Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 134 (2017) 894–903

Procedia Engineering

www.elsevier.com/locate/procedia

9th International Conference on Sustainability in Energy and Buildings, SEB-17, 5-7 July 2017, Chania, Crete, Greece

Sunlight analysis for the Kuwaiti Government dwelling design and effects on householders' health

Mohammad Alhazim[a]*, John Littlewood[a], Keireine Canavan[b], Penny Carey[c]

[a]*The Ecological Built Environment Reseaech & Enterprise Group,*
[b]*Digital Textiles Research Theme (DIGIT)*
Cardiff Metropolitan University, Cardiff School of Art & Design,
Cardiff, CF5 2YB, UK.
[c]*Portakabin Limited*
New Lane, Hunington, York
YO32 9PT, UK

Abstract

This paper discusses access to sunlight and daylight in contemporary Kuwaiti Government dwellings. Prevalence of vitamin D deficiency among the Kuwaiti population is related to a lack of exposure to sunlight radiation. Householders' of the contemporary Kuwaiti Government dwellings in Al-Nahda town in Kuwait have been selected as a case study for the research project. Householders' were interviewed about sunlight access into their dwelling and health issues associated with living in the dwelling. The research project includes a new design for the Kuwaiti Government dwellings, which has been analysed for sunlight and daylight access as related to Al-Nahda town location in Kuwait.

Keywords: Sunlight; daylight; vitamin D; contemporary; dwelling; householders';

1. Introduction

The State of Kuwait has an abundance of sunshine year-round. The average sunlight and daylight per year is 4383 hours, which averages to 12 hours of sunlight and daylight per day. This is divided into an average of 3347 hours (76%) of sunlight per year, or 9 hours of sunlight per day. The remaining 1036 hours (24%) is daylight per year, or 3 hours of daylight per day which is likely present with cloud, shade, haze, or low sun intensity [1].

* Corresponding author.
E-mail address: moalhazim@cardiffmet.ac.uk

10.1016/j.egypro.2017.12.492

In contrast, in the UK the average of sunlight and daylight per year is 4383 hours, which averages to 12 hours of sunlight and daylight per day. This is divided into an average of 1460 hours (33%) of sunlight per year, or 4 hours of sunlight per day. And the remaining 2923 hours (67%) is daylight per year, or 8 hours of daylight per day which is likely present with cloud, shade, haze, or low sun intensity [2]. This illustrates that the average sunlight hours in Kuwait is more than double that of the UK. However, in 2017 a few studies estimated that nearly 100% of the Kuwaiti population suffers from lack of vitamin D [3 and 4], but only about 40% of the UK population suffers from vitamin D deficiency [5]. Despite the tremendous availability of sunlight in Kuwait compared with the UK, the percentage of vitamin D deficiency in the Kuwaiti population is more than double that of the UK population. The high percentage of vitamin D deficiency in the Kuwaiti population is likely related to the custom of covering the body, particularly with women, for local cultural and religion reasons.

In Kuwait, the household dwelling is the main place where householders' can uncover their body for personal comfort. Also, as dictated by Kuwaiti culture, this is where women spend the majority of their time. Hence, the dwelling is considered to be the only place where householders' can get exposure to sunlight. Before the introduction of western architecture almost 60 years ago, a traditional Kuwaiti house was designed to ensure private places for the householders' to get exposure to adequate sunlight. This resulted from a house design that focused inward on a courtyard, which provided complete privacy for the householders' (see Figure 1 below) [6 and 7]. In 2013, at the Mediterranean Green Energy Forum in Morocco, a conference paper was presented titled "Design Philosophy of the traditional Kuwaiti house". This paper explored in depth the differences between the traditional Kuwaiti house and modern architecture. After 1954, the design of the typical Kuwaiti house began to transform from the inward-focused plan to an outward oriented plan. This shift occurred due to globalization and worldwide commercial exchange, especially with western countries following the discovery of oil in Kuwait in 1938 [8 and 9]. The transformation to the outward-oriented plan in contemporary Kuwaiti house design has impeded the privacy of the householders' because of the outward-facing windows, which requires the shuttering of windows most of the day, preventing access to sunlight (see Figure 2 below). Consequently, the householders' lack of exposure to sunlight has resulted in a prevalence of vitamin D deficiency among the Kuwaiti population [10 and 11].

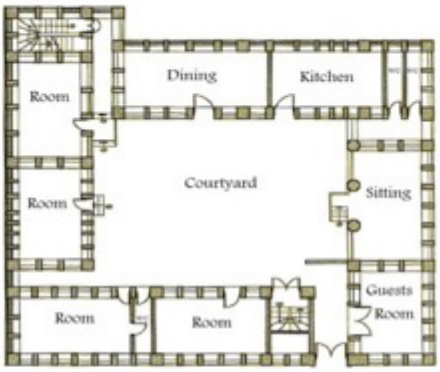

Figure 1: Inward plan of traditional Kuwaiti house (By researcher).

