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Assessment of Luminosity Levels, Distributions, and Uniformity in Offices, Laboratories, and Lecture Theatres: Case Study of Federal University of Health Sciences, Otukpo

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Abstract
An interesting area of research that is of great concern in work places is the levels of luminosity, distributions, and uniformity of indoor spaces. Poor indoor lighting has been reported to have negative impacts on human health, comfort, performance, and productivity. Therefore, the need to create comfortable, productive, and healthier environments cannot be overemphasized. In this study, we attempt to assess the luminosity in indoor spaces at Federal University of Health Sciences Otukpo; in order to assess the existing lighting conditions. The luminosity levels at offices, laboratories, and lecture theatres were measured in the morning (8 am - 11:50 am) and afternoon (1 pm - 4:30 pm) in February, 2024 using Lux Meter (model: 1010B). Descriptive statistics was employed in data analysis. Results revealed that the existing lighting conditions in the offices can be categorised as dim, satisfactory, and good. This could be upgraded to bright and glaring, depending on the occupant's task. About 60 % of the sampled laboratories are up to the required standard, while 40 % need to be upgraded. Measured luminosity in the surveyed indoor spaces was not evenly distributed. Furthermore, the illuminance uniformity was determined. We hereby recommended that luminosity levels in most of the surveyed indoor spaces be upgraded to the required standard. The findings of this study suggest that besides the measurement time, month and season of the year could also affect illuminance of indoor spaces. The observed luminosity has implication on the comfort, health, productivity, and performance of both students and staff.
Keywords: Luminosity, indoor spaces, Lux meter, lighting system, Federal University of Health Sciences, Otukpo

Introduction

An interesting area of research that is of great concern in work places is the levels of luminosity, distributions, and uniformity of indoor spaces. Poor indoor lighting has been reported to have negative impacts on human health, comfort, performance, and productivity [1]. Therefore, the need to create comfortable, productive, and healthier environments cannot be overemphasized.

Lighting plays a critical role in creating optimal conditions for learning, productivity, and overall well-being in both educational and work environments. Adequate lighting systems, appropriate lighting design, and proper light quality have been shown to have a significant impact on various aspects of human performance and health [1, 2, 3, 4]. However, inadequate luminosity can lead to eyestrain, fatigue, headaches, create a feeling of discomfort and isolation, and can increase the risk of accidents. Therefore, adequate luminosity is very vital in all indoor spaces during the day and night time.

Lighting can be natural, artificial, or hybrid based on their sources [5, 6]. The Sun, a luminous object is the primary sources of illumination for the Earth. Sunlight through windows, skylights, or other openings in buildings is used as natural lighting. This is generally considered as the best type of light for indoor spaces. Artificial lightings commonly used are fluorescent, LED, incandescent, and halogen lightings, among others. The choice of the artificial lighting is based on several factors [6]. Some are relatively cheap and easy to install (e.g. incandescent and fluorescent lightings), produces a warmer and more inviting light (e.g. incandescent lighting), more energy-efficient (e.g. LED and halogen lightings), and have long lifespan (e.g. LED lighting). However, some can cause eyestrain and fatigue due to their flickering and glare (fluorescent lighting), less energy-efficient (incandescent lighting), produces a harsher light (e.g. halogen lighting), and are expensive (e.g. LED lighting).

Furthermore, the type of light fixtures, the colour, and the level of glare used depends on the needs of the occupants and the specific purpose of the space [7]. Hybrid lighting combines both natural and artificial lighting systems to maximize energy efficiency and comfort. In quantifying light levels accurately, luminosity meters (radiometers or photometers) are used for measuring the intensity or luminosity of light. Luminosity meters are used in photography, cinematography, lighting design, agriculture, environmental monitoring, among others.

Several scholars have assessed luminous intensity at residential areas, workplaces, public spaces, school environs, etc. [3, 8, 9]. Evaluating the luminosity levels in different offices [10] noted that appropriate lighting conditions positively impact employee productivity, mood, and overall satisfaction.

[11] Observed that in educational settings such as classrooms and lecture theatres, lighting can influence students' cognitive abilities and academic performance. Well-designed lighting that provides adequate brightness and uniformity can enhance focus, attention, and comprehension. Proper lighting also contributes to creating visually engaging, stimulating, and safe learning atmospheres. However, inadequate lighting conditions may lead to visual discomfort, eyestrain, and reduced concentration levels [12]. Inadequate lighting, such as low luminance or excessive variability, has been linked to negative effects on alertness, mood, and overall well-being, leading to decreased productivity and increased risk of errors [2, 13].

Lighting is a crucial factor influencing employee performance and productivity in office settings. Balanced lighting can enhance employees' visual comfort, reducing eyestrain and the incidence of headaches. Sufficient lighting levels that minimize glare and provide suitable contrasts can improve visual comfort, reduce errors, and increase work efficiency [2, 10, 12].

