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Research Article
Estimation of the Angstrom Turbidity Parameters in the Ultraviolet Spectrum over Bangi, Malaysia

[1]Ohoud Aljawi, [1]Geri Gopir, [1]W.M.A.Wan Mohd Kamil and [2]Nor Sakinah Mohamad

[1]School of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[2]PERMATApintar National Gifted Center, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Abstract

Background and Objective: It is important to note the significance of atmospheric turbidity in evaluating local area's air pollution. It also provides vital criteria to control the extinction of solar ultraviolet radiation from reaching the land on cloudless day. This study aims to investigate the dependence of Angstrom's turbidity parameters in the following wavelengths 300, 320, 340, 360, 380 and 400 nm in the ultraviolet radiation. In addition, an investigation of atmospheric extinction coefficient has been undertaken. **Material and Methods:** The measurement was done in Bangi, Malaysia at the coordinates of 2°55' N, 101°46' E and the setting was also 50 m above sea level. The experiment was carried out using the Avantes AvaSpec spectrometer (2048×64-USB 2) between January-December, 2014. Furthermore, the Langley plot was used in the calculation of the atmospheric extinction coefficient of the wavelength from the ultraviolet spectrum. On top of that, the linear regression of best fitting method based on log-log plot of atmospheric extinction coefficient vs. wavelength was employed to explore the Angstrom parameters α and β. **Results:** The analysis of the results shows that, the total atmospheric extinction slightly decreasing when the wavelength increasing. On the other hand, it was observed that β value which is related to turbidity index was relatively high in dry season (April-September) with the value of 10.99-13.70. Meanwhile, the value decreased in rainy season (October-March) with the value up to 5.48. Nevertheless, the value of the Angstrom parameter α was related to the size distribution of extinction particles. Also, the wavelength exponent α varied from 0.79-2.50. It was also noted that the best value α was 1.32, recorded in the first quarter (January-March) of 2014. **Conclusion:** Angstrom parameters have maximum values found in mid-year. However, the minimum values were recorded in the beginning and end of the year of 2014.

Key words: Angstrom parameters, extinction coefficient, langley plot, turbidity coefficient, ultraviolet radiation, wavelength exponent

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Corresponding Author: Ohoud Aljawi, School of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia Tel: +60126586122

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Solar ultraviolet radiation enters the terrestrial atmosphere through two methods scattering and absorption and it is affected by the matter of atmosphere. In absorption condition, atmospheric gases are uniformly mixed and have the same variable in a turbid and clean, dry atmosphere. Meanwhile, the effects due to aerosol, scattering, water vapor absorption are quite variable due to the wide range of aerosols and water vapor concentrations in the atmosphere[1]. Furthermore, Angstrom turbidity coefficient has been competent in presenting the extinction of the solar radiation under clear sky[2]. It helps to shape climate modeling and climate change in pollution studies. In addition, it measures the concentration of particles in suspension, aerosols and water vapor that absorb, reflect and scatter radiation[3]. Moving on, the radiation of particle in terms of energy application is between 150 and 4000 nm and this is about 99% of solar radiation. About 7.5% of this value is in the form of ultraviolet radiation[4]. Furthermore, the absence of atmospheric pollutants caused the solar ultraviolet outside the Earth's atmospheric to be relatively constant. At a certain wavelength, the intensity of solar ultraviolet radiation that arrived to the Earth's surface was attenuated. It was removed virtually by the absorption and scattering of indifferent wave bands by various atmospheric gasses, air molecules and other atmospheric constituents[5]. The scattering and absorption of a solar radiation in the Earth's atmosphere changed the intensity of the incoming solar radiation. There are three sources from the atmospheric extinction in the Earth's atmosphere that are important for ground-based measurements aerosol scattering, Rayleigh scattering by molecules and molecular absorption. These operations also caused the attenuation of solar ultraviolet radiation. The amount of attenuated solar ultraviolet radiation passing through the atmosphere can be evaluated using Beer's-Bouguer's-Lambert's law[6].