Figure 2: Outward plan of contemporary Kuwaiti Government dwelling (By researcher).

House design is a major contributor to human wellbeing, especially regarding space and sunlight. As urban living increases population density, there is a greater need for free space for movement, children's play, and for the flow of light and air [12]. Stagnant air and the absence of sufficient sunlight has adverse health implications on the growth of children and the wellbeing of adults. A house's green space provides an area for physical exercise, recreation, and family social interaction [13]. This paper includes a new design for the Kuwaiti Government dwelling that aims to avoid the issues identified by householders' regarding privacy and access to sunlight and daylight, which are presented by contemporary Kuwaiti Government dwelling design. The new design addresses the householders' feedback and requirements and is also compatible with an ecological design approach. The new design has been analysed for access to sunlight and daylight during summer and winter based on Al-Nahda town location in Kuwait. The results of this analysis demonstrate the new design advantages and disadvantages, and identify frameworks related to development of the new design.

2. Importance of vitamin D for housing residents in Kuwait

Vitamin D deficiency results from inadequate sun exposure and poor dietary intake of foods containing vitamin D. Lack of vitamin D can result in symptoms such as fatigue and weakness, pain in the joints and muscles, and mood swings. These symptoms are warning signs that should be addressed with treatment [17 and 18]. Vitamin D homeostasis plays a critical role in glucose metabolism, associating vitamin D deficiency with obesity and diabetes [15]. Vitamin D deficiency also increases the risk of developing a range of common conditions including heart disease, stroke, hypertension, depression, cancer, hip fractures, muscle weakness, bone pain, loss of balance, gum disease, disrupted sleep, deafness, psoriasis, multiple sclerosis, high blood pressure, body sway, recurrent infections, chronic disorders, fractures, rickets, osteomalacia, and osteoporosis [3, 14 and 18].

Recognized as a pro-hormone that plays multiple roles, Vitamin D is important in maintaining optimum health of the human body. Vitamin D is also called the sun-vitamin, since it is produced in the human body when the skin is exposed to sunlight. Vitamin D is also available through consumed food and in supplement form. Direct sun exposure represents 90% of vitamin D production in humans whereas only 10% of vitamin D comes from diet [4, 14, 15, and 16]. The functions of vitamin D in the body play an important role in modulating the immune system, serving as a potent immune-modulator, regulating cell proliferation and differentiation, and providing lymphocyte activation and cytokine production. Intake of vitamin D also helps maintain levels of calcium and phosphorus absorption in the blood; these minerals are essential for healthy bones, teeth, and muscles [17]. Also, vitamin D helps to support brain and nervous system health, regulate insulin levels and aid diabetes management, and support lung function and cardiovascular health [18]. It supplies a protective effect for the body against various diseases and conditions such as heart disease, cancer, diabetes, and multiple sclerosis [14]. Combining sun exposure and consumption of vitamin D is recommended for maintaining normal vitamin D levels. For example, vitamin D levels can typically be maintained by spending ten to fifteen minutes per day between 09:00 am to 03:00 pm three times per week, exposing 40% of the body area, such as the back, arms, and legs to the sun, as well as eating foods containing vitamin D [3, 4, and 15].

In Kuwait, the incidence of obesity and diabetes have increased alarmingly, since the discovery of oil in 1938. [15]. According to the Kuwaiti Ministry of Health, in 1970 obesity affected approximately 11% of the Kuwaiti population, while diabetes affected approximately 6%. However, in 2017, the proportions have increased dramatically with obesity affecting approximately 42% (25% for women and 17% for men) and diabetes affecting approximately 25% (15% for women and 10% for men) of the Kuwaiti population [19]. Few studies from Kuwait have examined the association between vitamin D levels and obesity and diabetes in the Kuwaiti population. Of those studies, the findings suggest that vitamin D deficiency is associate with both obesity and diabetes in Kuwait, where the incidence of both conditions is rapidly increasing [15 and 18]. The official percentage of the Kuwaiti population suffering from vitamin D deficiency has been recorded as high as 80% (48 % for women and 32 % for men), but in 2017 it is estimated to be closer to 100% [3 and 4].