Generally, they are best practices and standards recommended for lighting in indoor spaces such as offices, laboratories, lecture theatres, etc. by both international and nation agencies. Therefore, there is need to assess the existing lighting conditions at Federal University of Health Sciences Otukpo (FUHSO) to ensure its attained required standard. This is because luminosity levels (under- or over-illumination) in educational-academic spaces can affect students, researchers, as well as other staff in the environment [14].

The specific objective of this study is to measure the level of luminosity and its uniformity in offices, laboratories, and lecture theatres and recommend where necessary for improvement. This study is significant as it hopes to provide valuable information about the level of luminosity in indoor spaces in university environs. The findings of this study will be of interest to students, staff, university administrators, architects, interior designers, university community, and policy maker, among others working in university environs.

Materials and Methods

Field survey

This study was conducted between 5th - 9th February 2024 in offices, laboratories and lecture theatres at FUHSO. 10 offices, 5 laboratories, and 4 lecture theatres were surveyed (See Table 1). The materials used for this research are: Digital Lux Meter (Model: LX1010B), measuring tape, marker, and stop watch. Physical features such as surface area of windows and their geographical positions, presence of curtains, sky conditions, lighting sources (e.g., fluorescent, LED, incandescent, halogen lightings, etc.,), their sizes, position, and mounting height in the surveyed offices, laboratories, and lecture theatres were properly examined.

Study area

The study was carried out at Federal University of Health Sciences Otukpo, Benue State. Otukpo is located at latitude 7.198 °E and longitude 8.139 °N. It is characterized by mean temperature of about 27.2 °C and mean annual rainfall of about 244 mm. Otukpo is situated in Guinea savannah zone of the country. The area is not exempted from the epileptic power supply experience in the country at large. FUHSO was among the universities established in Nigeria in 2021. The vision and mission of FUHSO is to be a world-class university that nurture, train, and produce excellent healthcare professionals that can performed and compete favourably in any part of the world. Therefore, there is need for general assessment of lighting system to ensure the university attains world standard. Hence, this study investigates luminosity level in offices, laboratories, and lecture theatres; in order to evaluate the efficiency of the existing lighting systems and ensuring compliance with the standard lighting regulations, and also recommend where necessary for improvement. The surveyed offices, laboratories, and lecture theatres are shown in Table 1, while the map of Nigeria showing the study area is presented in Figure 1.

Table 1: Surveyed Offices, Laboratories, and Lecture Theatres used for this study

Office	Code	Lat (o)	Lon (o)	Laboratory	Code	Lat (o)	Lon (o)	Lecture Theatre	Code	Lat (o)	Lon (o)
Office 1	A	7.234	8.147	Physics	PHY	7.234	8.149	Lecture theatre 1	A	7.234	8.147
Office 2	B	7.234	8.147								
Office 3	C	7.234	8.148	Chemistry	CHM	7.235	8.148	Lecture theatre 2	B	7.245	8.147
Office 4	D	7.228	8.142								
Office 5	E	7.234	8.148	Biology	BIO	7.234	8.148	Lecture theatre 3	C	7.234	8.147
Office 6	F	7.234	8.148								
Office 7	G	7.234	8.147	Physiology	PHS	7.234	8.149	Lecture theatre 4	D	7.245	8.147
Office 8	H	7.234	8.148								
Office 9	I	7.234	8.148	Computer Science	COM	7.228	8.142				
Office 10	J	7.234	8.148								

