Preliminary Report of Light Pollution in Indonesia Based on Sky Quality Observation

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Abstract. We observed night sky quality in several LAPAN stations (Agam, Bandung, Pontianak, Sumedang, Garut, Pasuruan, and Biak) which were conducted from April until July 2018 using Unihedron Sky Quality Meter LU-DL type. Observational data from all of the observational points were then sent regularly to a centralized database for further use. Although most of the measurements were done in overcast conditions, we were able to determine the representative clear sky brightness statistically. The results showed that the light pollution level of the most of the stations are moderate (the values at Biak, Agam, Sumedang, and Pontianak are 20.0, 19.5, 19.6, and 17.7 mpsas respectively) and the stations which are located near or in cities are high (Bandung and Pasuruan with 17.1 and 18.0 mpsas, respectively). In a particular station (Garut) the light pollution is low (20.6 mpsas), so it is good to make this spot to be a location of astrotourism.

Keywords: night sky observations; Unihedron Sky Quality Meter; light pollution; astrotourism

1. Introduction

There are many challenges faced by astronomical communities, professionals and amateurs alike, related to the observing activities. There are some issues in this respect, e.g., location, equipment, and human resources, but the most pressing issue is the light pollution. Light pollution can disturb astronomical observations especially to the faint object observations. Other problems are that people can’t see the beauty of night sky, the disruption of the circadian rhythm in human and animals, and the efficiency of energy in street lamps in cities. The investigated the light pollution and its impacts [1]. They analyzed the pollution which occurred in Europe, Asia, North America, and they concluded that light pollution is a global issue. They observed that light pollution affects 88% of world population and 99% of United States population. The discussion same problem and observed that this problem also affect many regions like Central Africa and Central Asia which was previously thought were free from this problem [2]. Nevertheless, they observed also that Venice is not affected by light pollution due to the policy of the local government related to the light pollution. This problem of light pollution is directly related to the sky quality. The better the sky quality, the lesser is the light pollution. The sky quality can be measured using Sky Quality Meter device. This device records the light emitted by the sky and calculates the incident radiation in various wavelength, and the pollution in each wavelength can be measured. The measurement sky quality of a city in Holland in blue, green, red, and infra-red wavelengths has been succesful [3]. His results indicated that the level of light pollution in a certain
location depends on the dominant wavelength of the sky brightness of the location. The propagation of light in a polluted atmosphere was analyzed to obtain sky brightness [4]. They used a radiation propagation model which applied to various atmospheric conditions including various types of aerosols, i.e. volcanic and meteor dust and atmospheric gases like ozone. Their calculation was then applied to make a map of air pollution in several locations and they found that the sky quality and air pollution depends on several parameters, including atmospheric composition and ground reflectance. The sky quality observation in 12 locations in Italy for 12 years [5]. The time of observations and locations are varied, from height of 15 m until 1366 m above sea level and during winter and non-winter season. The observations conducted after astronomical twilight. They found that the existence of ground snow has no effect to the sky quality. Sky quality observation of Postdam-Babelsberg which is located about 23 km from Berlin was conducted [6]. The observations were conducted in two conditions, during moonlit sky and during overcast. They found that the sky quality was more influenced by the cloud cover than by the changing lunar radiation due to the changing lunar phases. From this analysis we see that the sky quality observations are more extensively conducted in the more developed countries. So, there is some need to conduct similar observations in other regions which have no record of sky quality observations, especially Indonesia. It is hoped that from these observations we get some insights about the extent of light pollution in Indonesia and if there is any location in Indonesia which are best candidate to be a dark sky park to promote astrotourism.

This paper is organized as follows. Section 2 discussed data and methodology used in this investigation. Section 3 discussed the analysis of the data obtained, while section 4 presented the results of this analysis. Discussion and conclusion of this investigation is presented in section 5.

2. Methodology

Data of this investigation were obtained from several LAPAN stations, i.e. Agam, Pontianak, Sumedang, Garut, Biak, Pasuruan, and Bandung stations in which the locations are shown in Table 1 and Figure 1.

Table 1. Geographical coordinates and conditions of 7 observation stations

| Stations   | Longitude     | Latitude      | Remarks     |
|------------|---------------|---------------|-------------|
| Agam (AGM) | 100° 19’ 10.00” E | 0° 13’ 48.00” S | Rural       |
| Pontianak (PTK) | 109° 20’ 23.00” E | 0° 02’ 48.00” N | Peri urban  |
| Bandung (BDG) | 107° 40’ 40.21” E | 6° 55’ 32.03” S | Urban       |
| Sumedang (SMD) | 107° 50’ 13.97” E | 6° 54’ 47.08” S | Rural       |
| Garut (GRT) | 107° 41’ 31.97” E | 7° 39’ 00.22” S | Rural       |
| Pasuruan (PSR) | 112° 40’ 00.00” E | 7° 34’ 00.00” S | Peri urban  |
| Biak (BIK) | 136° 01’ 00.00” E | 1° 17’ 00.00” S | Urban       |

Figure 1. Locations of sky quality observations using Unihedron Sky Quality Meter across Indonesia.
The Unihedron Sky Quality Meter are SQM-LU types in which the equipment can be set to make continuous observations in predetermined intervals. These equipment were put in a housing to protect them from humidity and direct sunlight. This type of photodiode-based instruments has effective field of view of $\sim 20^\circ$ and produce sky brightness data in mag/arcsec$^2$. All SQM was set to record zenithal sky brightness magnitude from 5 pm to 7 am with sampling rate of one minute, regardless weather conditions and moon phases. Figure 2 shows the equipment we use to record the sky quality.