Moving on, a number of coefficients are used to examine the turbidity of the atmosphere. In general, Angstrom's turbidity coefficient is chosen because it takes into account the effects of scattering and absorption caused by aerosols, simultaneously. It should be noted while aerosols absorb radiations of some wavelengths, it scatters solar radiation at all wavelengths. Also, the rate of absorption is smaller than scattering. Nevertheless, it is a common practice to explain the value of aerosols by an index of turbidity[7-10].

Furthermore, the reduction of solar energy when it went through the atmosphere indicated that there is an atmospheric turbidity. This is important to help evaluate the existence of solar radiation and daylight under clear sky. In addition, the Angstrom exponent α is measured the size of particles. Large value of α indicated a relatively high ratio of small particles to large particles. However, the Angstrom turbidity β is an index representing the amount of turbidity in the atmosphere. It is crucial to understand these basic principles if one want to improve understanding of attenuation effects in climate models[11].

Apart from that, several studies have been conducted to quantify the atmospheric extinction value of solar radiation in a variety of fraction by scattering, absorption and the angstrom turbidity coefficient. Nevertheless, difference in methodology, altitude, instrument and the solar radiation wavelength selection made the results of this study incomparable with other analysis[12-18]. However, there does not exist many published data for Bangi in Malaysia.

Building on the analysis of previous literatures as mentioned above, this study aimed to investigate the total atmospheric extinction of solar ultraviolet radiation using Langley method. This study also aimed to analyze the results obtained to evaluate if Angstrom parameters are competent in the study of atmosphere turbidity.

Hence, this study aimed to identify a data set for atmospheric extinction in solar ultraviolet radiation using various atmospheric constituents in Bangi, Malaysia. It should be noted that atmospheric extinction measurement provided the baseline of atmospheric turbidity in this area of study.

MATERIALS AND METHODS

In this study, Avantes AvaSpec ULS 2048X64-USB2 spectrometer was used to measure the solar ultraviolet radiation intensity or spectral. In addition, the spectral resolution was 1 nm and was recorded for the wavelength in the range of 300-1100 nm, in ultraviolet (UV), visible (VIS) and near infrared (NIR) spectra. This apparatus enabled fast scanning of the spectrum without the need of a moving grating. Besides that, the fiber optic formed a passage for the solar radiation to the spectrometer and was equipped with a cosine corrector, which provided a 180 degree field view. The spectrometer was calibrated every 60 h with a calibration device Avalight-DH-CAL light source for UV/VIS/NIR with spectral range of 205-1099 nm. In addition, the calibration lamp Avalight-DH-CAL had a light deuterium and halogen source for UV/VIS/NIR (205-1099 nm) and halogen light-VIS, NIR (350-1095 nm). The spectrometer was calibrated with a standard lamp by the National Renewable Energy Laboratory (NREL) in the United States of America.

Moving on, the portable instrument was placed at the roof of the School of Applied Physics building of Universiti

Kebangsaan Malaysia, with coordinates of 2°55' N latitude and 101°46' E longitude and is 50 m above sea level. Malaysia is located near the equator, the climate is categorized as equatorial being hot and humid throughout the year. Therefore, the weather in that region is limited range in their temperatures and less climate change over a year than is found in other zones. Due to that factor, no significant changes can be seen in the weather in the last 3 years compared to that time. That's mean the data and results can be reflected. In addition, the experimental work was conducted from January-December, 2014 from 8:00 am to 6:00 pm local time. The solar irradiance was measured from 300-1100 nm in unit [(W cm^{-2}) nm^{-1}]. Apart from that, the atmospheric conditions at certain time frame were characterized by heavy rainfall and cloud. It should be noted that the measurement was done in accordance to the direction of the sun direction by following a shadow. It was executed by observing the shadow of the cosine corrector stand the device was tilted until the shadow disappears. Then, the measurement of solar radiation was taken.

Moreover, it is important to take into account the climate of the country. Malaysia is of equatorial climate it is hot and humid throughout the year, there are also several seasons in Malaysia. The dry season is typically from April and September (Southwest monsoon) while October-March are rainy (Northeast monsoon).