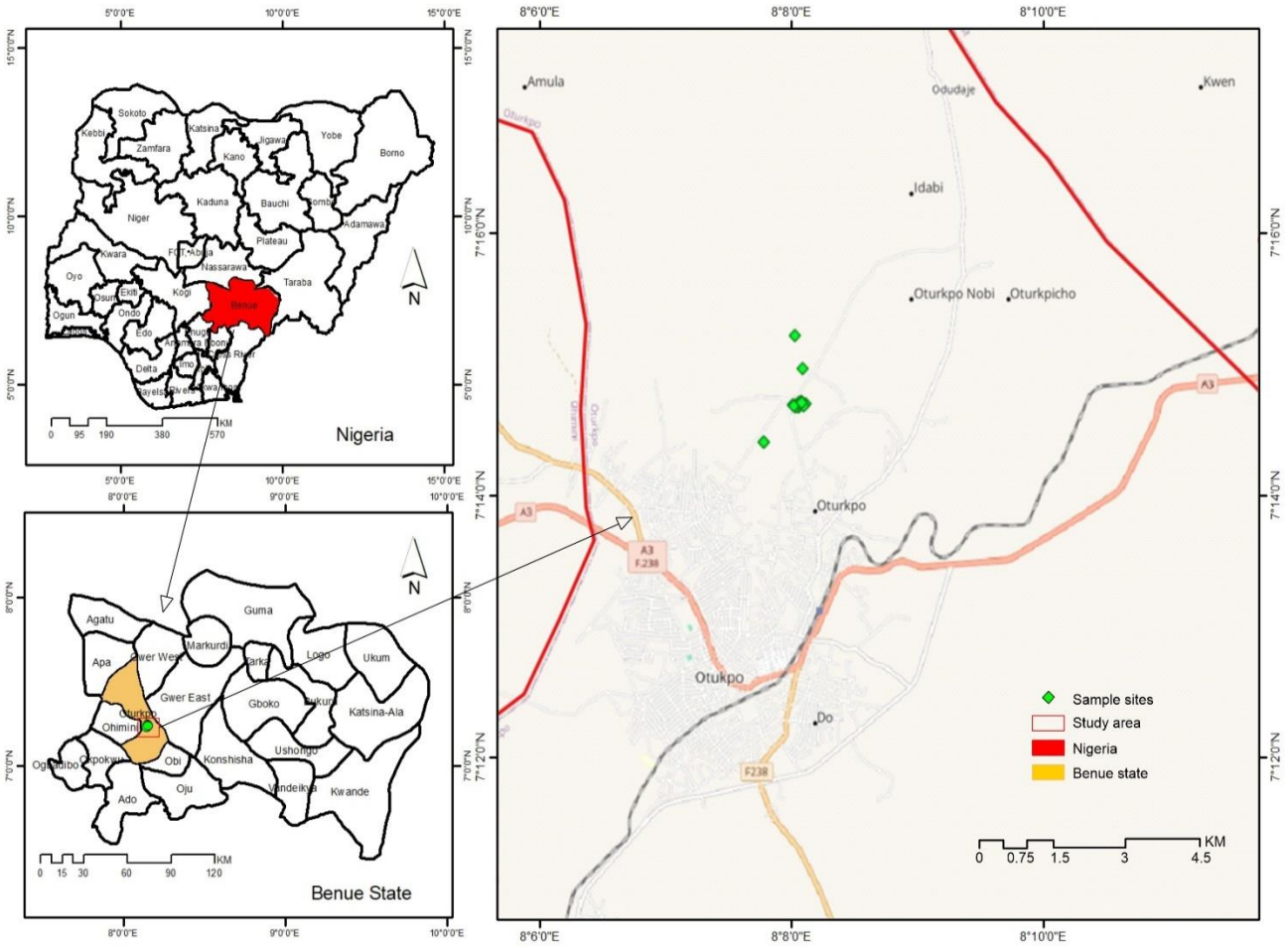

Figure 1: Map of Nigeria showing the study area

Illuminance measurement

Each of the offices, laboratories and lecture theatres surveyed were evenly divided into twenty (20) equal parts using measuring tape. The luminosity meter was held at the height of 75 cm above the ground level during each measurement. An interval of 2 minutes was taken between each measurement when lights were switched ON and 1 minute when lights were switched OFF. The measurements were taken when all light(s) was switched ON and OFF for both morning (8 am - 11:50 am) and afternoon (1 pm - 4:30 pm) measurement. In this study, natural light (sunlight or daylight) was not separated from the artificial light. Thus, the measured luminosity is from both natural and artificial lights. Descriptive statistic was then employed in data analysis. The average readings with the associated standard errors were compared with the recommended standards for offices, laboratories and lecture theatres.

Furthermore, illuminance uniformity in each of the surveyed office, laboratory, and lecture theatre was computed using equation 1 [10].

$$U_R = \frac{Eh_{min}}{Eh_{avg}} \qquad (1)$$

Where Eh_{min} and Eh_{avg} are minimum and average illuminances respectively.

Results and Discussion

It could be observed from Figure 2a that, for the 10 offices surveyed in the morning when lights were switched ON, office B recorded the lowest average luminosity (155.20±8.56 lux) while office I recorded the highest average luminosity (194.65±8.08 lux). On the other hand, when lights were switched OFF, office A recorded the lowest average luminosity (95.15±3.26 lux) while office J recorded the highest average luminosity (147.75±10.07 lux) (Figure 2b). It is pertinent to note that the luminosity levels observed when lights were switched ON were relatively high as compared to when lights were switched OFF. This could be attributed to the natural and artificial lightings used for illumination. This indicates that daylight (resulting from sunlight) may not produce sufficient luminosity for indoor spaces during morning hours (8 am - 11:50 am). This shows the need to use artificial lighting during morning hour in indoor spaces.

