Diurnal Variation of Atmospheric Light-Absorption Characteristic of Total Suspended Particles in Bangkok

Narisara Siriwattananonkul[1*], *Mitsuhiko* Hata[2], *Surat* Bualert[3] and *Thunyapat* Thongyen[4]

[1]Division of Environmental Design, Graduate School of Natural Science and Technology, Kanazawa University, Kanazawa 920-1192, Ishikawa, Japan
[2]Faculty of Geosciences and Civil Engineering, Institute of Science and Engineering, Kanazawa
[3]Department of Environmental Science, Faculty of Environment, Kasetsart University, Bangkok, 10900, Thailand
[4]Department of Environmental Technology and Management, Faculty of Environment, Kasetsart University, Bangkok, 10900, Thailand

Abstract. In this study, the diurnal variation of light absorption characteristic of total suspended particles (TSP) collected in Bangkok, Thailand, during the haze season was investigated. Daytime and nighttime TSP samples were analyzed for carbonaceous components using thermal/optical carbon analysis and UV-vis spectrophotometry. TSP mass concentrations exhibited clear temporal variation, with higher average levels during the daytime. Carbonaceous components show distinct behaviors, with organic carbon (OC) consistently occurring at higher concentrations and exhibiting greater temporal variation than elemental carbon (EC). Light absorption at 365 nm displayed clear diurnal variation and showed a weak relationship with TSP mass concentration, characterized by considerable scatter. In contrast, clearer associations were observed between Abs_{365} and OC concentration for both water and methanol extracts, particularly during nighttime. These results indicate that variations in aerosol light absorption are more closely associated with organic carbon abundance than with total particle mass alone. Overall, the findings suggest that diurnal variability in carbonaceous aerosol properties contributes to changes in the optical behavior of urban aerosols in Bangkok.

1 Background

The study of atmospheric aerosol particles is essential for understanding their effects on human health. Their influence on the Earth's radiative balance is also widely recognized. Current understanding remains limited regarding their contributions to climate processes. Among atmospheric aerosols, light-absorbing aerosol components play an important role in modifying solar radiation distribution. Energy transfer occurs between the surface and the atmosphere. This process contributes to global warming. Several particle types contribute to

* Corresponding author: hata@se.kanazawa-u.ac.jp

light absorption. These include black carbon, mineral dust, and organic compounds classified as brown carbon (BrC)[1], [2]. A complex mixture of chromophoric substances characterizes these particles. Compounds such as polyphenols, nitroaromatics, and humic-like substances are commonly identified[3]. A broad wavelength ranges from ultraviolet (UV) to the visible wavelength is involved in the absorption process. Particle composition plays a key role in determining optical response. Emission-related influences include both combustions from biomass burning, coal combustion, and secondary organic aerosol (SOA) generation [2], [4], [5].

This study examines the diurnal variation of light-absorbing atmospheric particles in total suspended particles (TSP) collected in an urban area of Bangkok. Variations in optical properties and carbonaceous components were evaluated under daytime and nighttime condition.

Bangkok represents a tropical megacity where anthropogenic activities, including traffic, construction and cooking account for more than 80% of particle emissions and exhibit pronounced diurnal patterns [6], [7]. Investigation of aerosol light absorption under such urban tropical conditions remain relatively scarce. Time-dependent change in optical properties and their relationship with emission sources and atmospheric conditions therefore require further examination,

In this study, the diurnal variation of light-absorbing atmospheric particles in Total Suspended Particles (TSP) collected from an urban area in Bangkok was examined. Light absorption characteristics related optical properties and carbon components were analyzed to evaluate variations in aerosol light absorption and abundance under different atmospheric conditions during daytime and nighttime.

2 Materials and Methods

2.1 Sampling and sample preparation

Sampling was conducted at the Faculty of Environment, Kasetsart University, Bangkok. A high-volume air sampler (TISCH Environmental) was employed for the collection of total suspended particles. The instrument was operated at a nominal flow of 1.4 m^3/min. The sampling campaign extended from February 19 to March 21, 2025. The sampling schedule was conducted in two times. Daytime sampling was conducted between 08:00 to 19:00. Nighttime sampling covered the period from 20:00 to 07:00. Quartz fiber filters (8×10 inches; Pall Life Sciences, USA) were prepared prior to sampling. Thernal treatment was performed at 350 °C for 1 hour. Conditioning was then carried out for 48 hours. Two field blanks were prepared and handled following the same procedures as the sample filters.