Moving on, the trigonometric relationship between the solar position in the sky and the surface coordinated on the earth should be noted. This is to be composed in the calculation of the solar radiation reaching a horizontal surface. Sun altitude and zenith angle is importance as well[6]:

$$\alpha = 90-\theta_z \tag{1}$$

Where:

- α = Sun altitude or solar position
- θ_z = Zenith angle, also called the zenith distance, in degrees

Furthermore, the path length of air mass increases with the angle between the source of solar radiation and zenith. From this, it can be concurred that the sun's elevation path through the sky affect the air mass quantity. Hence, it varied with time and latitude of observer. Generally, a place that is above Earth's atmosphere has air mass of zero. This is caused by the lack of atmospheric attenuation of solar radiation[19]. The air mass (m) can be calculated using non-refractive plane parallel atmosphere equation:

$$m = \sec\theta_z \tag{2}$$

It should be noted that air mass is an important factor in Langley method. Therefore, Langley method should be used to measure the attenuation or monochromatic extinction coefficient for solar ultraviolet radiation or other portion of solar radiation[20]. Meanwhile, this method is based on Beer-Bouguer-Lambert law:

$$I_\lambda = I_{0\lambda}\, e^{-\tau\lambda m} \tag{3}$$

The total atmospheric extinction is given by (τ) and it corresponded to Rayleigh scattering (τ_R) and the absorption of gases (τ_{Gas}), such as ozone (τo_s), aerosols (τ_{Aer}) and water vapour (τ_w). Moreover, I_λ given in W m^{-2} is the intensity emerging from the medium after traversing a distance m, $I_{0\lambda}$ given in W m^{-2} is the intensity measurement atmosphere peak. The latter is also known as the extraterrestrial intensity for the solar ultraviolet radiation. Also, the total extinction coefficient is τ_λ in UV radiation region. Nevertheless, since Langley plot is a graph of Ln I_λ versus m, it gives a value of a total atmospheric extinction from the negative slope of the straight-line of the plot.[21] Hence, the quantity (τ_λm) is the monochromatic extinction optical thickness.

In addition, the total atmospheric extinction (τ) at the wavelength (λ) in nm can determine the Angstrom parameters of α and β. The parameter β is known as the turbidity coefficient. In Eq. 4, β was varied from 0.0 for free atmosphere to 0.5 or even higher values (>1) for extremely turbid atmosphere. It can also be defined as the aerosol optical thickness at λ = 1 µm. Furthermore, Angstrom turbidity formula helped to define the spectral behavior of aerosol optical thickness by providing the parameter α. It also correlates with the size of the distribution of aerosol particles[14,22-24]. The parameter α should vary from 4-0 and low α value correspond to significant existence of large particles and vice versa. It is worth mentioning that the comment value of α in most studies ranges from 0.5-2.5[22,25].

Building on previous discussions, the Angstrom model suggested a formula of the extinction of the atmospheric aerosol. It can be approximated over a limited wavelength λ (expressed in nm) and appears[23]:

$$\tau_\alpha\lambda = \beta\, \lambda^{-\alpha} \tag{4}$$

Where:

- $\tau_\alpha\lambda$ = Aerosol optical depth in vertical direction
- λ = Wavelength in nm
- β = Turbidity coefficient that relates to particle density
- α = Spectral behavior of the aerosol optical thickness that relates to the size distribution of aerosol particles

A least square fit is the appropriate method if one is to evaluate the ability of the Angstrom equation to imitate the spectral behavior of aerosol optical thickness by using a log-log of atmospheric extinction and the wavelengths it gives[23]:

$$\text{Ln}\ \tau_\lambda = \alpha\ \text{In}\ \lambda + \text{In}\ \beta \tag{5}$$

The wavelength in the ultraviolet radiation used in this research were 300, 320, 340, 360, 380 and 400 nm. Equation 4 can be used also to calculate the aerosol optical depth for the whole spectral range (300-400 nm), after the Angstrom parameters are defined[5].

