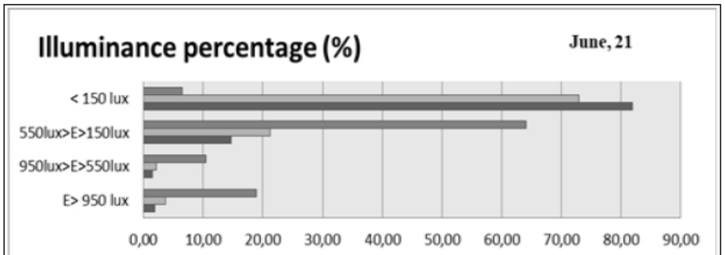
	8.00 am	12.00 am	16.00 p.m
June			
March			
December			

At winter Solstice (21 December), we found also that the insufficient illuminance percentage in the depth zone of the room (table 5) at the earliest and the latest hours of the day was significant (49.45% at 8.00 am and 47.00% at 16.00 pm) (figure 9), caused by the sun's course which is the shortest and the lowest above the horizon in this solstice which make the sun's rays collided with the surrounding walls (H=5.00m) of the courtyard.

That It is noted also that there is no more than 10.45% of the uncomfortable illuminance in all months, but in all cases, this uncomfortable zones registered in zones front of window or door (table 5) which are not used often to perform domestic daily activities.

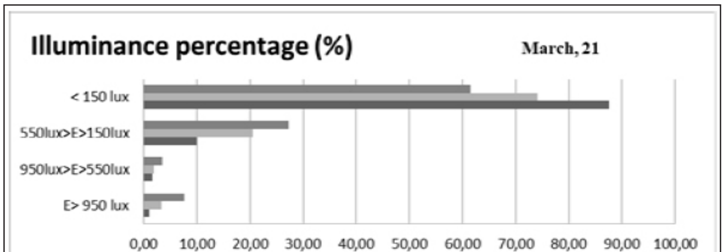
- *Room 2:*

Contrary to the first room, the results of this room were mostly indicating a high percentage of insufficient illuminance level with an average of: 53.76% in June (figure 10), 74.42% in March (figure 11) and 84.36% in December (figure 12).



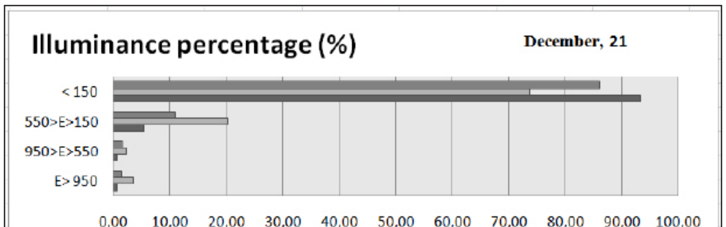
	E> 950 lux	950lux>E>550lux	550lux>E>150lux	< 150 lux
16 p.m	18,90	10,47	64,08	6,55
12 a.m	3,65	2,20	21,25	72,90
8 a.m	1,96	1,49	14,71	81,84

Figure 10. Illuminance percentage average (%) for room 2 in summer solstice. (Source: Author)



	E> 950 lux	950lux>E>550lux	550lux>E>150lux	< 150 lux
16 p.m	7,65	3,53	27,25	61,57
12 a.m	3,33	1,96	20,59	74,12
8 a.m	0,98	1,57	9,88	87,57

Figure 11. Illuminance percentage average (%) for room 2 in spring equinox. (Source: Author)



	E> 950	950>E>550	550>E>150	< 150
16 p.m	1,45	1,57	10,94	86,04
12 a.m	3,61	2,27	20,39	73,73
8 a.m	0,59	0,59	5,49	93,33