Vitamin D deficiency was found to be prevalent in Kuwait since 1995; however, no studies are available regarding vitamin D status in Kuwait before that date [3]. As a country with ample sunshine year-round, it is surprising to find such a high deficiency of vitamin D in the Kuwaiti population [3, 4, and 18]. It appears that the high vitamin D deficiency found in the Kuwaiti population results mainly from reduced exposure to the sunshine, and this lack of exposure is related to the lifestyle, cultural, and religious practices of the population, along with the design of contemporary Kuwaiti dwellings [15 and 18]. In 2015, at the Architectural Engineering Institute conference in the USA, a conference paper was presented titled "Responses of Kuwaiti Government dwelling occupants regarding their perception, preferences, and behaviours in their current dwelling." This paper examined householders' perceptions of their mental and physical health as residents of Kuwaiti Government dwellings. Harsh weather conditions, along with the absence of privacy and lack of interior courtyards in the contemporary Kuwaiti dwellings prevents people from enjoying outdoor activities and confines them to the indoors. Consequently, this appears to have resulted in high rates of vitamin D deficiency in the Kuwaiti population [3 and 4]. The limited sun exposure for women, due to the customary style of dress which shields most of the body from the sunshine when outdoors appears to be related to exceptionally high rates of vitamin D deficiency in comparison to men [3, 4 and 15]. Typically, women living in traditional Kuwaiti houses with a courtyard available could increase sun exposure, and the resultant availability of vitamin D, by shedding the shielding clothing while at home [3].

Given the role vitamin D deficiency may play in the high prevalence of obesity and diabetes in the Kuwaiti population, increasing sun exposure to enhance vitamin D availability may potentially have a significant positive impact, especially in high-risk populations [15]. Given this information, architects should learn to appreciate and understand the interaction between a building and its occupants, balancing the way in which they address design for health benefits and energy efficiency [3 and 4]. This paper aims to improve the design of contemporary Kuwaiti Government dwellings in order to achieve that balance.

3. Methodology

3.1 Design strategy for the new Kuwaiti Government dwelling

The initial new design strategy for the Kuwaiti Government dwelling, which addresses issues identified in existing Kuwaiti Government housing, was analysed in a conference poster titled "Kuwaiti occupants feedback on Government dwellings at Al-Nahda town", and was presented at the 6th International Conference on Sustainability in Energy and Building in 2014 in the UK. The new design of the dwelling, based on the feedback of 140 householders' (seventy husbands and seventy wives), interviewed between December 2013 and February 2014, aims to meet the householders' needs and desires. The new design address dwelling layout, sunlighting, daylighting, and architectural identity, all in the context of the local culture and environment. It considers vernacular architectural methods, traditional Kuwaiti houses, and ecological features, as well as techniques of countries with similar climate to Kuwait. It also draws on methods and features found in recent examples from areas that incorporate ecological features in building design, such as Masdar City in Abu Dhabi, Plan Abu Dhabi 2030, Desert Rose in Dubai, and Msheireb in Qatar. For instance, Masdar City focused on solutions for: energy-efficient lighting, the percentage of window glazing, optimal natural light, use of environmentally-friendly concrete, and thick walls made of dried coral and gypsum [20 and 21]. In addition, the researcher's Kuwaiti background and personal experience of local customs and traditions informed and influenced the development of the new dwelling design.

The primary design goal of the new dwelling is to reduce its footprint, since the increased demand for the Kuwaiti Government dwellings requires measures to ensure that sufficient land is available for all [22]. Therefore, the new dwelling proposes to reduce the dwelling footprint from $400m^2$ to $300m^2$. This reduced size is still adequate to provide for the householders' requirements. Al-Nahda town in Kuwait, the case study of the research project, now contains approximately 460 dwellings in an area of $200,000m^2$. Use of the new dwelling design in the same area would provide 167 additional dwellings, resulting in a 30% increase in available dwellings. This change would reduce pending demands for Kuwaiti Government dwellings, help to keep up with the fast-growing demands, and provide optimal land utilization for housing.

Sunlighting, daylighting, and orientation of private outdoor spaces are major considerations in new dwelling design, as the outward-facing design of the existing Kuwaiti Government dwellings was deemed incompatible with householders' needs and requirements. A chief concern was that the windows and outdoor spaces were oriented externally, which resulted in decreased privacy (see Figure 2 above). Therefore, the revised dwelling design has adopted the inner courtyard plan as a primary design strategy to avoid the issues identified in the existing Kuwaiti Government dwellings (see Figure 3 and 4 below). This method has historically proved its worth whether in traditional Kuwaiti house, and in vernacular and traditional buildings (see Figure 1 above) [21 and 23]. The inner courtyard design has been applied in the new dwelling design to provide outside private space for various activities for the householders' with ample sunshine, and affording the privacy that was the crucial consideration for the householders', especially for women. In addition, it provides sunlight and daylight for interior spaces facing the courtyard, which helps to reduce reliance on artificial lighting and energy usage (see Figure 5 and 6 below). Also, the courtyard generates wind movement, allowing hot air to ascend and cooler air to descend, which helps to reduce the temperature of the courtyard and the surrounding rooms [24].

