

## **An evaluation of natural lighting levels in students' hostels in a suburb of Kumasi, Ghana**

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### **ABSTRACT**

*The role that natural lighting plays in buildings cannot be underestimated. Natural light is integrated into buildings because of its potential economic benefit and the effect on the occupants' psychological and physiological well-being. This study concentrates on Ayeduase, a suburb of Kumasi, Ghana, where poor architectural designs could affect the performance of students. Therefore, the primary aim of this study is to help improve the health (general well-being) and visual comfort of students living in Ayeduase, by creating awareness of the positive effects of natural light on humans. Questionnaires and interviews, as well as empirical measuring of daylight levels in the spaces of selected hostels were used. Analysed data revealed that the level of illuminance in the hostels is considerably poor and this resulted in students using artificial lighting throughout the day. Nevertheless, the negative effect of this situation can be prevented from occurring in further developments in Ayeduase (and Ghana as a whole), by educating the public on the benefits of using natural lighting in buildings and by enforcing laws that will ensure that buildings have maximum openings that allow enough daylight into the interior spaces. These measures will help reduce utility costs, improve the well-being of building occupants and increase the performance of students.*

**Keywords:** Natural Lighting; Building Science; Occupants; Perception.

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### **INTRODUCTION**

Light has always been a predominant factor in the activities of mankind. Many efforts have been made to design buildings that use a great percentage of natural light, in both the developed and the developing countries. Large amounts of money, which almost surpass the cost of a building, are used to light up spaces in buildings. In the year 2002, the cost of electricity in Ghana was 6 US cent per kWh [1]. This enormous cost of electricity could be reduced if natural lighting is prioritized in building designs. In actual fact, natural lighting gives a natural view of materials and tends to produce more positive responses than to artificial lighting. Natural light has psychological and physiological effects on the occupants of a building and as such should be considered well when designing [2]. Natural or daylight is also said to most closely match the visual response that through evolution, humans have come to compare with all other light [3].

The increasing population of students at the Kwame Nkrumah University of Science and Technology (KNUST) campus has instigated the proliferation of several hostels in the neighbouring communities. Ayeduase, a suburb of Kumasi, provides hostels to an appreciable number of KNUST students. Natural lighting in most of these hostels is nothing to write home about. One cannot help to have only artificial lighting on the corridors and rooms of these hostels, even when it is a bright sunny day.

As noted by [4], the presence of daylight in buildings maximizes the architectural potential while increasing human comfort and visual perception. Most of these hostels lack the essential resource which nature offers freely. Openings of these hostels are poorly designed or positioned. It has become a normal practice that lighting in these hostels is

achieved only through artificial means. This in actual fact could have a negative effect on the performance of students living in such hostels, since lighting has a psychological and physiological influence on the life of an individual. As buttressed by [2], on a cloudy day or under poor lighting conditions, the inability to perceive the colours from light can affect our mood and energy level. This invariably, increases accidents, reduces mental performance and as a result, could decrease students' academic performance.

This study is aimed at identifying the key operational determinant hindering the use of natural lighting in buildings and how this situation could be improved in Ayeduase students' hostels.

It is hoped that the results of the study will contribute to the general well-being of students and improve upon the quality of buildings being constructed in Ghana.

Since time immemorial, man has sought for ways and means of living comfortably in his environment. Man is a diurnal being who needs good natural light in the day for him to function psychologically and physiologically sound in his environment.

Varying opinions have been published about the physics of light by different writers. A Scottish physicist named James Clerk Maxwell (1831 - 1879) showed that electric and magnetic fields fluctuating together can form a propagating wave, which was named an electromagnetic wave [5]. Further, light is said to be this type of wave. Maxwell knew that a changing electric field produced a magnetic field. In 1905 Einstein concluded that light is composed of corpuscles, or discontinuous quanta of energy [5]. Light is also the form of radiant energy that stimulates the organs of sight [6].