RESULT AND DISCUSSION

The diurnal variation of solar ultraviolet intensity and the calculated values of the sampling hours are presented in Fig. 1. This graph illustrated the data set of the solar ultraviolet irradiance UV from clear sky. Furthermore, the diurnal variation of the hourly solar ultraviolet irradiance in Fig. 1 showed that the ultraviolet intensity were low at 9 am, 5 and 6 pm. This was caused by a wide and big atmospheric mass and the occurrence of the largest zenith angels. Moreover, the value of UVA intensity was at peak during local noon time. This was the result of the atmospheric path length being the lowest at noon time the sun was overhead, causing the spectrometer system to receive more direct solar radiation[26].

Apart from that, the wavelength used in this study is UV between 300 and 400 nm. They were chosen based on the corresponding data available. In addition, the data collected during the measurement period were fitted into a linear function. An example of the Langley plot obtained with data sampling and the respective fitted lines for bands in the near ultraviolet radiation regions is shown in Fig. 2a-f, the total atmospheric extinction (τ) is also represented by the fitted line slope. It is also inversely proportional to the UV radiation wavelength. The scattering and absorption of the total atmospheric extinction is decreased when the wavelength is increase as demonstrated in Fig. 3.

Based on the data collected so far, the total atmospheric extinction helped to define the Angstrom turbidity coefficient β and α. These coefficients were determined using solar ultraviolet radiation data. Six wavelengths 300, 320, 340, 360, 380 and 400 nm for UV spectrum were used, from January-December, 2014. The values >1 for Angstrom coefficient were estimated to be present in extremely turbid climates. The monthly values of Angstrom turbidity β and the wavelength exponent α, at Bangi, Malaysia are shown in Table 1. Meanwhile, Fig. 4 demonstrates the Angstrom method for deterring α and β. However, Fig. 4 present the linear fitting of In τ (λ) vs the In λ in spectral range 300-400 nm for 12 months. The value of Angstrom parameters and the coefficient of correlation appears in Fig. 4.

It is observed that the value of β reached its peak in April, May and June, 2014. Then, it slowly decreased to its minimum in October, November and December, 2014. After that, it gradually increased in July, August and September. Then, it decreased again in January, February and March, completing an annual cycle. It can be observed that the period with high values was parallel to the dry season and vice versa. This might

Table 1: Atmospheric turbidity parameters for the year 2014 at Bangi, Malaysia

Month	α	β
January-March	1.32±0.27	7.37±1.63
April-June	2.50±0.54	13.70±3.20
July-September	1.89±0.27	10.99±1.61
October-December	0.79±0.15	5.48±0.92

*Values are the mean of replicates ±standard error of the mean

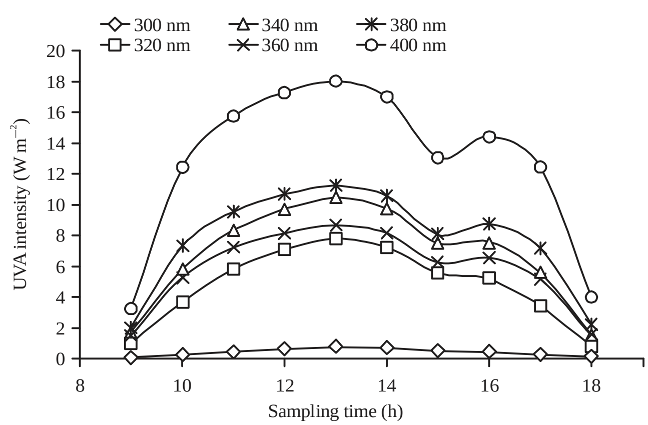

Fig. 1: Example of calculated solar irradiance in the ultraviolet between 300 and 400 nm for January-March, 2014 at Bangi

