Journal of Electrical Engineering, Electronics, Control and Computer Science – JEEECCS, Volume 7, Issue 23, pages 5-10, 2021

Experimental Analysis of the Performance of the New Economic Electric Lamps and Their Effect on Human Health

Abraham Dandoussou
Department of Electrical and Power Engineering
University of Buea
Kumba, Cameroon
dandoussou@gmail.com

Pierre Kenfack
Depatment of Electrical and Power Engineering
University of Buea
Kumba, Cameroon
pierrekenfack2003@yahoo.fr

Frank Arthur Tiwa
Department of Electrical and Power Engineering
University of Buea
Kumba, Cameroon
arthur_tiwa@yahoo.fr

Abstract **– This paper presents an experimental analysis of the performance of some new economic electric lamps and their effects on the human being. The performance related to the lighting of these lamps was measured by a lux-meter and interpreted by the Matlab® tool. Four types of electric lamps, including the new economic lams have been used in this research work. There are: Fluorescent Lamps (FL), Compact Fluorescent Lamps (CFL), Incandescent Lamps (IL) and Light Emitting Diode Lamps (LED). Experimental data have been adjusted to theoretical mathematical model. The results show that the luminance of the lamp decreases exponentially with the height where the lamp was placed from the floor. Henceforth, LED lamps and FLs are economically better than the other lamps in term of energy savings and cost. Otherwise, ILs which emit a significant amount of UV radiation can be harmful. FLs produce rays that can cause an inflammation of the conjunctiva and cornea. And finally, LED lamps present the risk of development of cataract.**

Keywords-Lux-meter, artificial lamps, luminance, energy savings, sunlight, cataract

I. Introduction

The world has been using fire as an artificial light source. Fire is known as the first primary light source. Humans discovered fire early in their history and they used to burn or to heat materials like stones as light sources. Today, approximately 1.6 billion people still use flame-operated lamps [1-3].

Natural light is produced by any light source that doesn't need electricity. We have for example sunlight produced by the sun, moon light produced by the moon, star light produced by stars, fire produced at the beginning by stones. In fact, in order to have fire, people were using stones and cotton [4;5]. However, even if natural light is not expensive compare to artificial light, it could not make life comfortable. That is why artificial light has been produced from electrical means. The first electrical light was produced by incandescent lamps. These lamps contain carbon or tungsten that is heated until it glows [6;7]. The carbon-based incandescent lamps produce light that is close to daylight and it is not good for eye. That is why halogen lamps were fabricated with tungsten filament and a mixture of gases inside the tube. These modern incandescent lamps produce light close to the daylight and good for vision [8;9]. Researches went on with the production of other types of electric lamps like fluorescent lamps (FLs), compact fluorescent lamps (CFLs) and light emitting diode (LED) lamps. Fluorescent lamps are low-pressure lamps that produce visible light from a phosphorous coating put inside the tube. They are cheap, efficient and very good for illumination. CFLs have two, four or six small fluorescent tubes mounted on a base. They are very efficient and work like FLs. LED lamps become a new technology of electric lamps and they produce light by electroluminescence process. At the beginning, LED lamps were used as indicators [9].

From incandescent lamps to LED lamps, it has been observed that the electric power decreases. And consequently, it improves energy savings. It was also observed that the quality of light produced by lamps was not the same. As soon as artificial light is produced by electric lamps to compensate the absence of sunlight in a particular place, it is important to know its effects on human being's health. In fact, sunlight is a portion of the electromagnetic radiation given off by the sun in particular infrared (IR), visible, ultraviolet (UV) and X-rays light. The existence of nearly all life on Earth is fueled by light from the sun. However, the UV radiation in sunlight has both positive and negative health effects, as it is both a principal source of vitamin D3 and a mutagen. Vitamin D is useful for strengthening bones and inhibiting the growth of some cancers. Long-term sunlight exposure can provoke the development of skin cancer, skin aging, immune suppression and eye diseases such as cataracts and macular degeneration [10]. Short-term exposure can cause sunburn, snow blindness and solar retinopathy [10;11].

This paper aims to show the performance (lighting level and power savings) of electric lamps based on experimental measurements. These measurements also help to find out the effects of the produced light on human being health.