The luminosity levels observed in the surveyed offices when lights were switched ON and OFF ranges between 155.20±8.56 - 194.65±8.08 lux and 95.15±3.26 - 147.75±10.07 lux respectively. These are below the recommended standard of 300 – 500 lux for office spaces by the Illuminating Engineering Society of North America (IESNA) [8]. This suggests that the existing lighting system in the surveyed offices need urgent upgrade to the required standard. The lighting conditions in the offices when lights were switched ON can be categorise as satisfactory (101 – 200 lux), while when lights were switched OFF can be categorise as dim (51 – 100 lux) and satisfactory (101 – 200 lux) according to classification of light intensity [15]. It is interesting to note that, light intensity measured at the 20 sampled points in each of the surveyed offices are not the same. It varied from one sampled point to another within the same surveyed indoor space. This implies that the luminosity was not evenly distributed. The illuminance uniformity in the surveyed offices in the morning when lights were switched ON and OFF were 0.5 – 0.8 and 0.5 - 0.7 respectively. This suggests that the illuminance uniformity in some of the offices are slightly below the recommended minimum standard of 0.8 [10].

For afternoon measurement when lights were switched ON, it could be observed that for the 10 offices surveyed, office A recorded the lowest average luminosity of 166.85±9.00 lux, while office H recorded the highest average luminosity of 221.65±6.55 lux (Figure 3a). From Figure 3b, when lights were switched OFF, office A recorded the lowest average luminosity (106.40±2.87 lux) while office J recorded the highest average luminosity (158.75±8.17 lux). Luminosity levels observed when lights were switched ON in the afternoon were relatively high as compared to when lights were switched OFF. This clearly shows the contribution of artificial lighting even in the afternoon (1 pm - 4:30 pm).

The luminosity levels observed in the surveyed offices when lights were switched ON (166.85±9.00 - 221.65±6.55 lux) and OFF (106.40±2.87 - 158.75±8.17 lux) were below the recommended standard of 300 – 500 lux for office spaces. This suggests that the existing lighting system in the surveyed offices need urgent improvement. Based on the classification of lighting effect, the lighting conditions in the offices when lights were switched ON can be categorised into satisfactory (101 – 200 lux) and good (201 – 400 lux), while when lights were switched OFF can be categorize as satisfactory (101 – 200 lux) only [15].

Comparing luminosity levels in the morning when lights were switched ON (155.20±8.56 - 194.65±8.08 lux) and OFF (95.15±3.26 - 147.75±10.07 lux) and afternoon when lights were switched ON (166.85±9.00 - 221.65±6.55 lux) and OFF (106.40±2.87 - 158.75±8.17 lux) depict that the time of the day also contribute to luminosity levels in indoor spaces This could be attributed to natural lighting that enhance the indoor luminosity, since it was not restricted. The findings of this study suggest that artificial lighting in indoor spaces (e.g. offices, laboratories, lecture theatres, etc.) should be used at all time, and not limited to night time; as its the usual practice by some persons to avoid energy wastage. Furthermore, the illuminance uniformity in the surveyed offices in the afternoon when lights were switched ON and OFF ranges from 0.6 – 0.8.

From the average luminosity at the surveyed laboratories in the morning when lights were switched ON (Figure 4a), CHM and PHY recorded the lowest (347.20±23.68) and highest (414.70±67.75) luminosity levels. For morning measurement when lights were switched OFF (Figure 4b),

CHM laboratory recorded the lowest average luminosity (277.45±18.03 lux), while PHY laboratory recorded the highest average luminosity (367.85±56.50 lux). The illuminance uniformity in the surveyed laboratories in the morning when lights were switched ON and OFF were 0.5 – 0.7 and 0.5 - 0.6 respectively. These low values suggests that the light intensity was not uniformly distributed.

Similarly, the luminosity levels in the afternoon at PHY, CHM, BIO, PHS, and COM laboratories when light were switched ON are 529.00±63.31 lux, 489.10±41.52 lux, 487.55±33.06 lux, 510.95±38.59, and 516.45±34.97 lux respectively. The luminosity levels in the afternoon at PHY, CHM, BIO, PHS, and COM laboratories when lights were switched OFF are 462.15±54.23 lux, 407.08±39.12 lux, 433.40±28.85 lux, 427.15±35.60, and 414.70±35.07 lux respectively. It is worthy of note that luminosity levels in the afternoon when lights were switched ON were relatively higher as compared to when lights were switched OFF. According to the IESNA, the standard luminance for laboratories is between 500 – 750 lux [4, 10]. From the surveyed laboratories, the luminosity levels at PHY, PHS, and COM laboratories in the afternoon when lights were ON are within the recommended standard, while others are slightly below the required standard.

Interestingly, the measured luminosity levels in the surveyed laboratories are relatively high. This could be attributed to the month (i.e., February) when this research was carried out. February is the peak of dry season in the studied area when the amount of solar radiation received are very high due to clearness of the sky. This suggests that besides the hour of the day, month and season of the year could also reduce or enhance illuminance of indoor spaces. We therefore recommend similar assessment during rainy season particularly in August or September, the peak of cloud activity in the studied area. The illuminance uniformity observed in the laboratories in the afternoon when lights were switched ON and OFF were 0.5 – 0.6 and 0.4 - 0.5 respectively.