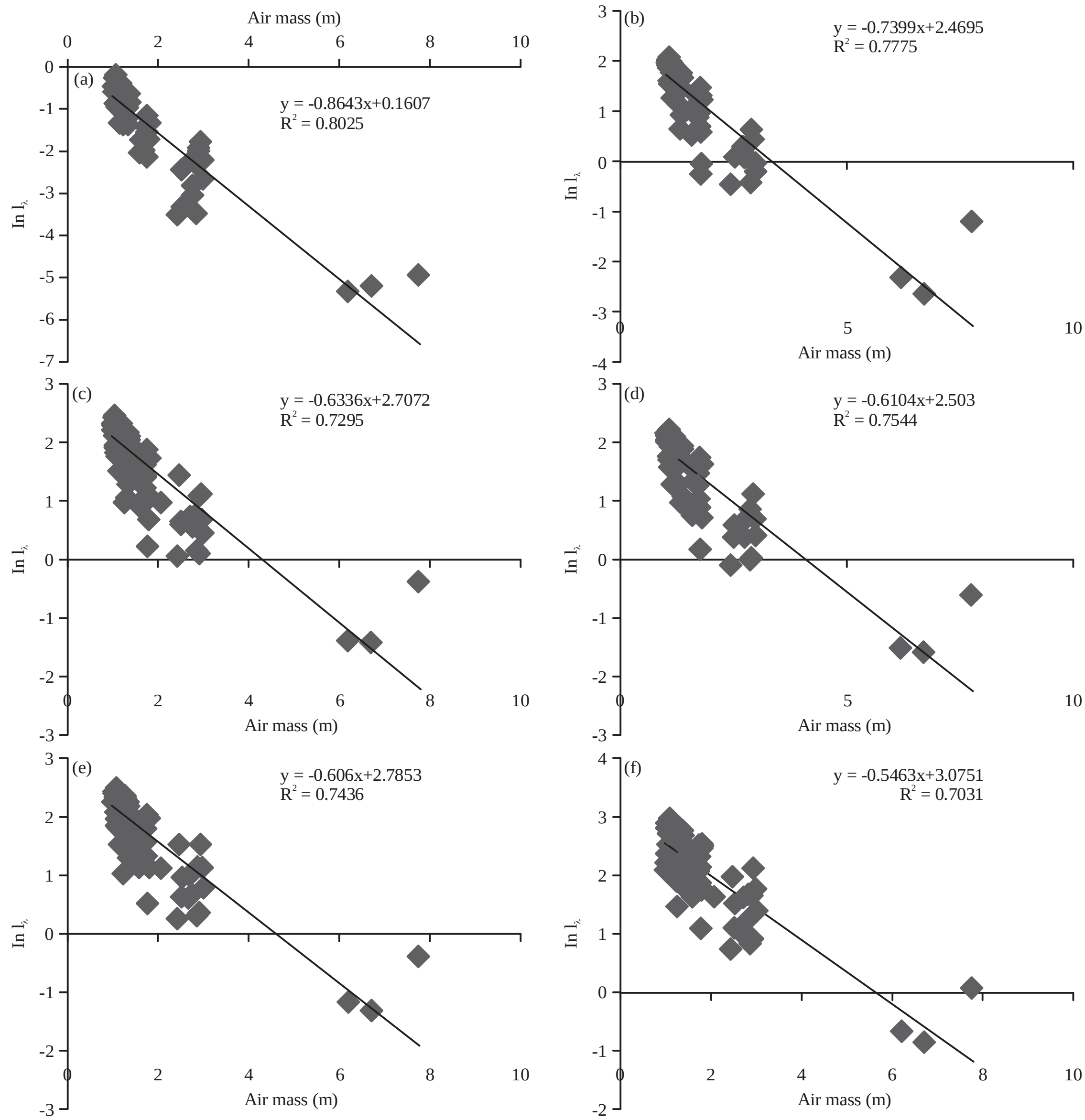

Fig. 2(a-f): Example for Langley plot for UV radiation and respective liner functions obtained by the least square from January-March, 2014, (a) 300 nm, (b) 320 nm, (c) 340 nm, (d) 360 nm, (e) 380 nm and (f) 400 nm