II. Material and Methods

A. Material

The following equipment was used for the experimental measurements during this research paper:

- An USB data-logging light meter (lux meter) for measurement the light flux produced by any light source. For this work the used lux meter is a PCE-174 having specifications given in table I.
- Electric lamps given in table II.

TABLE I. Technical Specifications Of The Lux Meter

Ranges	40.00 – 4000 Lux; 40.00 – 400.00 kLux; 40.00 – 4000 fe; 40.00 kfe
Resolution	0.1-1-10-100 Lux; 0.01-0.1-1-10 Foot-candle
Accuracy	±5 % of reading ±10 % digits (< 10,000 Lux) ±10 % of reading ±10 % digits (> 10,000 Lux)
Repeatability	±3 %
Memory	16,000 readings
Rate of measurement	Between 2 seconds and 9 hours
Overload indicator	OL
Screen refresh rate	1.5 per second
Operating conditions	0 to 40 °C / 32 to 104 °F / 80 % r.h
Display	$3^{3/4}$ digit LCD
Power supply	9 V battery
Dimensions	Device: 203x50 mm / 7.9x2.9x1.9 In (widthxheightxdepth) Light sensor: 115x60x20 mm / 4.5x2.3x0.7 In (widthxheightxdepth) Cable length: 150 cm
Weight	280g/9.8 oz
Standards	Safety: IEC-1010-1; EN 61010-1 EMV; EN 50081-1; EN 50082-1 corresponding with DIN 5031; DIN 5032

TABLE II. Specifications Of Electric Lamps

Electric Lamps	***Specifications***	***Number***
Fluorescent Lamp	36 W; 220 V AC; 50/60 Hz; T8	01
Compact Fluorescent Lamp	40 W; 110 to 130 V or 220 to 230 V AC	01
Incandescent Lamp	40 W, 60 W and 100 W; 240 V AC	03
Light Emitting Diode	9 W, 20 W, 29 W and 40 W; 170 – 240 V AC	04

B. Operation Principle

The experimental measurement was carried out according to the following steps. All the measurements were done in the evening in order to reduce the effect of the daily light on the produced light.

- First, use a meter to measure the height at which we will place our lux-meter. We will take as maximum height 200 cm.
- With the lamp on, turn on the lux-meter and place its probe at this height on a fixed support to prevent it from bursting.
- Use the USB cable to connect the lux-meter to the PC and open the software. With the software opened, set the sample time to 1 second and start saving data.
- After 15 seconds, stop the recording and save the recorded data.
- At the same height, follow these steps for all the lamps that are used in the experiment.
- With a step of 20 cm, vary the height of the probe and make the same measurements.
- All measurements are carried out, use the software Matlab® to process the obtained data. For each lamp, the curves of the luminance according to the height are plotted. By using cftool command, the mathematical model is obtained.

C. MATLAB® Program and Fitting Method

```
%program for processing the collected data.
%EXAMPLE: light emitting diode (LED) 20W.
% values of different heights in centimeters.
H=20:20:200; % in centimeters
%values of different flux in lux
L=…..; %for example L=[60.01 70.83 82.37 99.97 132.31 187.90 291.94 484.27 933.25 2770]; % in lux
% trace of the corresponding curve.
plot(H,L);
xlabel('height (cm)');
ylabel('luminance (lux)');
title('light emitting diode (LED) 20W');
```

Matlab® tool "*cftool*" has been used to adjust the experimental points to a theoretical model proposed by the authors and given by equation (1). Parameters a, b, c and d were determined using a least mean square method to adjust experimental points. In this equation,

- Function f is the luminance of the light produced by a lamp (in Lux);
- Variable x is the height at which the lamp is fixed and the floor (in cm);
- Parameter a has a dimension of the luminance (in Lux);
- Parameter b is in cm-1;
- Parameter c has a dimension of the luminance (in Lux);
- Parameter d is in cm-1.

$$f(x) = ae^{bx} + ce^{dx} \qquad (1)$$

III. Results and Discussion

A. Experimental Results

Figures 1 to 9 show the variation of the luminance for the various types of lamps used in this work. From the curves, it is clear that the luminance decreases when the height increases. Mathematical model of the luminance has been determined by adjusting experimental points to the function given in equation 1. Table III gives the values of coefficients a, b, c and d for each type of lamp and with respect to its rated power, with R^2 the root mean square. It can be noted that coefficients a and c are relatively high, compare to coefficients b and d. The least mean square method is used to determine the values of parameters a, b, c and d.