However, natural light is the only light that makes architecture architecture as said by Louis Kahn and cited by [7]. The sun releases a power flux of 63 MW, equivalent to six thousand million lumens, for every square metre of its surface area. Of this, about 134 kilolux reaches the earth's outer atmosphere. The atmosphere absorbs about 20% of this light and reflects another 25% back into outer space. A fraction of the remaining 55% reaches the ground directly, as sunlight, the rest is first diffused by the atmosphere (skylight) - these two together make up daylight [8]. All natural light emanates from the sun, the light entering buildings either being direct light from the sun or reflected light. The illuminance provided by a bright sunny sky may be as much as 100,000 lux, though light of this intensity often causes glare and overheating. The importance of light in architecture has been expressed by Le Corbusier [9]: Architecture is the masterly, correct and magnificent play of volumes brought together in light. Furthermore, the history of architecture is said to be the history of the struggle for light. [10] did not only have an architectural view of natural lighting, but also saw the need to pinpoint what day lighting does in different aspect of buildings (visual stimuli, lighting energy savings, reduction in building energy savings, minimization of operating costs and the maximization of productivity, etc).

Natural light has direct and indirect effects on human beings: the direct effects are caused by chemical change in tissues due to the energy of the absorbed light, while the indirect ones concern the regulation of the basic biological functions and the production of hormones, connected to light exposure. Therefore, to improve well-being, satisfaction and productivity, especially in hostel buildings, it is very important to project indoor spaces with specific attention to occupants comfort. A study by West as cited in [13] found that prison inmates who had different views to outside the window (natural light) facing vegetation and mountains had lower sick-related cells than the ones who had their windows oriented to the courtyard where noise from passers-by emanated. Natural light is generally known to be a remedy for curing skin diseases. Natural light contains the right amount of UV radiations that the skin needs for its proper functioning. Exposure to UV radiations produces vitamin D in the skin which is essential for metabolic functions, including the absorption of calcium and phosphorus [7].

On the benefits of natural lighting, [2] found that there is increased student and teacher attendance, increased achievement rates, reduced fatigue factors, improved student health, and enhancement of general development. Furthermore, natural lighting eliminates noise and flickering from electric light sources and provides the best quality of light available in classrooms, gymnasiums, and corridors. Their extensive research has also shown that students in windowless classrooms are more hostile, hesitant, and maladjusted. Moreover, students in windowless classrooms tend to be less interested in their work and complain more [2].

In 2004, Ghanaians consumed 5,158 gigawatthours (GWh) of electricity. It is estimated that about half of this amount is consumed by domestic (or residential) consumers for household uses such as lighting, ironing, refrigerating, air conditioning, television, radio and the like [11]. In all, lighting was found to consume more electricity than any other appliances because of poor architectural designs of some houses. Illuminations in these houses are switched on from morning to evening so that spaces could be used for activity. Moreover, the choice of

external surfaces near a building can either enhance or detract from the character of illumination within a building. This presupposes that effective landscaping, which will enhance proper reflection, must be ensured, if adequate natural lighting is to be admitted into a building [12]. Designing buildings with a natural lighting strategy in mind will definitely ease the burden of electricity costs, improve well-being and increase productivity.

## MATERIALS AND METHODS

The lack of adequate accommodation on University campuses in Ghana is a paramount problem students are confronted with. The problem has been curtailed by inefficient hostel buildings sited in the neighbouring towns of Universities. Students are forced to stay in such hostels to continue with their studies. Unfortunately, poor architectural designs of hostels which manifest in the use of artificial lighting throughout the day have invariably increased the discomfort of students residing in them. The objective of this paper is to examine the quality of natural lighting in Ayeduaase (6° 40' 32" North, 1° 33' 44" West) students' hostels. The town was selected because it has most of the top ranked hostels (considered to shelter about 40% of students) around the KNUST. Despite the fame that the town enjoys, natural lighting is a major problem in most of the hostels. In this context, the main objectives of the research study are;

- To examine how lighting levels affect the occupants of the hostels;
- To find out how natural and artificial lighting are used by students; and
- To study possible health effects of long exposure to poor lighting.

The methods used in this research were questions, interviews, observations and empirical measurements.

The main areas of information needed from the respondents were related to their background, knowledge and possible effects of natural lighting with regards to the physiological and psychological outcome.