It could be observed from the average luminosity at the surveyed lecture theatres (A, B, C, and D) in the morning when lights were switched ON (Figure 6a) that, A and D recorded the lowest (290.10±21.64) and highest (442.40±20.03) luminosity levels. For morning measurement when lights were switched OFF (Figure 6b), A recorded the lowest average luminosity (216.10±22.07 lux) while D recorded the highest average luminosity (377.35±17.91 lux). The estimated illuminance uniformity in the surveyed lecture theatres in the morning when lights were switched ON and OFF were 0.4 – 0.7 and 0.4 - 0.5 respectively. These values are below the minimum recommended value of 0.8 [10].

In the afternoon when lights were switched ON, the lowest and highest average luminosity at A and C are 319.95±19.39 and 463.10±19.35 (Figure 7a). The average luminosity at the lecture theatres ranges from 319.95±19.39 – 463.10±19.35. When lights were switched OFF, the lowest and highest average luminosity of 251.00±16.53 lux and 403.45±19.97 lux were observed at A and C respectively (Figure 7b). The average luminosity at the lecture theatres ranges from 251.00±16.53 – 403.45±19.97 lux.

The international Commission on Illumination (CIE) standard for lecture theatre is between 500 - 2000 Lux [10]. The observed luminosity levels in all the lecture theatres are not up to the required standard except lecture theatres C and D that are slightly below the standard. This depicts that the existing lighting conditions in the surveyed lecture theatres require improvement to the required standard. During afternoon measurement, the illuminance uniformity in the lecture theatres when lights were switched ON and OFF ranges from 0.5 – 0.7 and 0.4 – 0.8 respectively.

From the aforementioned, the observed average luminosity level in the surveyed offices required upgrade to the recommended standard of 300 – 500 lux. The existing lighting conditions in the offices can be categorize as dim (51 – 100 lux), satisfactory (101 – 200 lux), and good (201 – 400 lux). The average luminosity levels in the surveyed laboratories are relatively high. However, lighting in 60 % of the sampled laboratories are up to the standard, while 40 % required upgrade to the recommended standard. The observed luminosity levels in all the lecture theatres are not up to the required standard. Lecture theatres C and D are slightly below the standard.

Furthermore, since each of the offices, laboratories and lecture theatres were evenly divided into 20 equal parts and measurements were taken at each sample site, it is interesting to note that the measured luminosity at each sampled point is not the same. They varied from one sample point to another. This implies that luminosity in the surveyed offices, laboratories and lecture theatres were not evenly distributed. This could be attributed to factors such as geographical position of windows, measurement time, surface area of windows, light intensity (i.e., types of lighting system), presence of curtains, clear or cloudy days (weather condition), among others. According to [17], even luminance in indoor space is very necessary for minimum lighting level. The findings of this study suggest that artificial lighting in indoor spaces should be switch ON at all time, and not limited to night time only as it is the common energy-saving measure by some persons. Furthermore, we observed that besides the hour of the day, month and season of the year could also reduce or enhance illuminance of indoor spaces; if the illuminance is based on both natural and artificial lighting.

Generally, the observed illuminance uniformity in offices, laboratories and lecture theatres ranges from 0.4 – 0.8. The minimum uniformity ratio of 0.8 is recommended by the CIBSE for workplace illuminance uniformity [10]. This depicts that illuminance uniformity in most of the surveyed sites are relatively low. Lighting in about 10 – 20 % of the surveyed spaces have the recommended minimum illuminance uniformity of 0.8, while 80 - 90 % do not. This

shows that the illuminance uniformity in most of the surveyed sites require upgrade to the recommended standard. It may interest you to note that FUHSO was established in 2021 and the observed results may be usual for an institution that is three years into its operation.

The findings of this study generally depict that, indoor spaces with lighting below the recommended standard tend to have poor luminosity level, uneven distribution of light intensity, and poor illuminance uniformity. This could affect the staff and students. Therefore, the existing lighting system need to be upgraded as this will enhance focus, attention, concentration levels, comprehension, reduce errors, increase productivity, as well as overall well-being of staff and students [2, 11, 14, 16]. Thus, the findings of this research have implication on the comfort, productivity, and performance of students and staff. The scientific insight from this study will be useful to students, staff, university administrators, interior designers, architects, etc. We hereby recommend improvement of the existing artificial lighting sources, adherence to best practices and standards, as well as properly harnessing natural lighting. This will create conducive atmosphere that promotes teaching, learning, productivity, innovation, and well-being; that will contribute to national development. This study assessed luminosity levels in indoor spaces from natural and artificial light. Further studies can focus on evaluation of the two scenarios separately for better comparison and improvement where necessary.