Figure 1. Luminance variation curve of a 40 W incandescent lamp in function of the height

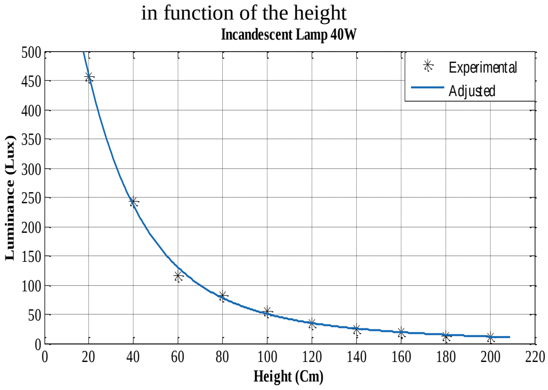


Figure 2. Luminance variation curve of a 60 W incandescent lamp in function of the height

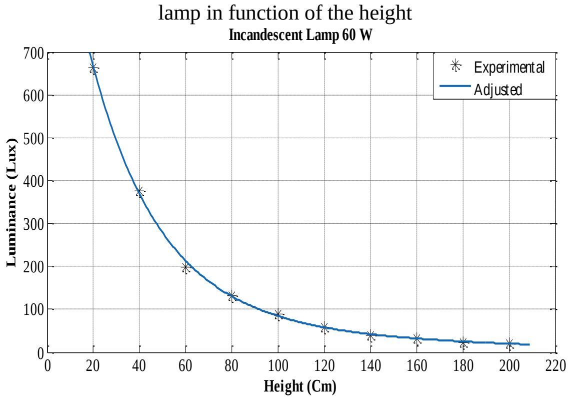


Figure 3. Luminance variation curve of a 100 W incandescent lamp in function of the height

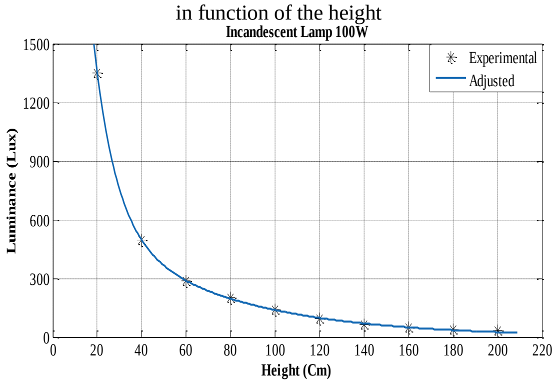


Figure 4. Luminance variation curve of a 36 W tube fluorescent lamp in function of the height

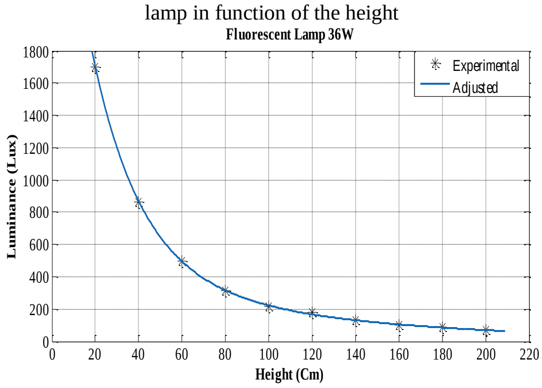


Figure 5. Luminance variation curve of a 40 W Compact Fluorescent lamp in function of the height