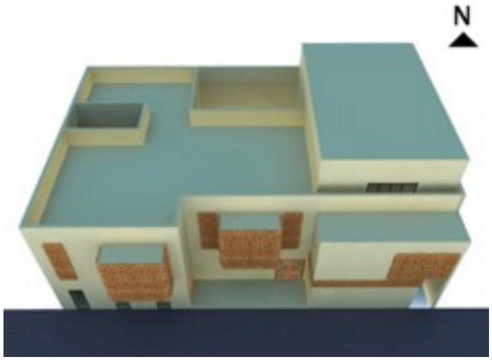

Figure 3: Façade of the new dwelling design (By researcher).

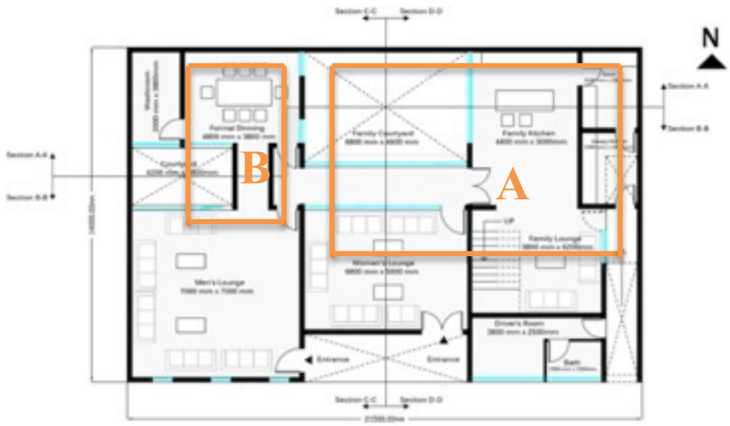

Figure 4: Ground floor plan of the new dwelling design (By researcher).

Figure 5: Summer south section of the new dwelling design (By researcher).

Figure 6: Winter south section of the new dwelling design (By researcher).

The new dwelling design includes a three-story structure of approximately $530m^2$. The design consists of an interior private courtyard, a men's guest lounge with formal dining area and toilet, a women's guest lounge, two family lounges, family dining, kitchen, and master bedroom with bathroom and dressing room, three suite bedrooms, a driver's room with bathroom, a maid's room with bathroom, a utility room, and a private roof. Most of the dwelling windows face the courtyard to ensure sunlight, daylight, and adequate privacy for the householders'. Spaces not facing the courtyard have either a skylight to provide sunlight and daylight or windows facing outward but covered with mashrabiya. Mashrabiya is a lattice screen that allows passage of sunlight to the interior to provide both sunlight and privacy. In contrast, from the interior, the lattice screen allows views through it to the exterior. Historically, this method has proved its worth in vernacular and traditional buildings [21 and 23].

Designing private outside spaces in the new dwelling plan, such as the courtyard and the roof, in addition to the daylighting of interior spaces surrounding the courtyard, provides adequate sun exposure for the householders' and increases access to beneficial sun radiation and reduction of potential vitamin D deficiency.

ArchiCAD, SketchUp, and Revit software were identified as appropriate and used to design the new dwelling. The characteristic features of the software are compatible with each other and with most other programs. They provide a variety of tools to form different building objects such as slabs, walls, doors, windows, and roofs. In addition, the software can be utilized to model a virtual building using a wide range of materials. It efficiently creates 3D models that are easy to modify and also provides the ability to create photo-realistic views of the spaces with the use of cameras.

3.2 Sun path analysis

Sun path analysis of Al-Nahda town location is a fundamental factor in the design of the new dwelling. The sun path of the site location impacted design decisions regarding building shape, spatial layout, orientation, window placement, and sunlight and daylight access. Understanding the passage of the sun across a site location is necessary to determine the effect of obstructions and shadows cast by adjacent buildings, trees, and landforms, all of which impact decisions on site location and potential design. In addition, a sun path diagram illustrates how the site location receives sunshine and shade during different times of the day and year (see Diagram 1 below), which has influenced in the courtyard design of the new dwelling.

Sun path diagram provide a broad overview of sun on a site location, as represents the annual changes in the path of the sun across the sky at different times during the day throughout the year via a two-dimensional chart. Sun path diagram provide the solar azimuth (the horizontal angle that the projection of the sun's position makes with north) and altitude (the vertical angle that the sun makes with the horizon) for any time of the day on any date. Also provide a summary of sun position relative to a site location, which the architect can consult when considering solar access, shading requirements, and design options. SketchUp software was used to analyse the sun path for the new design of the dwelling.