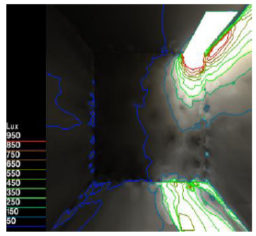
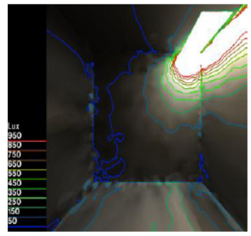
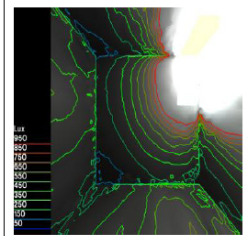
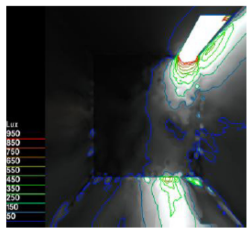
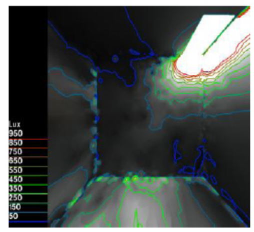
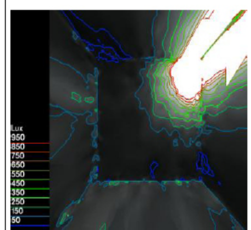
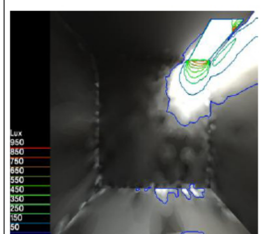
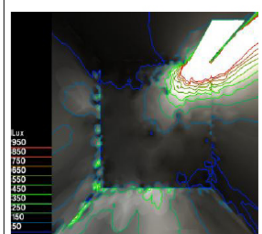
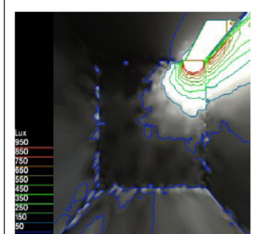
Figure 12. Illuminance percentage average (%) for room 2 in winter solstice. (Source: Author)

The lack of a sufficient ratio of openings in this room that ensure a direct relationship with the external environment, which is represented by the courtyard is the main cause of this percentage and which do not allow users of this space to carry out daily activities indoors that require a specific amount of light, especially that requires a lot of accuracy or that have many details: sewing, embroider or Purification of wheat for example.

In the other side, this average of insufficient illuminance may be useful if this room is used as a sleeping or napping area because sombre places are more comfortable for these activities.

As figures 10, 11, 12 show, it is noticeable that there is a 21.95 % of adequate illuminance average by year, And a large portion of this ratio recorded in the summer solstice (33.34% in June) because of the height course of the sun in this month and the existence of a small window in height which contribute also to introduce some sun rays interior the space. This quantity of light is most often found in the forward areas near the door and not in depth (table 6).

Table 6. Isolux plot of room 2 illuminance simulation.

	8.00 am	12.00 am	16.00 p.m
June			
March			
December			

- *Results of the courtyard simulation:*

Obtained results from courtyard simulation indicate that the courtyard perform as an outdoor area with an illuminance average between 2500 lux to 9500 lux as a major value in all period of the experiment As shown in the Isolux plot in figures 13, 14 and 15.

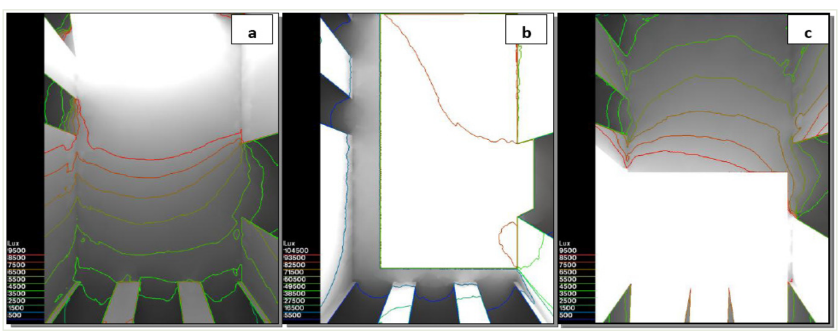


Figure 13. Isolux plot of courtyard illuminance simulation in summer solstice. (a) At 8.00 am; (b) at 12.00 am; (c) at 16.00 pm. (Source: author).