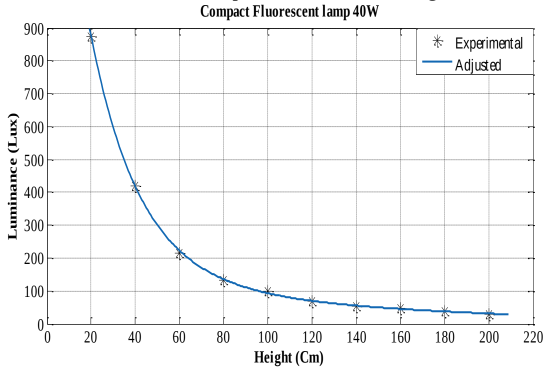


Figure 6. Luminance variation curve of LED 9 W in function of the height

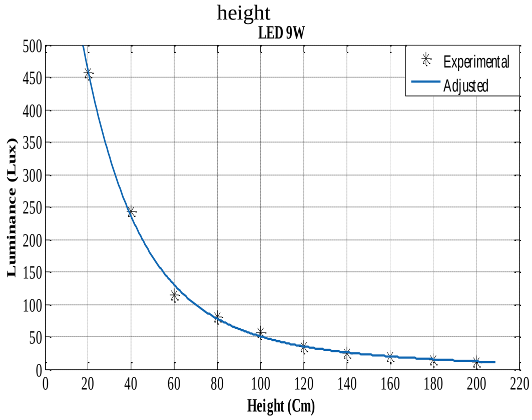


Figure 7. Luminance variation curve of LED 20 W in function of the height

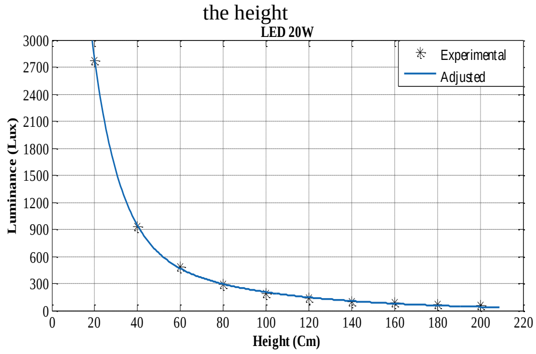


Figure 8. Luminance variation curve of LED 29 W in function of the height

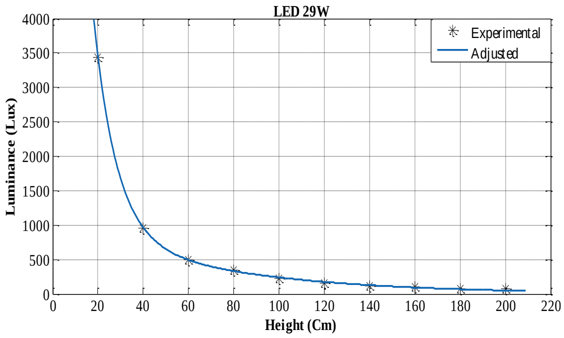
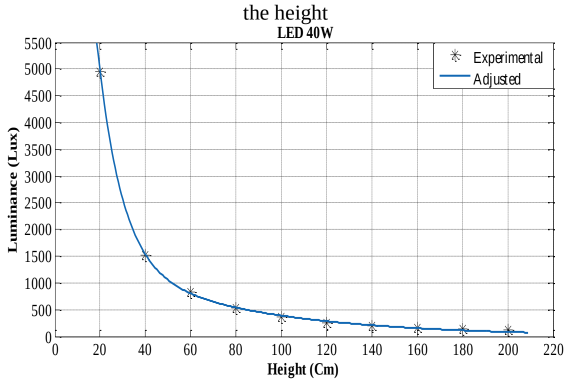


Figure 9. Luminance variation curve of LED 20 W in function of the height



B. *Discussion*

Table IV shows some values of the luminance in function of the distance between the working surface and the ceiling. It is clear that LED lamps (from 20 W) and fluorescent lamps are better than the other lamps. According to the standard, there is a needed number of lamps per room which on the total luminance required. From the obtained results in table IV, any user of electric lamps can find out the advantage of using LED lamps or FLs instead of using ILs (in term of energy savings).

For example, let's consider an office area that has a length of 20 m, a width of 10 m and a height of 3 m. The ceiling to desk height is 2 m. The area to be illuminated to a general level of 250 Lux. Let's find out the number of lamps (IL 100 W or LED 40 W are installed) and the energy saved.

For IL 100 W, one lamp produces 24.89 Lux at the height of 2 m. Hence, for this office, 11 lamps are needed.