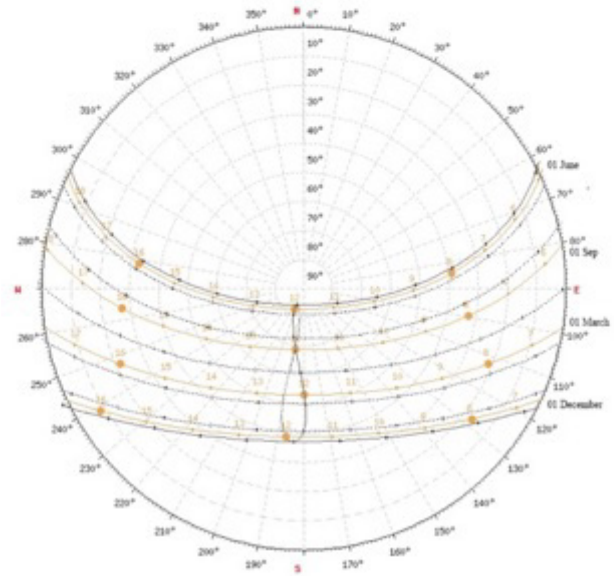

Diagram 1: Sun path diagram for four periods (March, June, September and December 2017) at (8:00 AM, 12:00 PM and 16:00 PM) (Sun earth tools, 2017).

3.3 *Sunlight and daylight analysis*

The new dwelling design has been tested for sunlight and daylight analysis thorough Revit software to measure the interior sunlight and daylight levels, as well as to control the measurement and orientation for the open plan inner courtyard. The inward-facing windows were adapted in the new design of the dwelling. The criteria for daylight levels recommended for comfort in the dwellings has been derived from the CIBSE (see Table 1 below), as the CIBSE is the standard-setter and authority on building services engineering [25].

Table 1. CIBSE recommended comfort criteria for dwellings (CIBSE, 2016).

Room type	Maintained illuminance/lux
Bathrooms	150
Bedrooms	100
Hall/stairs/landings	100
Kitchen	150-300
Living rooms	50-300
Toilets	100

4. Results

4.1 Sun path analysis

Sun path analysis has been applied in one neighbourhood of Al-Nahda town (see Figure 7 below). The analysis was conducted over two periods, June and December, to cover the summer and winter seasons. The analysis also covered three times of day: sunrise, noon, and sunset. The sun path analysis was essential in designing the new dwelling. The assessments of the sun's changing position in the sky throughout the year, and how those changes impact sunlighting, daylighting, and shade, provide important information in dwelling design. (see Figures 8, 9, 10, 11, 12, and 13 below).

Figure 7: Neighbourhood in Al-Nahda town (By researcher).

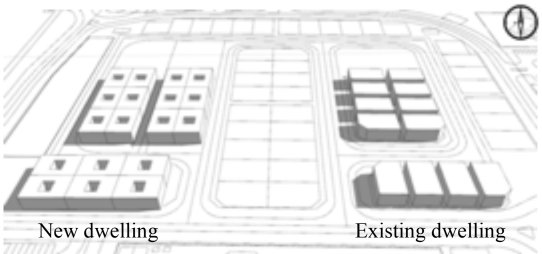

Figure 8: Sun path analysis in summer at 08:00 AM (By researcher).

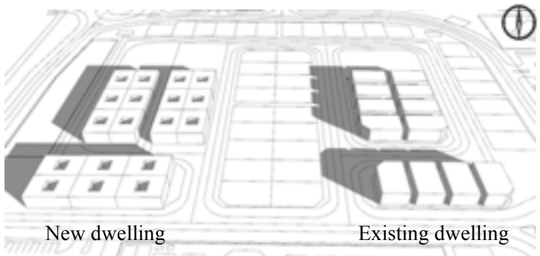

Figure 9: Sun path analysis in winter at 08:00 AM (By researcher).

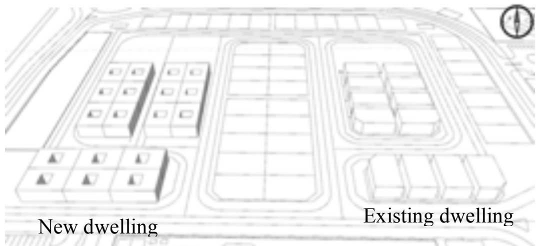

Figure 10: Sun path analysis in summer at 12:00 PM (By researcher).

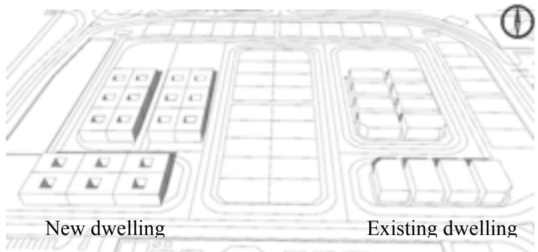

Figure 11: Sun path analysis in winter at 12:00 PM (By researcher).