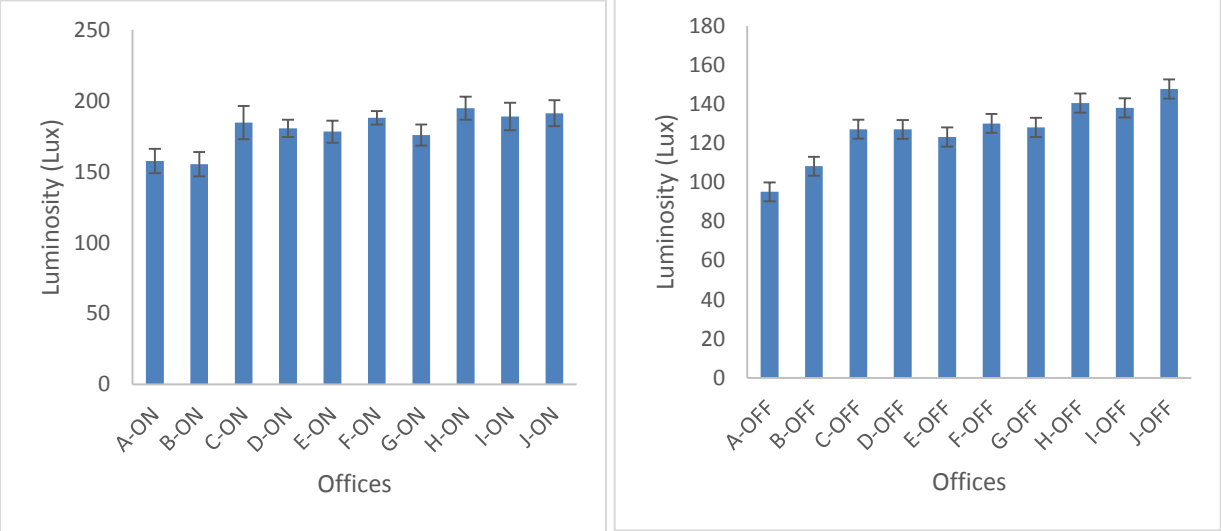

Figure 2: Average luminosity at offices in the morning when lights are switched (a) ON and (b) OFF

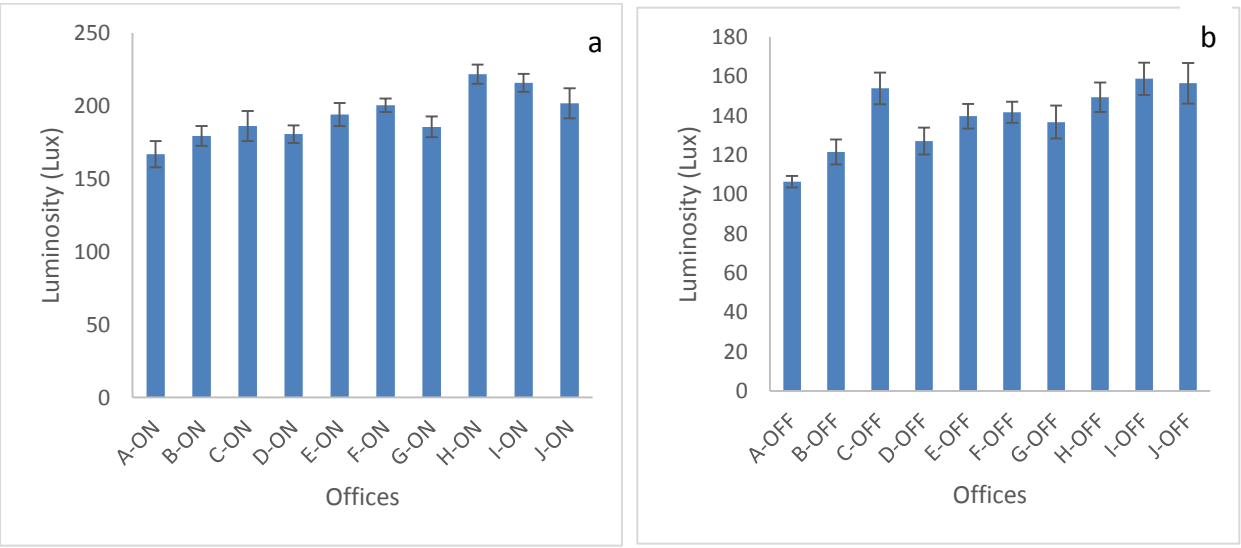

Figure 3: Average luminosity at offices in the afternoon when lights are switched (a) ON and (b) OFF