![Figure 2. Unihedron SQM LU-DL equipments with its accessories.](image)

This equipment was designed to fetch the data automatically in a certain period of time.

These data were obtained from April until July 2018. These data were obtained under different sky conditions, during dark and full Moon, low and high cloud cover, and clear and overcast condition. The data then sent to Bandung and stored in a repository and organized according to data source (7 stations) to be analyzed by the researchers. The results of the observations can be summarized in Table 2 and Figure 3 below. We can see that the sky conditions in Indonesia depended upon the proximities of those various locations to the source of night sky. There are places which are very dark, especially in Sumedang and Garut, but there are some places that are very bright like in Bandung and Pasuruan which are urban and peri urban in nature, respectively. From the data obtained, we then made some plot in which we want to see the correlation of the sky brightness with the time of observations.
Figure 3. Data plot of several observational points, i.e. (a) Biak, (b) Garut, (c) Agam, (d) Bandung. These plots showed various conditions of sky qualities. These observations showed also the sky conditions above the observational points which are mainly in cloudy conditions.

Table 2. Results of observations from LAPAN stations. These results showed the nature of light pollution in those places.

| Code | Data Amount [nights] | Location | Brightness [mpsas] | Remarks   |
|------|----------------------|----------|-------------------|-----------|
| AGM  | 29                   | Agam     | 19.8              | Rural     |
| BDG  | 50                   | Bandung  | 17.3              | Urban     |
| BIK  | 43                   | Biak     | 19.7              | Rural     |
| GRT  | 61                   | Garut    | 20.8              | Rural     |
| PSR  | 69                   | Pasuruan | 17.6              | Peri-urban|
| PTK  | 39                   | Pontianak| 18.0              | Peri-urban|
| SMD  | 67                   | Sumedang | 20.1              | Peri-urban|

3. Results of Discussion
We then conducted other observations, in which the data was acquired in a different manner compared with the data obtained from the stations. Whereas the station’s data were obtained from a fixed location in an extended period of time, the other method is taking the data in a moving fashion but in a shorter period of time compared with that of the fixed locations. The purpose of this observation is to get the night sky quality maps in a certain area so we can get some insight about the light pollution map in the area. This time we conducted three modes of observations. The first one is the same mode of observations as in the stations. The second one is the same as the first one, but we used a kind of baffle to prevent stray light from entering the equipment. The third mode used a handheld sky quality meter. The measurements were conducted in an area which surrounds Bandung and Sumedang which can be seen in the Figure 4.
In this mode of observation, the data was recorded every 1 minute using the SQM and using the handheld equipment the data recorded every 1 km. Using this mode of observation, we got about 3200 data in which the distance traversed is about 120 km. From the data obtained in moving mode, we got values of night sky brightness along the distance traversed during the observations. We can see several bright points, but also some points which are very dark, i.e. the value of the sky brightness is more than 19. From this mode of observations, we can see that in general the night sky brightness of Bandung and its surrounding area are not very good due to the light pollution. Figure 6 summarized the observations and the data obtained in these modes. The NSB observations which had been conducted in Bandung-Sumedang area above had shown us the map of sky brightness/light pollution in this area. We can see some regions which are very polluted, and some other regions which are not polluted at all. These observations showed also that moving mode of NSB observations is a good way to get a detailed picture of sky brightness/light pollution in a certain region.

Figure 4. Area traversed during the measurements in moving mode.

Figure 5. Results of NSB observations with some locations which were highlighted due to its brightness. (a) Highlighted points (b) the brightness of these points.
As a control mode, handheld observations had proved it to be a good measurement of the reliability of this mode. We made a correlation of this observation upon one another as shown in Fig 6. These pictures showed us that these three modes of observations have good correlation among one another.

Figure 6. Correlation of three modes of observations, (a) correlation of LU-DL with and without baffle, and (b) LU-DL with baffle with handheld observations.

4. Discussion and Conclusion

We have observed night sky brightness (NSB) in several locations in Indonesia for some extended period of time. These observations had shown us the importance of the distributed observations and should be expanded, both spatially and temporally. Furthermore, moving NSB observations which conducted in some limited area can be used to measure the level of light pollution in this area. From the results of our investigation, we can propose some regions which can be used as a place of astrotourism because of its pristine environment with respect to the NSB observed. This could also be used as some example to other regions in preserving the beauty of the night sky so the light pollution in other areas can be reduced. We are planning to continue the NSB observations we have conducted in some other places so the map of light pollution over Indonesia can be completed and we can make further contribution to the international community about the level of light pollution in Indonesia.

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