Light Pollution Measurement at Selected Sites of Peninsular Malaysia on 9th of June 2018

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Abstract. Light pollution is regarded as one of environmental issues, although it is often neglected by vast majority of us. It has severe impacts on human health & nocturnal creatures. Due to that, measurement of light pollution is crucial as it serves as an indicator on how polluted our sky. The objective of this paper is to compare light pollution measurement at designated sites. For this paper, we choose four (4) stationary sites that are located according to cardinal directions i.e. Selangor Observatory (BCS), Kuala Lipis (LPS), Besut (BST) and Langkawi National Observatory (ONL). All sites were installed Sky Quality Meter (LU-DL type). The measurement is in magnitude per arc second (m/arc sec²) unit. The higher the measurement value indicates the less polluted sky. We found that 9th of June 2018 was identified as best day for the four (4) sites based on the average of sky magnitude along night. The less polluted site is LPS site with 21.15 m/arc sec² and the worst site is BST with 19.58 m/arc sec². Measurement of light pollution in the long run is vital in order to have a reliable dataset and for protection of the night sky brightness.

1. Introduction
The discovery of incandescent light by Thomas Edison in 1879 has marked the modern era of electricity. Since then, the night sky around the world getting illuminated every night by artificial light. Our exposure to the artificial light makes us no longer experience the darkness of the night [1]. The loss of the dark sky at night means our sky is getting polluted. Pollution is the presence of a substance that has harmful effect to living organisms. Light pollution comes in many ways, for instance, skyglow, light trespass and glare. It is getting worsen after light emitting diodes (LED) revolution, as it is known for their environmental friendliness in terms of lower energy consumption, low cost, ease of regulation and long lifespan and hence being mass produces and used widely.

There are several major reasons why we regard light pollution as environmental issues: 1) light pollution has caused low contrast seeing. Therefore it is difficult for astronomers to observe faint signals of light from the distant objects in outer space. Dark sky is important especially to astronomers as it is a key scientific resource in order to understand how universe works [2][3], eventually it is becoming a global concern for astronomers[4]; 2) it has severe impacts on human health & nocturnal
creatures [5]. LEDs have problem related to the strong blue component in their spectrum that scatters easily and affects our ecosystems and public health [6,7].

In general, human eyes have three (3) different photoreceptors cells i.e. cone, rod and intrinsically photosensitive retinal ganglion cells (ipRGC). The third light-sensing contains a light sensitive protein - melanopsin. Melanopsin showed a peak spectral sensitivity between 460nm and 484nm which is blue light. Melanopsin is important because it synchronize circadian rhythms (24-hour light/dark cycle), regulation of pupil size, release of melatonin, visual perception function and many more [8].

Due to that, ground measurement of light pollution is crucial as it serves as an indicator on how polluted our sky [9]. Measurement of light pollution has three (3) types: 1) night sky spectrum measurement; 2) astronomical measurement for quality of night sky; and 3) sky glow measurement [10]. Ngadiman, Shariff and Hamidi [11] identified there are at least five (5) sensors that has been used in light pollution or night sky brightness measurement viz. Pitch Black Meter (PBM), Light Detector Tool (APC), Photomultiplier Tube (PMT), Sky Quality Meter (SQM) and Charge-Coupled Device (CCD).

The objective of this paper is to compare light pollution measurement at selected sites of Peninsular Malaysia on 9th of June 2018 that fall between the cities and rural areas category. Among all sites, only ONL and LPS have been measured its quality of night sky with reading 21.45 mag/arcsec² circa 2013 [12] and 21.45 mag/arcsec² in August 2010 [13]. It is important to know the minimum and maximum range of each site in order to calculate the percentage of magnitude can varied. We also will look on the factors that contribute to the values.

2. Methodology
Presented data in this paper is a part of a bigger research i.e. Night Sky Brightness Database Project (NSB-DP) in Malaysia. This NSB-DP consists of six (6) stationary sites that includes Peninsular of Malaysia (West Malaysia) and Borneo (East Malaysia). The sites are selected due to the strategic location and less polluted aspect. For this paper, we choose four (4) stationary sites that are located according to cardinal directions of Peninsular Malaysia as in Table 1:

| Stationary Sites                        | Coordinates       |
|----------------------------------------|-------------------|
| Selangor Observatory (BCS), Selangor   | 3.819°N, 100.814°E|
| Kuala Lipis (LPS), Pahang              | 4.178°N, 102.080°E|
| Besut (BST), Terengganu                | 5.808°N, 102.585°E|
| Langkawi National Observatory (ONL), Kedah | 6.30°N, 99.781°E  |

Light pollution at the selected sites were measured using the most prevalent and well-engineered meter i.e. Sky Quality Meter (SQM). This meter measures the visual brightness of the night sky in scale of magnitude per arc second (mpsas) or abbreviated as mag/arcsec² unit. This scale is reverse logarithmic which means a difference of 5 magnitudes is a factor of 100 times of the light intensity [14]. The higher the measurement value indicates the less polluted sky - Figure 1.