Tape measure was used to measure floor areas and building elements (windows) of the buildings. Furthermore, PC Environment Interface equipment was used to measure the illuminance level in three hostels (NAH, HSH and GEH). The one month measurement period (March 1 to 31, 2011) resulted in data which was grouped in MS Excel to generate mean values. The values (indoor and outdoor illuminances) were used to calculate the daylight factors of the spaces.

## RESULTS AND DISCUSSION

### NAH (Block B) Hostel

This is a four (4) storey hostel accommodating 48 students and located at the western part of Ayeduaase. It has a 1.8 m high fence wall and the compound is landscaped with pavement bricks. The general layout of the spaces is double-banking (rooms sandwiched with a corridor), the corridor width is 1.8 m and the floor area for each room is 12 m<sup>2</sup>. The corridors are furnished with brown terrazzo for the floor, cream colour paint for the walls, and white colour paint for the ceiling. Each room has a balcony, a washroom, and the floors are furnished with light terrazzo, cream colour paint on walls and white paint on the ceiling (Fig. 1).

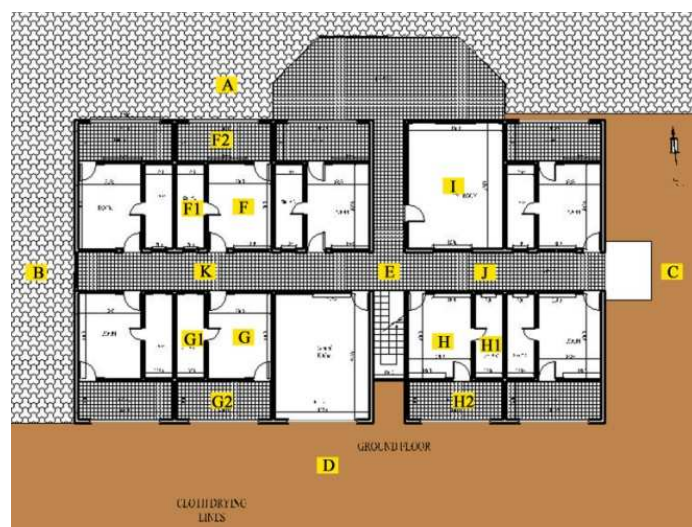


Fig 1 Schematic floor plan of the hostel (block B) showing measurement locations

The mean outdoor illuminance tabulated was 19,735 lux. The mean illuminance for two rooms (F and I) on the northern wing of the hostel was 50.7 and 17 lux. The daylight factor (see Equation 1) for the spaces (F and I) was calculated to be 0.257% and 0.086%.

$$\text{Daylight Factor (DF)} = E_i / E_o \times 100 \quad (1)$$

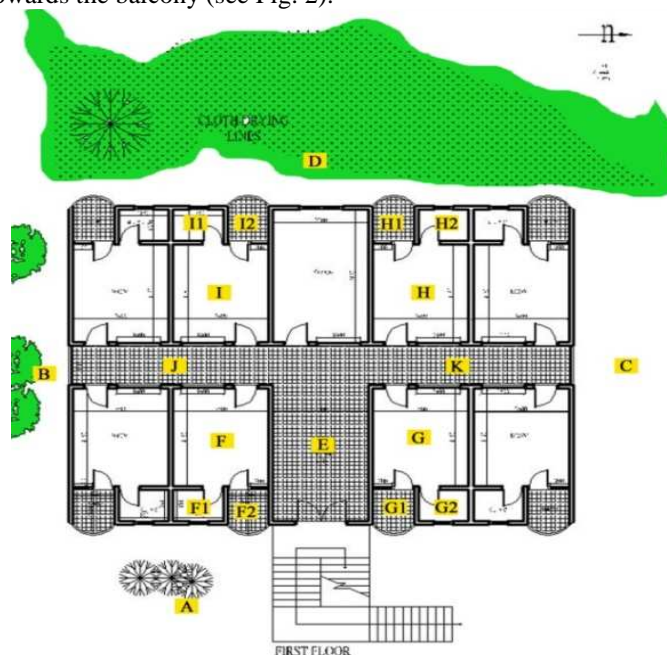
where  $E_i$  is indoor and  $E_o$  outdoor illuminances

The mean daylight factor for the spaces in the southern wing was calculated to be 0.04%.