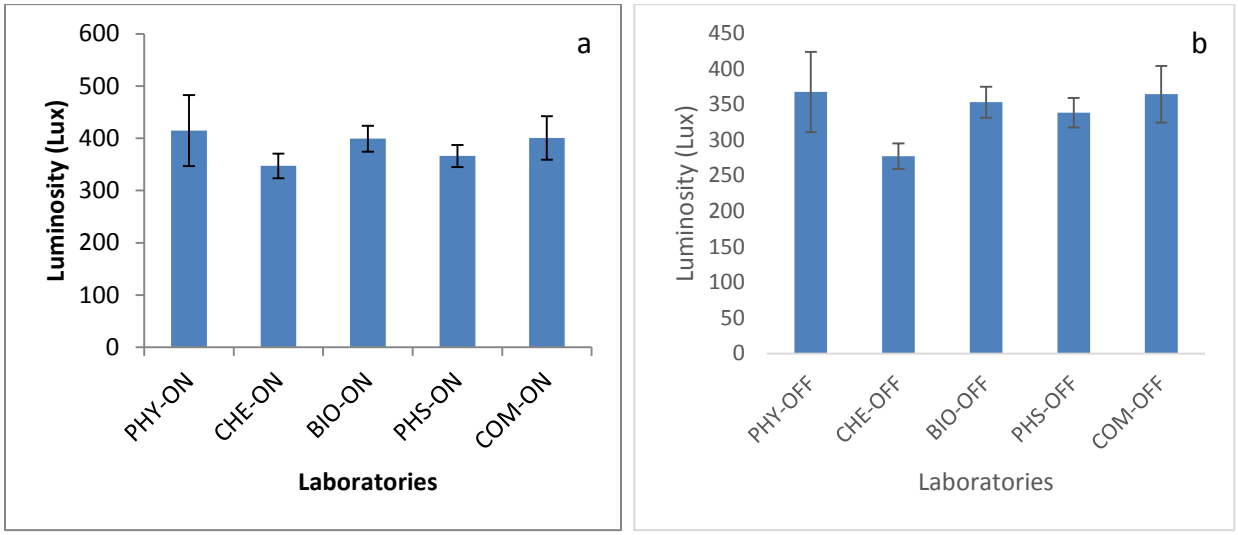

Figure 4: Average luminosity at the laboratories in the morning when lights are switched (a) ON and (b) OFF

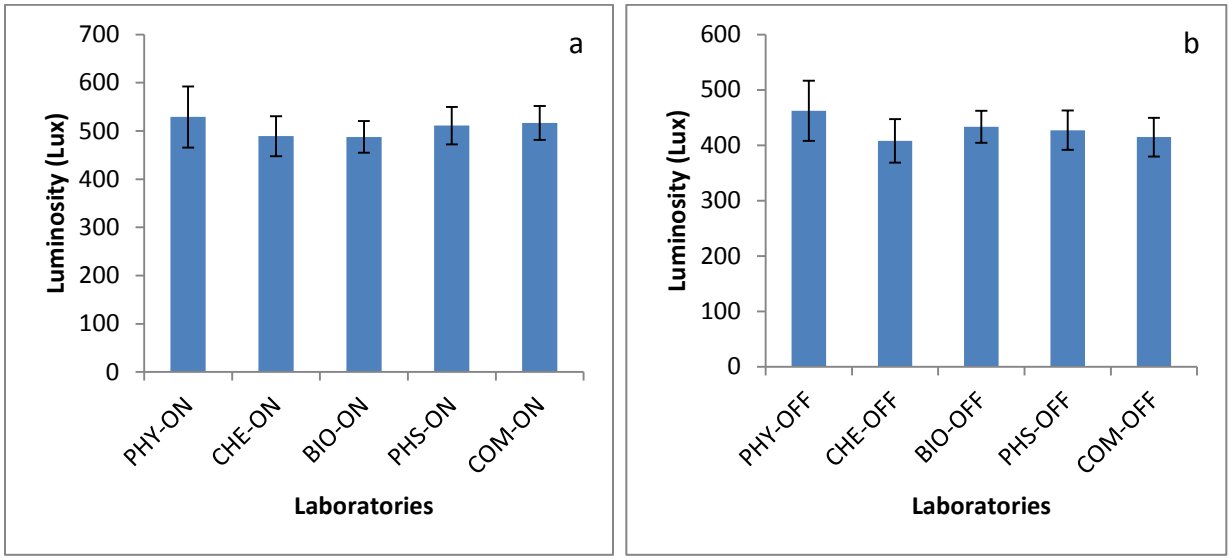

Figure 5: Average luminosity at the laboratories in the afternoon when lights are switched (a) ON and (b) OFF