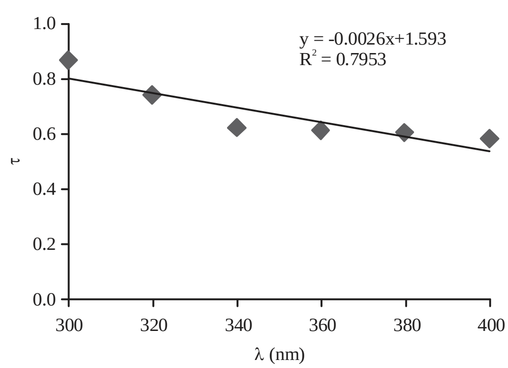

Fig. 3: Total atmospheric extinction value at UV radiation wavelength

be due to the circulation of wind from continental (Northeast monsoon) during April-June. Such wind increased the atmospheric turbidity because of the dust particles it carried. Moving on, air temperature increases on July-September day time peak temperature was 33-38°C. This increased heat convection, causing dust particles to be lifted from the soils into atmosphere. Moreover, low β was also caused by aerosols of the continental origin. This is another case that contributes to atmospheric turbidity, especially to regions that have frequent showers like Bangi.

Since they are large in size, the rain is competent enough to remove them from the atmosphere. This is why

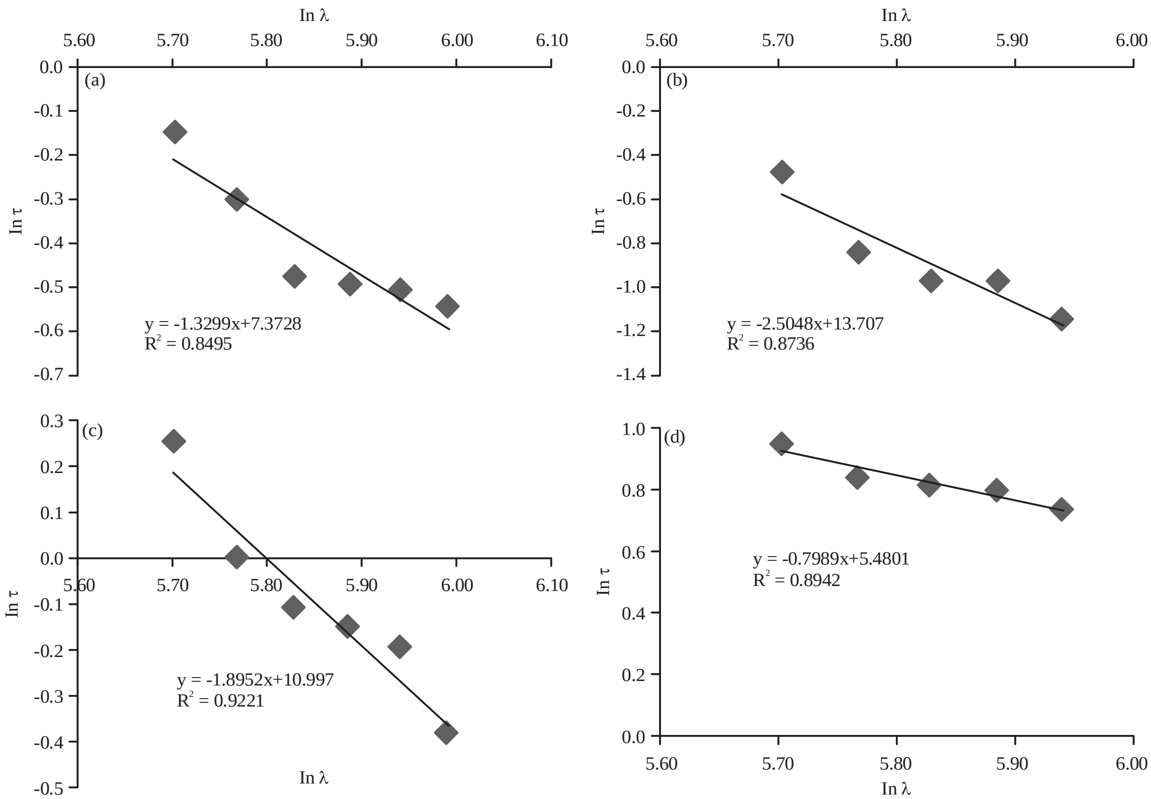

Fig. 4(a-d): Liner regression equation for 12 months in 2014, each three months present on one linear, (a) January-March, (b) April-June, (c) July-September and (d) October-December

atmospheric turbulence is lower during rainy seasons. Nevertheless, wavelength exponent α is inversely proportional to Angstrom turbidity β values.