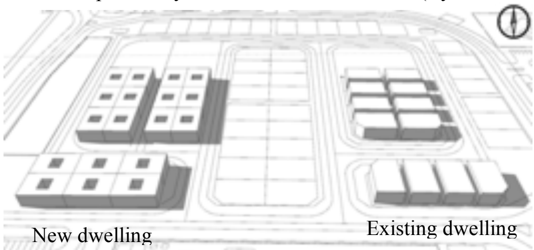

Figure 12: Sun path analysis in summer at 04:00 PM (By researcher).

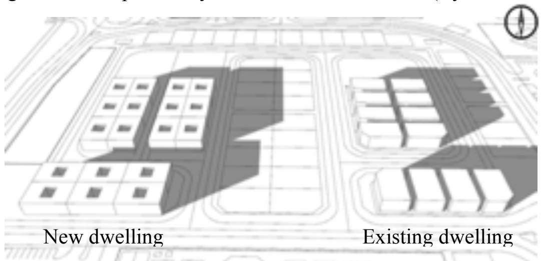

Figure 13: Sun path analysis in winter at 04:00 PM (By researcher).

4.2 Sunlight and daylight analysis

Sunlight and daylight analysis have been applied in the different spaces on the ground floor and first floor of the dwelling: these represent the spaces which are most occupied by the householders', such as the lounge, kitchen, and dining room. The analysis was conducted over two periods, June and December, to cover the summer and winter seasons. A south-facing dwelling was analysed at noon time with clear sky, when the sun transits the local celestial meridian, is at its highest altitude in the sky, and the shadows cast are shortest (see Figures 14, 15, 16, and 17).

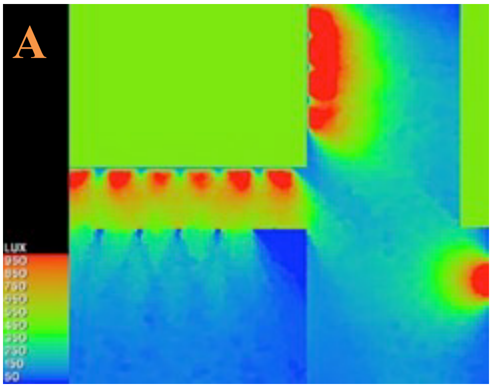

Figure 14: Sunlight analysis in summer for kitchen area (By researcher).

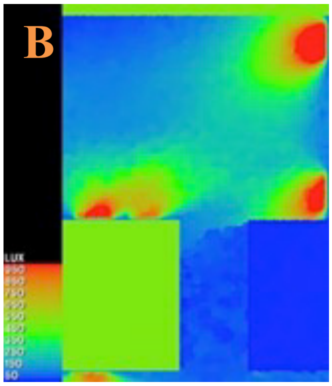

Figure 15: Analysis in summer for dinning room (By researcher).

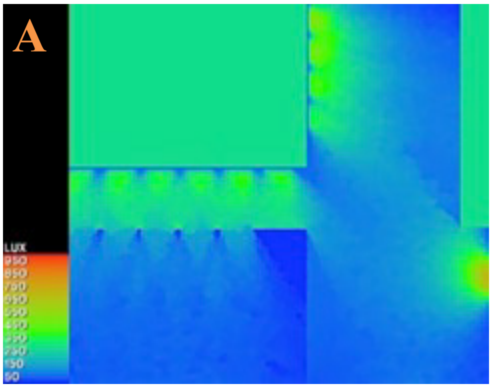

Figure 16: Sunlight analysis in winter for kitchen area (By researcher).

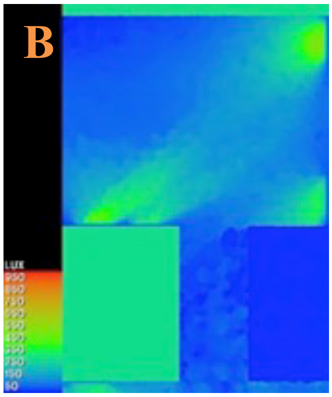

Figure 17: Analysis in winter for dinning room (By researcher).

5. Discussion

The design strategy for the new dwelling was primarily inspired by the design of the traditional Kuwaiti house and the design of houses in other countries which share some of the local customs and traditions of Kuwait, and have similar climate such as Egypt, Cyprus, Turkey, and Iran. The traditional Kuwaiti house and the houses of the other countries were either one or two stories, with few and small rooms in the house and the courtyard occupied the largest part of the house. Those constraints were based on the occupants needs at that time and the limited availability of construction materials. However, the challenge in the design for the new dwelling is to provide both a private courtyard of adequate size and an outside private space on the roof for the various activities for the occupants, meet the householders' requirements and desires, including a preference for a two-story dwelling with many large rooms, all on a site not exceeding 300 square meters. Also, privacy was identified as a crucial element for the householders', both for the inside and outside spaces of the dwelling. Another challenge of the research was to design the new dwelling with access to sufficient sunlight and daylight in both the inside and outside spaces of the dwelling during all times of the year to reduce the potential of householders' vitamin D deficiency, decrease reliance on artificial lighting, and decrease energy usage.