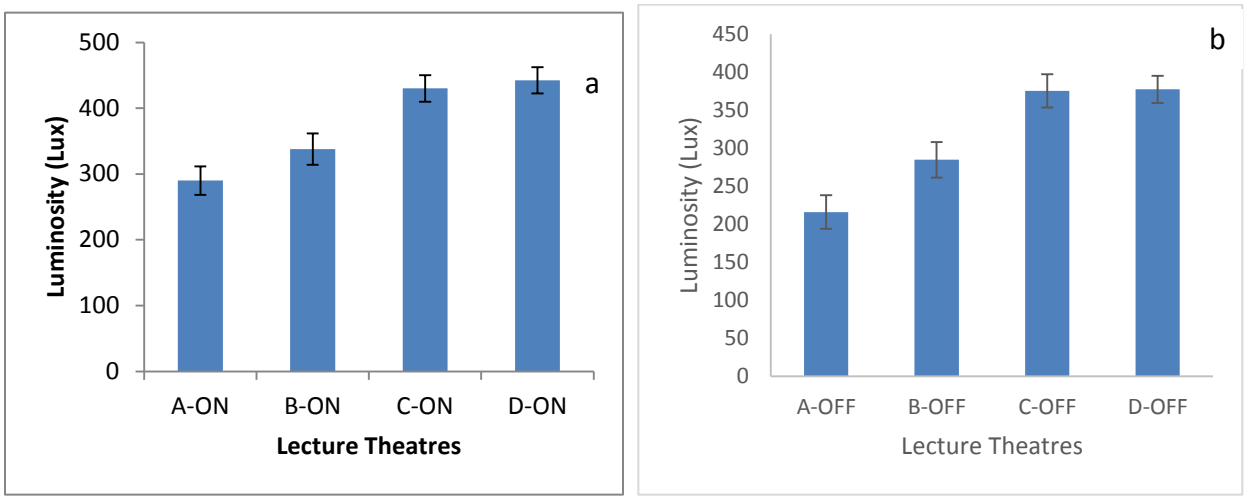

Figure 6: Average luminosity at the lecture theatres in the morning when lights are switched (a) ON and (b) OFF

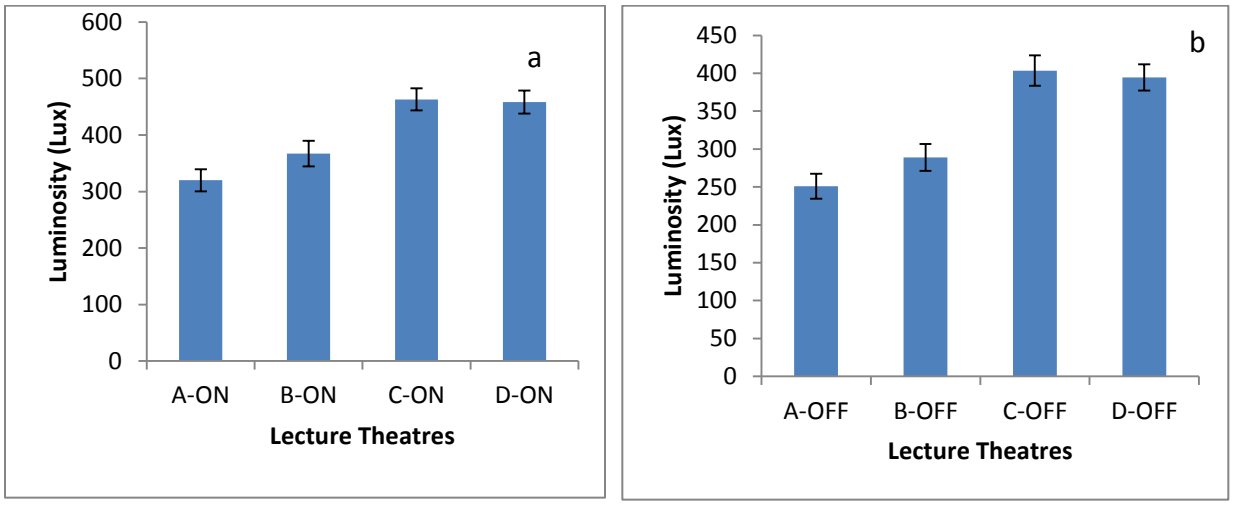

Figure 7: Average luminosity at lecture theatres in the afternoon when lights are switched (a) ON and (b) OFF

Conclusion

The following conclusions were drowned from this study:

i. Average luminosity levels observed in the surveyed offices are below the recommended standard of 300 – 500 lux.
ii. The existing lighting conditions in the offices can be categorize as dim (51 – 100 lux), satisfactory (101 – 200 lux) and good (201 – 400 lux).
iii. About 60 % of the sampled laboratories are up to the standard, while 40 % required upgrade to the recommended standard of 500 – 750 lux.
iv. The measured luminosity in the surveyed indoor space was not evenly distributed.
v. The findings of this study suggest that besides the measurement time, month and season of the year could also reduce or enhance illuminance of indoor spaces.
vi. Illuminance uniformity in about 10 – 20 % of the surveyed space was up to the standard of 0.8, while about 80 - 90 % was not.
vii. The existing lighting systems need general upgrade to the recommended standard.
viii. The findings of this study suggest that artificial lighting in indoor spaces should be switch ON at all time, and not limited to night time only.

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