Furthermore, local agricultural and industrial activities affect atmospheric turbidity as well. It was noted that β value in this study is the highest among other studies of the other region.

In the current study, Angstrom parameters have maximum values in the dry season (April-June) and minimum value in the rainy season (October-December). A similar study was conducted in Thailand but different method was used to determine Angstrom's turbidity coefficient β. Also, it is worth mentioning that β value in Bangi, January, 2014 is similar to those at Mukdahan, Thailand around 9.18[17]. Similar finding also were reported in previous studies[24,27-30].

The Angstrom wavelength exponent α, their monthly averaged value between 1.3 and 0.79 is commonly employed for most natural aerosols. The low value of α is present large particles. It should be noted that the value of 1.3 between January-March, 2014 was suggested by Angstrom it is the ideal value for natural atmospheric.

CONCLUSION

This study has examined the Angstrom parameter turbidity and wavelength exponent from solar ultraviolet spectral irradiance measurements in 1 year at Bangi, Malaysia. In addition, the Langley method produced a good value representation of the atmospheric attenuation.

Moreover, β and α value were found to be higher in dry season, which is relatively in the middle of the year. It was caused by the Northeast monsoon and high convection. However, the rainy season in the first quarter and fourth quarter of the year present the lower value of β and α. This is in contrast to rainy season, as the aerosols were removed by the rain.

SIGNIFICANCE STATEMENT

This study discovers the Angstrom parameters in Bangi Malaysia that can be beneficial for knowing the atmospheric turbidity. This study will help researcher to define the turbidity particles size and the amount of turbidity in the atmosphere through solar ultraviolet radiation. Thus, a new theory on this research is using atmospheric extinction to obtain Angstrom parameters.