The results illustrate that artificial lighting would be needed, since the DF values were all below 2% [8 and 13]. This analysis insinuates that it is not the amount of light from the sun that is inadequate, but rather how to get the natural light into the interior of the building. In addition, [14] outlines that the recommended daylight factors for a living room, a bedroom, and a typing and computing room should not be less than 1%, 0.5% and 4% respectively. The studied rooms are used as a learning place for students, and as such, the daylight factor should not be less than 4%. Herewith, one could conclude that the illuminance levels in the NAH Hostel rooms are poor and that natural lighting strategies are not well utilized.

### HSH Hostel

This facility is a four storey hostel located beside the Ayeduase-Kotei road on the eastern side of Ayeduase. It is a double bank hostel with a 1.7 m corridor width and a 14.53 m<sup>2</sup> floor area for each room. The corridors are furnished with polished light brown tiles on the floor, brown paint on the walls and white paint for the ceilings. Each room has a balcony, a washroom and the floors are furnished with polished white tiles, light brown paint for the walls and white paint for the ceilings. Two window walls with a size of 9.3 m<sup>2</sup> each are located opposite of each other, containing windows with a size of 2.4 m<sup>2</sup> and 1.1 m<sup>2</sup> respectively, with the bigger one leading into the corridor and the smaller one oriented towards the balcony (see Fig. 2).



**Fig 2 A conceptual floor plan of HSH hostel showing positions where measurements were taken**

To obtain a general knowledge on the illuminance in the HSH hostel, the western and the eastern part of the hostel were studied. The western part has the annotations of 'I' and 'H' while the eastern part has the annotations of 'F' and 'G'. Considering the western side of the hostel during the morning period (8:00-10:00 hrs.), the internal spaces (I and H) and the outdoor space (D) recorded 6.15 lux, 3.5 lux and 3340 lux respectively. Hence, the daylight factor at "I" and "H" could be calculated as 0.184% and 0.104%.

Consequently, the afternoon period recorded daylight factors of 0.035% for "I" and 0.038% for "H". At hours 16:00 to 18:00, the daylight factor for "I" recorded 0.321% while "H" recorded 0.154%. The illuminance levels at the eastern part of the hostel were different. Daylight factors of 0.059% to 0.330% were tabulated. These illuminance values are low when compared to the recommended levels [12 and 14]. This was partly due to the smaller window to wall ratios of the external walls (less than 20%) [15]. The light brown paint also has a lower reflectance value and

thereby reducing the total illuminance of the interior spaces [16]. The use of white coloured paints (70-90% reflectance) would help improve upon the quality of the spaces [7].

### GEH Hostel

This is a three (3) storey hostel (105 capacity) located on the western side of Ayeduaase. The hostel has 30 rooms and a small courtyard in the middle of the facility. Finishes for the corridor are polished brown tiles for the floors, brown colour paint for the walls and white colour paint for the ceilings. The finishes for the rooms are polished yellow tiles for the floors, yellow paint for the walls and white paint for the ceilings. The hostel has a 1.55 m corridor width and a 14.3 m<sup>2</sup> floor area for each room. The two window walls have a size 9.6 m<sup>2</sup>, each containing windows of sizes 2.3 m<sup>2</sup> and 1.2 m<sup>2</sup> with the larger window directed towards the corridor and courtyard (Figs. 3 and 4).