Sun path analysis for the Al-Nahda site location assessed the sun's changing position in the sky during summer and winter, at different times during the day, and considered the resultant sunshine and shade. Figures 8, 9, 10, 11, 12, and 13, above, illustrate how the site location receives sunshine and shade from morning until afternoon and portray the differentiation between summer and winter. Understanding the passage of the sun across the site location was necessary to determine the effect of obstructions and shadows cast by adjacent buildings, trees, and landforms, all of which impact decisions on site location and potential design. Also, the sun path of the site location informed design decisions regarding building shape, spatial layout, orientation, window placement, and sunlight and daylight access.

Courtyard design and dimension in the new dwelling has influenced to the Al-Nahda site location in order to have access of sunlight and daylight into the internal spaces and external private spaces during the day as possible. The new dwelling has two courtyards; the main courtyard dimension is 31 square meters placed in the center of the dwelling to exposed from most of the dwelling spaces to provide sunlight and daylight, alongside the courtyard is intended to create attractive and comfortable outer private open space for occupants to enjoy outdoor living, safe place to play, fresh air and park like venue for rest and recreational activities. And the other courtyard dimension is 11 square meters placed on a side to exposed from the other spaces of the dwelling. The two courtyards designed crosswise with the dwelling design, and the dimensions granted through the dimension of site area and the proportion of the dwelling structure, as well as, to meet the occupants' requirement. The courtyard dimension determine from the available space and the purpose, so even if the courtyard dimension might be small, but its still beneficial to the quality of the dwelling by providing a place for privacy and rest, light and ventilation, and even if the space itself does not have much amenity value [26].

Figures 14, 15, 16, and 17, above, illustrate the sunlight and daylight analysis applied in the courtyard, kitchen area, and dining room of the new dwelling. The analysis helps to determine weaknesses and strengths of the design regarding access to sunlight and daylight and the efficiency of the design strategy of new the dwelling. Figures 14 and 15, above, illustrate the amount of sunlight and daylight in the courtyard, kitchen area, and dining room during afternoon in summer, and Figures 16 and 17, above, portray sunlight and daylight during afternoon in winter. In summer, the courtyard, shown in a green rectangle, indicates the illuminance spread over the area is around 450 lux; however, in the kitchen and dining room surrounding the courtyard, the illuminance varies between 950 lux and 50 lux. In the areas adjacent to the courtyard, shown in red, the illuminance is about 950 lux and in the areas more distant from the courtyard, shown in blue, the illuminance varies between 150 to 50 lux. This establishes that the illuminance is very high in the areas surrounding the courtyard, but is very low in the areas distant from the courtyard. In winter, the courtyard, shown in a blue-green shade, indicates that the illuminance spread over the area is about 250 lux. However, in the kitchen and dining room, surrounding the courtyard, the illuminance varies between 450 lux and 50 lux, whereas the areas directly adjacent to the courtyard, shown in green, have an illuminance around 450 lux, and the areas are distant from the courtyard, shown in blue, have an illuminance around 50 lux.

The analysis clarifies that the distribution of sunlight and daylight in the new dwelling design is unbalanced, both in summer and winter. High illuminance is concentrated around the courtyard, while the areas distant from the courtyard have a much lower illuminance. In addition, the available sunlight and daylight during winter are insufficient, whether in the courtyard or in the surrounding areas. This demonstrates weaknesses in the new dwelling design, which must be overcome through a revised design and further analysis, in order to achieve the best possible design. The further work for the research project will be to modify the design of the new dwelling to overcome the identified weaknesses regarding sunlight and daylight distribution. Different features will be applied in the new design that have been inspired by recent examples from areas that incorporate ecological features in building design. These features, such as cross beams, automated roofs, and plants, will be utilized in the revised design. In addition, shifting dwelling orientation, changing window placement, and varying window size will all be considered in design revisions. Also, further analysis will be apply in the dwelling design to measure the sunlight and daylight using dynamic daylighting metrics such as, spatial daylight autonomy (sDA), annual sun exposure (ASE) and useful daylight illuminance (UDI). Spatial Daylight Autonomy (sDA) will describe how much of a space receives sufficient daylight; specifically it describes the percentage of floor area that receives at least 300 lux for at least 50% of the annual occupied hours. Annual Sun Exposure (ASE) will describe how much of space receives too much direct sunlight, which can cause visual discomfort (glare) or increase cooling loads; specifically it measures the percentage of floor area that receives at least 1000 lux for at least 250 occupied hours per year. Useful daylight illuminance (UDI) will describe how much direct sunlight that falls into the space that occupants will find this glary and distracting, which could result a thermal discomfort. Having early stage metrics is critical to be able to give a clear picture of sunlight and daylight performance that help to make a good design decisions in the new dwelling to performing well overall.