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REFERENCES

1. Louche, A., M. Maurel, G. Simonnot, G. Peri and M. Iqbal, 1987. Determination of Angstrom's turbidity coefficient from direct total solar irradiance measurements. Solar Energy, 38: 89-96.
2. Angstrom, A., 1961. Techniques of determinig the turbidity of the atmosphere. Tellus, 13: 214-223.
3. Uscka-Kowalkowska, J., 2013. An analysis of the extinction of direct solar radiation on Mt. Kasprowy Wierch, Poland. Atmos. Res., 134: 175-185.
4. Myers, D.R., 2013. Solar Radiation: Practical Modeling for Renewable Energy Applications. Vol. 13, CRC Press, New York, pp: 1-15.
5. Srivastava, G.P., 2010. Surface Meteorological Instruments and Measurement Practices. Atlantic Publishers and Dist., New Delhi, pp: 22-31.
6. Iqbal, M., 1984. An Introduction to Solar Radiation. CRC Press, New York, pp: 56-66.
7. Kimball, H.H., 2000. Determination of atmospheric turbidity. Eos Trans. Am. Geophys Union., 13: 121-123.
8. Tadros, M.T.Y., M. El-Metwally and A.B. Hamed, 2002. Determination of Angstrom coefficients from spectral aerosol optical depth at two sites in Egypt. Renewable Energy, 27: 621-645.
9. Alnaser, W.E. and N.S. Awadalla, 1995. The linke turbidity factor and *Angstrom coefficient* in humid climate of Bahrain. Earth Moon Planets, 70: 61-74.
10. Hussain, M., S. Khatun and M.G. Rasul, 2000. Determination of atmospheric turbidity in Bangladesh. Renewable Energy, 20: 325-332.
11. Koontz, A., G. Hodges, J. Barnar, C. Flynn and J. Michalsky, 2013. Aerosol optical depth value-added product. US Department Energy, March 2013. https://www.arm.gov/publications/tech_reports/doe-sc-arm-tr-129.pdf
12. Angstrom, A., 1929. On the atmospheric transmission of sun radiation and on dust in the air. Geografiska Annaler, 11: 156-166.
13. Ackermann, J., 1998. The extinction-to-backscatter ratio of tropospheric aerosol: A numerical study. J. Atmos. Oceanic Technol., 15: 1043-1050.
14. Bokoye, A.I., A. de la Casiniere and T. Cabot, 1997. Angstrom turbidity parameters and aerosol optical thickness: A study over 500 solar beam spectra. J. Geophys. Res.: Atmos., 102: 21905-21914.
15. Jacovides, C.P., C. Varotsos, N.A. Kaltsounides, M. Petrakis and D.P. Lalas, 1994. Atmospheric turbidity parameters in the highly polluted site of Athens basin. Renewable Energy, 4: 465-470.
16. Ogunjobi, K.O. and Y.J. Kim, 2004. Ultraviolet (0.280-0.400 μm) and broadband solar hourly radiation at Kwangju, South Korea: Analysis of their correlation with aerosol optical depth and clearness index. Atmos. Res., 71: 193-214.
17. Janjai, S., W. Kumharn and J. Laksanaboonsong, 2003. Determination of Angstrom's turbidity coefficient over Thailand. Renewable Energy, 28: 1685-1700.
18. Li, D.H. and J.C. Lam, 2002. A study of atmospheric turbidity for Hong Kong. Renewable Energy, 25: 1-13.
19. Liou, K.N., 2002. An Introduction to Atmospheric Radiation. Vol. 84, CRC Press, New York, pp: 30-39.
20. Cerqueira, Jr.J.G., J.H. Fernandez, J.J. Hoelzemann, N.M.P. Leme and C.T. Sousa, 2014. Langley method applied in study of aerosol optical depth in the Brazilian semiarid region using 500, 670 and 870 nm bands for sun photometer calibration. Adv. Space Res., 54: 1530-1543.
21. Vazquez, M. and A. Hanslmeier, 2006. Ultraviolet Radiation in the Solar System. Vol. 113, Springer, The Netherlands, pp: 60-69.
22. Angstrom, A., 1964. The parameters of atmospheric turbidity. Tellus, 16: 64-75.
23. Cuomo, V., F. Esposito, G. Pavese and C. Serio, 1993. Determining Angstrom's turbidity coefficients: An analysis with a wide-range grating spectrometer. Aerosol Sci. Technol., 18: 59-69.
24. Koo, J.H., J. Kim, J. Lee, T.F. Eck and Y.G. Lee *et al*., 2016. Wavelength dependence of Angstrom exponent and single scattering albedo observed by skyradiometer in Seoul, Korea. Atmos. Res., 181: 12-19.
25. Cachorro, V.E., M.J. Gonzalez, A.M. de Frutos and J.L. Casanova, 1989. Fitting Angstrom's formula to spectrally resolved aerosol optical thickness. Atmos. Environ., 23: 265-270.
26. Aljawi, O., G. Gopir and A.B. Duay, 2015. Measurement of the solar ultraviolet radiation at ground level in Bangi, Malaysia. AIP Conf. Proc., Vol. 1657. 10.1063/1.4915227.

27. Wang, L., G.A. Salazar, W. Gong, S. Peng, L. Zou and A. Lin, 2015. An improved method for estimating the Angstrom turbidity coefficient β in Central China during 1961-2010. Energy, 81: 67-73.
28. Trabelsi, A. and M. Masmoudi, 2011. An investigation of atmospheric turbidity over Kerkennah Island in Tunisia. Atmos. Res., 101: 22-30.
29. Polo, J., L.F. Zarzalejo, P. Salvador and L. Ramirez, 2009. Angstrom turbidity and ozone column estimations from spectral solar irradiance in a semi-desertic environment in Spain. Solar Energy, 83: 257-263.
30. Esposito, F., L. Leone, G. Pavese, R. Restieri and C. Serio, 2004. Seasonal variation of aerosols properties in South Italy: A study on aerosol optical depths, Angstrom turbidity parameters and aerosol size distributions. Atmos. Environ., 38: 1605-1614.