Figure 1. Mag/arcsec² interpretive scale
For all four (4) sites, we used SQM-LU-DL that has data logging capabilities with USB interface and external battery holder. Due to the meter installation, all sites must meet stringent requirements: 1) unobstructed zenith; 2) meter is placed with minimum height at least 1.6m above the ground to avoid unwanted light; and 3) site accessibility and safety of the meter – Figure 2.

Figure 2. Meters setup for each site

This affordable meter is then encased in a dedicated housing for weather protection where we have to set for glass offset value – Figure 3. Field of view (FOV) of this SQM model comes with angular sensitivity of ~10° at Half Width Half Maximum (HWHM) and ~20° at Full Width Half Maximum (FWHM).

Figure 3. (a) SQM-LU-DL with battery holder (b) front of the meter that includes infrared blocking filter (c) the meter inside the housing minus the cap

3. Results & Discussion
Figure 4 shows the measurement for all sites on 9th of June 2018. The date is selected as the best day in June 2018 as the illumination of the moon is 28% at waning crescent phase. As for light pollution measurement we eliminated data from 20°-0° that includes twilight phenomena. The dotted lines marked the altitude of the Sun at twilight (dusk and dawn) which are: 1) civil twilight at 6°; 2) nautical twilight at 12°; and 3) astronomical twilight at 18°. While 20° is expected the night is clear from any remnant of sunlight.
Figure 4. Measurement for all sites on 9th of June 2018

From the Table 2, average mag/arcsec$^2$ for all sites is 20.42 that equivalent with 4.5-5 Bortle scale. The least polluted site at this particular date is LPS with 21.15 mag/arcsec$^2$ 00:30h. The range is from 20.10 to 21.15 mag/arcsec$^2$ which 21 times the intensity throughout the night. LPS is expected as darkest site as it is located at a rural area. Its measurement constantly 20-21 mag/arcsec$^2$ and never less than that. Comparing with LPS’ 2010 measurement, the quality of night sky of LP increased 0.69 mag/arcsec$^2$ which is 13.8 times the intensity.

The least polluted sites are then followed by ONL, BCS and BST. The data form ONL quite consistent but show at two points of sudden light intensity around 03:50h and 05:00h. ONL has becoming more polluted after five (5) years, with an increment of 0.77 mag/arcsec$^2$ approximately 15.4 times the intensity.

The variance of average between BCS and ONL is just 0.02 mag/arcsec$^2$. Nevertheless, BCS had a good quality of night compared to ONL with 21.04 mag/arcsec$^2$. This can be explained by looking at BCS’ range is 1.46 which is 29.2 times the intensity. It should be noted that the BCS data varied inconsistently due its location near to coastal area which likely affected to additional light that might come from the ships in the morning. While BST shows the low distribution of sky brightness between 19.06 to 19.88 mag/arcsec$^2$ never reach 20 mag/arcsec$^2$ making it the most polluted site.

| PARAMETER | ONL   | BCS   | BST   | LPS   | AVG ALL |
|-----------|-------|-------|-------|-------|---------|
| AVG       | 20.68 | 20.66 | 19.58 | 20.76 | 20.42   |
| MODE      | 20.8  | 20.99 | 19.68 | 20.87 | 20.59   |
| MINIMUM   | 19.98 | 19.58 | 19.06 | 20.10 | 19.68   |
| MAXIMUM   | 20.82 | 21.04 | 19.88 | 21.15 | 20.72   |
| RANGE     | 0.84  | 1.46  | 0.82  | 1.05  | 1.04    |
4. Conclusion
Overall, with the average 20.42 mag/arcsec$^2$ all sites are able to observe around 2,000 stars and definitely brighter stars. LPS site proven to be a potential candidate for an observatory due to its photometric night. From the result, this can be considered a threat for the existing observatories – ONL and BCS. Therefore, a comprehensive policy on protecting night sky brightness is seriously needed. Our next plan is to compare the varying temperature of each site with the magnitudes. It is important also the consider to measure the sky condition by using all sky camera. We conclude by quoting the President of the International Astronomical Union (IAU) at the closing ceremony of the International Year of Light 2015, "A world without stars would be like a world without flowers".

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