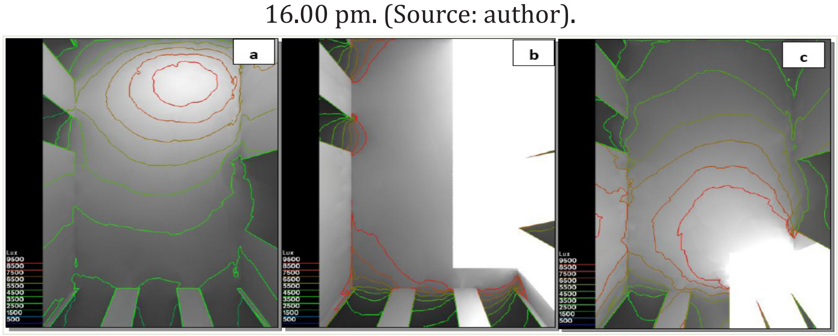


Figure 14. Isolux plot of courtyard illuminance simulation in spring equinox. (a) At 8.00 am; (b) at 12.00 am; (c) at 16.00 pm. (Source: author).

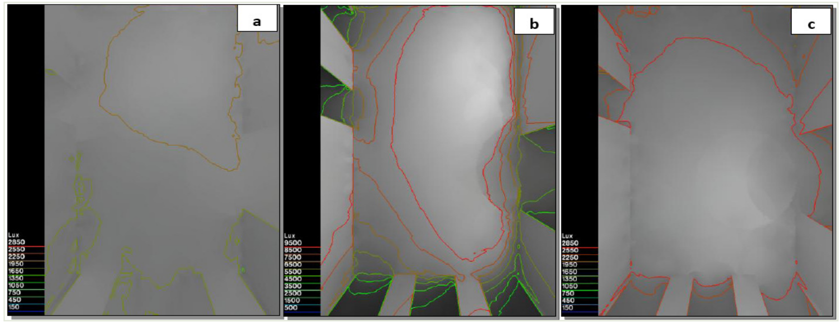


Figure 15. Isolux plot of courtyard illuminance simulation in winter solstice. (a) At 8.00 am; (b) at 12.00 am; (c) at 16.00 pm. (Source: author).

Although these values appear to be very large on the recommended values of illuminance in the visual comfort scale for performing daily house activities, but as previously shown results of the two rooms, the courtyard can works as an extension of this spaces especially when they have minimum contact with the exterior environment as previously seen in room 2.

These results confirm previous research in that the courtyard is the heart of the house, where different functions can take place during the day in full light. This "outdoor room" can be used as an extension of the kitchen or rooms in the mornings or as an extension of the living room in to entertain guests (Sthapak et al, 2014). The courtyard is a multifunctional space invites users to spend more time with no problem with the quantity of light needed when the daylight has insufficient quantities in the rooms because of the reduced size of the window and its location (above the door). Furthermore, the courtyard acts as a light reservoir by the important quantities of light he receives, serving adjacent rooms when there is a large opening ratio that serves to introduce light rays into the interior like previous case in room 1.

CONCLUSION

This paper presents the main results of an experimental study consecrate to highlight the visual performance of the courtyard in oasis house in the city of M'Chouneche. It has focused on determining the influence of the courtyard on the quantity of light in its peripheral spaces in the house and how it can contribute in the achievement of a natural daylight environment equivalent and comfortable with the nature of daily house activities for residents.

Regarding the interdisciplinary of the field of natural lighting, this study is limited to studying one physical parameter: the illuminance received by the horizontal area in each chosen space for simulation by Radiance software.

The obtained results shows that the courtyard in an oasis house work as a two duality element in providing a sufficient amount of natural daylight to perform different tasks:

- For pieces which have a sufficient opening ratio toward courtyard: the courtyard provide an adequate illuminance values equivalents with the recommended illuminance values in the visual comfort scale. The adequate openings enable sun rays to pass through the space according to sun course, date and hour. Here the courtyard works as source of natural daylight.
- For pieces which have an insufficient opening ratio toward courtyard: from the result, these pieces have always a problem of darkness because of the insufficient illuminance values which are not identical with the recommended in the visual comfort scale. In this case, the courtyard works as an exterior extension of these spaces, used to execute different daily house activities in a suitable visual environment.

To conclude, it has become clear that the courtyard in oasis house has a great importance not only in providing thermal comfort or ventilation, But it is also an essential element in providing and improving the natural daylight environment commensurate with the nature of daily household tasks.

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