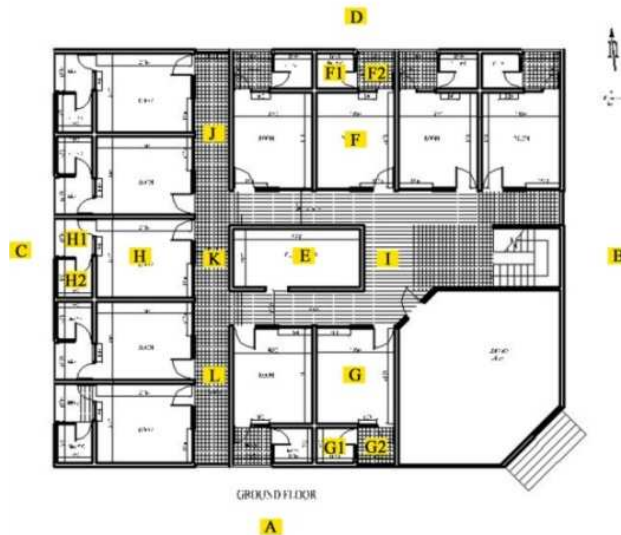


Fig 3 A schematic plan the hostel showing points where illuminance was measured



Fig 4 A view showing the inefficient courtyard of the hostel

The illuminance and daylight factors result on the northern part (annotated F and D) and the southern part (annotated G and A) are elaborated. In the mornings (8:00-10:00), the readings at “F” (room) on the northern side of the hostel recorded 1.6 lux, while the area marked “D” (outdoor) recorded 1307.5 lux. Hence the daylight factor at “F” could be calculated as 0.122%.

The mean illuminance at the room recorded in the afternoon (12-14hrs) produced a daylight factor of 0.487%. At the same area, the illuminance reading in the evening (16-18 hrs.) produced a daylight factor of 0.044%. The southern part of the hostel was also reviewed in terms of its illuminance. However, the poor pattern of low illuminance values continued. The reasons were that the window to wall ratios are low (less than 25% as against 60-80% for an efficient performance [17], the colour of the interior walls (yellow) has a high absorbance value as compared to white, the inefficient courtyard in getting the daylight to the rooms by virtue of its small size, the behaviour of the occupants, etc [18 and 19].

**Questionnaire and Interview results (all buildings)**

The questions (20 in number) were distributed to 30 students to ascertain their views on natural light in their hostels. Irrespective of the sample size [20], the students' views give indication on perception and behaviour in the hostels which could help improve upon the quality of buildings in general.

Some of the results of the interviews are outlined and discussed. On the activity the students most frequently carry out in the hostels, fifteen (50%) out of the thirty students chose reading and writing by hand, while twelve students chose working with the computer. Furthermore, twenty-four out of the thirty students said that they studied more in their rooms. Knowledge about the use of lighting (natural or artificial) in the hostels revealed that 95% of the respondents made use of artificial lighting throughout the day. This is understandable since the measured illuminances were really low. Illuminance levels of 400 to 500 lux are recommended for desktop activities (reading and writing) [8]. The health complaints (headache, eyestrain and itching, etc.) by 40% of the respondents could also be linked to the low illuminance levels within the spaces. Students who frequently remain and learn in their rooms during power outages could be the ones with more complaints.

Questions regarding user behaviour (the operation of windows to bring in natural light) resulted in over 70% of the students saying that they were able to operate the windows and use the shades (curtains) to improve upon their visual comfort. Rooms that are oriented towards the east and west could be observed to have the curtains in place to block direct and reflected solar radiation. This practice however, has the consequence that occupants then resort to the use of artificial lighting which could have energy penalties [21, 22, 23, 24 and 25]. The impact of switching on the light 'all the time' was mostly felt by students who had to bear the cost of their consumed electricity.

**CONCLUSION**

The study had the objective of evaluating natural light in students' hostels. This was because of the often poor designs that are created for students to use as hostels, without considering the use of sustainable design principles and occupants comfort. Through questions and empirical measurements, data was accrued which indicated poor illuminance levels in the spaces of the hostels and health complaints by the building occupants.

To alleviate the deteriorating effect of bad lighting conditions in the hostels (future buildings), the following should be considered:

- The education of students and landlords (hostel owners) about the positive effects and benefits of natural lighting;
- The rolling-up of window curtains especially in the afternoons as an effective means to allow light to penetrate into a space should be enhanced. Students should be taught to understand that it is of more importance to allow natural light into a space than to decorate the room with curtains;
- Strict policies on having surface finishes of high reflectance should be enforced in all the hostels in Ayeduaase;
- Natural lighting should be made the prior means of lighting hostels in the day by institutionalizing strict policies which oblige designers of hostels to adhere to the use of recommendations for sizing windows, the use of materials with high reflectance values and the use of sustainable design principles; and
- More technological means could include the use of light tunnels for every room and mechanized window curtains that roll up automatically to allow natural light into spaces.

These measures when applied could help improve upon the comfort of students, their well-being and help reduce energy consumption of buildings in Ghana. Future hostel buildings could also benefit from the application of the recommended measures.

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