After sampling, filter were enclosed in aluminum foil. Storage was conducted in sealed plastic bags at temperatures between 0-4 °C. This step minimizes volatilization and chemical degradation. Concentration of fine particulate matter with diameters smaller than 10 μm and 2.5 μm (PM_{10} and $PM_{2.5}$). Data were collected during the same period. A Tapered Element Oscillating Microbalance (TEOM 1405-DF; Thermo Fisher Scientific Inc. Waltham, MA, USA) was applied for monitoring near the sampling site at approximately 30 m above ground level.

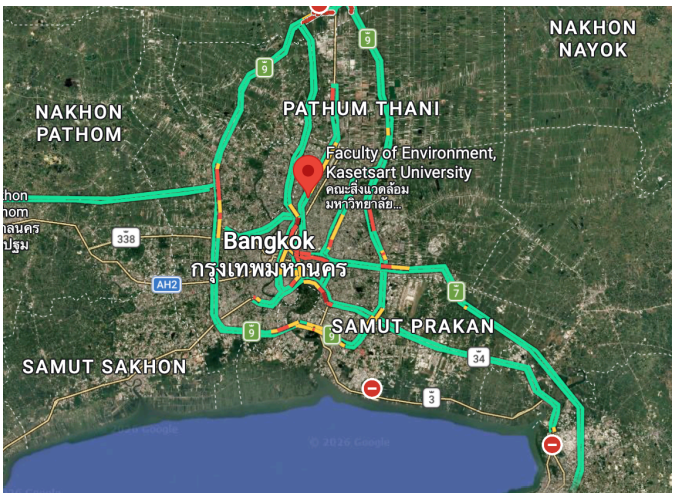

Figure. 1. Sampling location, installed on the rooftop Kasetsart University,specifically at the Faculty of Environment in Bangkok, Thailand. (Source: Google Maps, 2026)

2.2 Thermal/optical analysis

The quartz fiber filter (8 × 10 inches) was sectioned into eight parts for subsequent analyses. One section of the filter was allocated for carbon analysis. A portion of this section was punched into 1 cm^2 pieces. A thermal/optical carbon analyzer (Model 5L, Sunset Instruments Inc., Oregon, USA) was employed for carbon measurement. The analytical procedure followed the IMPROVE_TOR protocol [8]. Temperature conditions were applied in six difference temperature steps. The set point was 120, 250, 450, 550, 700, and 800 °C. These conditions enabled the determination of organic carbon (OC) and element carbon (EC) concentrations. The detection limit of the instrument was 0.1 μg cm^{-2}.

2.3 Filter extraction and Light absorption measurement

Light absorption properties were performed with UV-vis spectrophotometer (UVmini-1240, Shimadzu Corporation, Japan. Quartz cuvettes with 1 cm optical path length were employed methodological details following a previously reported procedure by Li et al. (2019) [8].. Measurements were conducted over a wavelength range of 300-700 nm. Prior to analysis, filter was sectioned into small pieces and put in in brown glass bottles for solvent extraction. Extraction procedures were performed separately for different solvent. One portion was treated with ultrapure water (>18.2 MΩ). Another portion was processed with methanol. Sonication was applied for 60 minutes in both cases. Filtration was conducted through 0.45 μm PTFE syringe filters. Insoluble materials were removed during this step. Extract dilution was carried out before measurement. This ensured compliance with Beer-Lambert law. Correction of spectral data was conducted with filter blank reference. A wavelength of 700 nm was selected to represent minimal aerosol absorption. Baseline normalization was carried out using this reference, consistent with earlier studies [9].

The wavelength-dependent absorption coefficients (Abs_λ) were calculated using equation (1):

$$Abs_\lambda = (A_\lambda - A_{700})V_l/(V_a \, x \, l) \times \ln(10) \quad (1)$$

The absorption coefficient at wavelength λ is denoted as Abs_λ (Mm^{-1}). Measured absorbance at wavelength λ is expressed as A_λ, while A_{700} corresponds to the absorbance at 700 nm and serves as the baseline reference. The parameter V_l (mL) represents the volume of extraction solvent, either water or methanol. The sampled air volume is indicated as V_a (m^3). The optical path length of the cuvette is defined as l (m), with a value of 0.01 m. Conversion from base -10 absorbance to natural logarithmic units was achieved by applying the ln(10) factor.