For LED 40 W, one lamp produces 83.07 Lux at the height of 2 m. Hence, for this office, 4 lamps are needed.

If the lamps are working for 8 hours per day, the energy consumed will be 0.8 kWh and 0.32 kWh for IL 100 W and LED 40 W respectively. So the energy saved will be 0.48 kWh.

So economically, LED lamps are better than ILs. For improper use of incandescent lamps, we can meet the problem of visual fatigue. Visual fatigue occurs more frequently when the visual system has to work at the limits of its capabilities and / or for a long time. Inadequate lighting is an additional factor of visual load and contributes to signs of eye and eye fatigue. This fatigue is manifested, among other things, by symptoms of irritation of the eyes and eyelids, visual disturbances, headaches, a weakening of certain visual functions, such as sensitivity to contrast, accommodation, etc. as well as a decrease in work efficiency. These lamps operate at high temperatures, so they can emit a significant amount of UV radiation which can be harmful if the exposure is long and the distance between the lamp and the user is short [12 – 16].

Fluorescent substances are excited by the ultraviolet radiation produced during the passage of electric current in the gas column. These rays can cause inflammation of the conjunctiva and cornea. They can also be at the origin of a cancer of the skin that remains very unlikely except in the case of a malfunction of the light source [12 – 16].

LED has a much more concentrated spectrum on the blue color. The blue light presents for the eyes the risks of development of a cataract which is an infection of the eye characterized by a gradual and slow specification of crystalline lens which leads to a decrease of the vision and a proven discomfort vis-a-vis the light sources. This is if the use is prolonged and short distance [12 – 16].

Acknowledgment

This research was carried out during the end of cycle project at the University of Buea, Cameroon.

CONCLUSION

The purpose of this paper was to study the performance of economic lamps and their effects on the human body. For our study, we considered 4 types of artificial lamps namely the incandescent lamp, the fluorescent tube lamp, the compact fluorescent lamp (CFL) and finally the Light Emitting Diode (LED). From the equations obtained, we can obtain an estimation of the lighting of each lamp at any desired height or the height corresponding to a predefined lighting. These equations have allowed us to stand out according to the international standard of the luminance, a standard specific to each used lamp where we mentioned for each room, the quantity of lighting necessary and the height to which the chosen lamp must be placed, to get this lighting. It should be noted that these artificial lamps have important effects on our health when the use is prolonged and short distance. Inadequate use of these lamps can cause eye and eye fatigue, headaches by weakening of certain visual functions such as contrast sensitivity, inflammation of the conjunctiva and cornea, risk of developing a cataract.

TABLE III. Parameters Of The Mathematical Model Of The Luminance

Coeff	**FL**	**CFL**	**IL**			**LED**			
	36 W	***40 W***	***40 W***	***60 W***	***100 W***	***9 W***	***20 W***	***29 W***	***40 W***
a (Lux)	3138	1809	827.5	1118	5902	835.2	10060	19110	23530
b (cm^{-1})	-0.04425	-0.04562	-0.04048	-0.03429	-0.09924	-0.04081	-0.07953	-0.09949	-0.09341
c (Lux)	492.4	176.8	112.4	122.2	758.1	111.9	989.9	1131	1789
d (cm^{-1})	-0.00981	-0.00869	-0.01139	-0.00936	-0.01707	-0.01125	-0.01597	-0.01561	-0.01533
R^2	0.9999	0.9998	0.9983	0.9992	0.9999	0.9982	0.9998	0.9999	0.9998

TABLE IV. SIGNIFICANT VALUES OF THE LUMINANCE ACCORDING THE WORKING SURFACE

Work surface height (cm)	IL40	IL60	IL100	FL40	CFL40	LED9	LED20	LED29	LED40
100	49.91	83.31	136.70	220.50	92.29	50.58	202.20	236.50	385.00
150	22.25	36.53	58.60	117.20	49.95	22.51	90.21	108.80	179.30
200	11.73	19.93	24.89	69.57	31.25	11.99	40.44	49.73	83.07

NB: the values are given in lux

REFERENCES

[1] Hilscher, A. (2002). Determination of the cathode fall voltage in fluorescent lamps by measurement of the operating voltage. Journal of Physics D: Applied Physics, 35(7) 1707-1715.