6. Conclusion

This paper discusses the design strategy for the new Kuwaiti Government dwelling and depicts the sunlight and daylight analysis regarding the new dwelling design for locations in Al-Nahda town in Kuwait. This paper is a part of the lead researcher's doctorate research project, conducted at Cardiff Metropolitan University. More data collection and analysis are in progress to complete the other parts of the research project. The initial sunlight and daylight analysis, illustrated in this paper, has identified that the new design presents some weaknesses regarding sunlight and daylight distribution within the dwelling. Further work investigating the latest examples from countries with similar culture and climate to Kuwait is ongoing, with the intention to incorporate ecological features in building design. Following the completion of the additional research, the new dwelling design will be revised and further analysis will be undertaken to improve the design of the new Kuwaiti Government dwelling.

References

[1] Kuwait Meteorological Center. Climate Information. Kuwait: Kuwait Meteorological Center; 2017.
[2] Met Office. Climate Information. UK: Met Office; 2017.
[3] Al-Ali N. Vitamin D Awareness Campaign. Kuwait: Amiri Hospital; 2017.
[4] Albasiri I. Vitamin D Deficiency in Children. Kuwait: Mubarak Al-Kabeer Hospital; 2017.
[5] More J. Prevention of vitamin D deficiency. *British Journal of Family Medicine*; 2016.
[6] Al-Najadah A, Al-Halwany A. *Architectural Styles and Traditional Woodwork in Kuwait.* Kuwait: The Public Authority for Applied Education and Training; 2004.
[7] Almusaed A. *Biophilic and Bioclimatic Architecture*. London: Springer-Verlag; 2011.
[8] Wali T. *The Statement in Architecture.* Bahrain: Gulf Panorama; 2007.
[9] Alshalfan S. *The Right to Housing in Kuwait: An Urban Injustice in a Socially Just System*. LSE Kuwait Programme on Development, Governance and Globalisation in the Gulf States; 2013.
[10] Memon R. *Kuwaiti Regionalism.* United Kingdom: Lobby Magazine; 2015.
[11] Mahjoub Y. Arab identity of the city and the challenges of rapid urban transformations. *Fifth Annual Conference on Social and Human Sciences,* Qatar: Qatar University; 2016.
[12] Astell-Burt T, Mitchell R, Hartig T. The association between green space and mental health varies across the lifecourse. *J Epidemiol Community Health* 2014; 68:578-583.
[13] McHarg L. An ecological method for landscape architecture. In *The Ecological Design and Planning Reader.* Island Press/Center for Resource Economics; 2014, p. 341-347.
[14] Gerber L, et al. Validity of Self-Reported Vitamin D Deficiency Among Midlife Arab Women Living in Qatar. *American Journal of Human Biology* 2016; 28:181-185.
[15] Zhang F, Al Hooti S, Al Zenki S, Alomirah H, Jamil K, Rao A, Al Jahmah N, Saltzman E, Ausman L. Vitamin D deficiency is associated with high prevalence of diabetes in Kuwaiti adults: results from a national survey. *BMC Public Health,* 2016.
[16] Rasoul M, Al-Mahdi M, Al-Kandari H, Dhaunsi G, Haider M. Low serum vitamin-D status is associated with high prevalence and early onset of type-1 diabetes mellitus in Kuwait children. *BMC Pediatrics*; 2016.
[17] Ware M. Vitamin D: Health Benefits, Facts and Research. *Medical News Today*; 2016.
[18] Al-Bathi B, et al. Knowledge, attitude and practice of patients attending primary care centers toward vitamin D in Kuwait. *Alexandria Journal of Medicine* 2012;48(3):277-282.
[19] Kuwaiti Ministry of Health. Statistics. Kuwait: Kuwaiti Ministry of Health; 2017.
[20] Karim A, Sari J. One Planet Living Principles and Sustainable Developments. Anhalt University; 2012.
[21] Masdar. Masdar Development. UAE: Masdar; 2016.
[22] Public Authority for Housing Welfare. Law of the General Organization for Housing Welfare. Kuwait: Public Authority for Housing Welfare; 2017.
[23] Almusaed A. Biophilic and Bioclimatic Architecture. London: Springer-Verlag; 2011.
[24] Hill F. Passive cooling. *Low energy building part a.* Powys: Centre for Alternative Technology; 2016.
[25] CIBSE. Environmental Design (CIBSE Guide A). London: The Lavenham Press Ltd; 2016.
[26] Almehrej M. A design guide for contemporary Saudi Arabian homes in Riyadh. Northumbria University; 2015.