[2] Sullivan, C. R. & Drescher, A. C. (1993). Influence of on-time and use frequency on cost-effectiveness of compact fluorescent lamps, Conference Record of the 1993 IEEE Industrial Application Society Annual Meeting, Toronto, Ontario, Canada, Oct 2-8, 1993, 2283-2290

[3] Rozanowska M, Jarvis-Evans J, Korytowski W, Boulton ME, Burke JM, Sarna T (1995). 46 Blue light-induced reactivity of retinal age pigment - in vitro generation of oxygen- reactive species. J BiolChem 270:18825-18830.

[4] Roehlecke C, Schaller A, Knels L, and Funk RH (2009) The influence of sublethal blue light exposure on human RPE cells. Mol.Vis. 15, 1929–1938.

[5] Godley BF, Shamsi FA, Liang FQ, Jarrett SG, Davies S, and Boulton M (2005). Blue light induces mitochondrial DNA damage and free radical production in epithelial cells. J. Biol. Chem. 280, 21061–21066.

[6] Argiles M, Cardona G, Perez-Cabre E, Rodriguez M (2015). Blink Rate and Incomplete Blinks in Six Different Controlled Hard-Copy and Electronic Reading Conditions. Investigative ophthalmology & visual science. 56(11):6679-85.

[7] Lee HS., Cui L., Li Y., Choi J-H., Li Z., Kim G. E., Choi W., Yoon K. C., (2016), Influence of Light Emitting Diode-Derived Blue Light Overexposure on Mouse Ocular Surface, PLoS One 11 (8), e0161041, doi: 10.1371/journal.

[8] Behar-Chen F., Martinsons C., Viénot F., Barlier-Salsi A., Cesarini J. P., Enouf O., Garcia M., Picaud S., Attia D., (2011), Light Emitting Diode (LED) for Domestic lighting: Any Risk for Eyes?, Prog. Ret Eye Res., 30:239-257.

[9] Lokendra P. S. and Goldy K., (2013), A Comparative Study on Design and Operation of Fluorescent Lamps, Cfls and Leds, Int. Journal of Engineering Research and Applications, Vol. 3, Issue 5, Sept-Oct, pp. 401 – 407

[10] Walker B. N., and Ilev I. K., (2017), Evaluation of the Potential Optical Radiation Hazards with LED Lamps Intended for Home Use, Health Phys., 112 (1), 11 – 17.

[11] Chou C. F., Cotch M. F., Vitale S., Zhang X., Klein R., Friedman D. S., Klein B. E., Saddine J. B., (2013), Age-Related Eye Disease and Visual Impairement Among U.S. Adults, Amer. J. Prev. Med., 45, 29 – 35.

[12] Sui G. Y., Liu G. C., Liu G. Y., Deng Y., Wang W. Y., Tong S. H., Wang L., (2013), Is Sunlight Expossure a Risk Factor for Age-Related Macular Degeneration?, A Systematic Review and Meta-Analysis, Br. J. Ophtalmol., 97, 389 – 394.

[13] Sliney D. H., (2002), How Light Reaches the Eyes and its Components, Int. J. Toxicology, 21, 501 – 509.

[14] Higlett M. P., O'Hagan J. B., Khazova M., (2012), Safety of Light Emitting Diodes in Toys, Journal of Radiological Protection, 32, 51 – 72.

[15] Kim J., Hwang Y., Kang S., Kim M., Kim T. S., Kim J., Seo J., Ahn H., Yoon S., Yun J. P., Lee Y. L., Ham H., Yu H. G., Park S. K., (2016), Association between Exposure to Smartphones and Ocular Health in Adolescents, Ophtalmic Epidemiology, 23 (4), 269 – 276.

[16] Delcourt C., Cougnard-Gregoire A., Boniol M., Carriere I., Dore J. F., Delyfer M. N., Rougier M. B., Le Goff M., Dartigues J. F., Barberger-Gateau P., Korobelnik J. F., (2014), Lifetime Exposure to Ambient UltraViolet Radition and the Risk for Cataract Extraction and Age-Related Macular Degeneration, The Alienor Study, Invest. Ophtalmol. Vis. Sci., 55, 7619 – 7627.