The wavelength dependence for light absorption by soluble chromophores was described using a power law equation:

$$Abs_\lambda = K \times \lambda^{-AAE} \quad (2)$$

The parameter K is associated with the concentration of light absorbing chromophores. The absorption Ångström exponent (AAE) describes the wavelength dependence of light absorption. AAE values for the filter extracts were derived from liner regression analysis of log ($Abs\lambda$) against log (λ). The fitting was performed over the wavelength interval of 330-550 nm. This wavelength range was selected to reduce interference from non-organic carbon absorption at shorter wavelengths, it also ensured an adequate signal-to-noise ratio for the measurements. The analytical procedure followed previously reported methodology)[10].

3 Results

3.1 TSP mass concentrations and diurnal variation of OC and EC concentration

A clear daytime-nighttime contrast was observed for organic carbon (OC), element carbon (EC), and TSP mass concentration during the sampling period. A total 58 samples were collected between February 19 and March 21, 2025. The TSP concentration during daytime (85.2 ± 16.5 μg m^{-3}, n = 29) exceeded that observed at nighttime (73.6 ± 24.1 μg m^{-3}, n = 29). The sampling period coincided with the haze season in Bangkok, which is associated with elevated particulate levels [10][11] OC concentrations remained higher than EC concentrations for both daytime and nighttime samples and showed greater temporal variability. In contrast, EC exhibited lower concentration with smaller variation. Temporal patterns of OC and EC followed those of TSP, with higher values occurring during periods of elevated particle loading. More pronounced day-to-day variation was observed for OC compared to EC. Daytime concentration were generally higher than nighttime values, although several exceptions occurred on specific dates as shown in Figure 2.

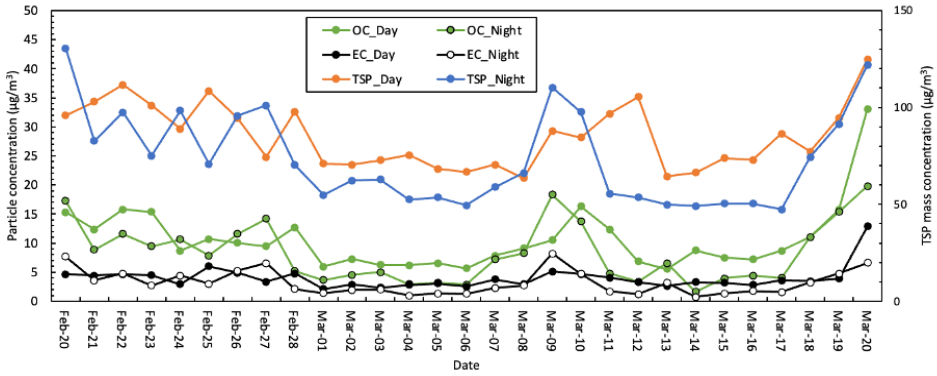

Figure 2. Diurnal variations of organic carbon (OC), elemental carbon (EC), total suspended particle (TSP) mass concentrations in Bangkok, Thailand, from February 19 to March 20, 2025.

The diurnal differences in particulate mass concentrations and carbonaceous components between daytime and nighttime during the sampling period are shown in Figure.3. The particle mass concentration of TSP, PM_{10} and $PM_{2.5}$ showed no significant differences between daytime and nighttime, as indicated by the overlapping distributions. In contrast, the carbonaceous components exhibited more distinct diurnal patterns. OC concentrations were consistently higher than EC for both daytime and nighttime samples and showed greater variation. EC concentrations exhibited smaller variation between daytime and nighttime throughout the sampling period. The broader distribution of OC concentrations suggests greater temporal variability compared to EC. This difference may reflect the combined influence of time-dependent emission activities, atmospheric mixing conditions, and secondary formation processes, which can vary between daytime and nighttime in urban environments. [12]

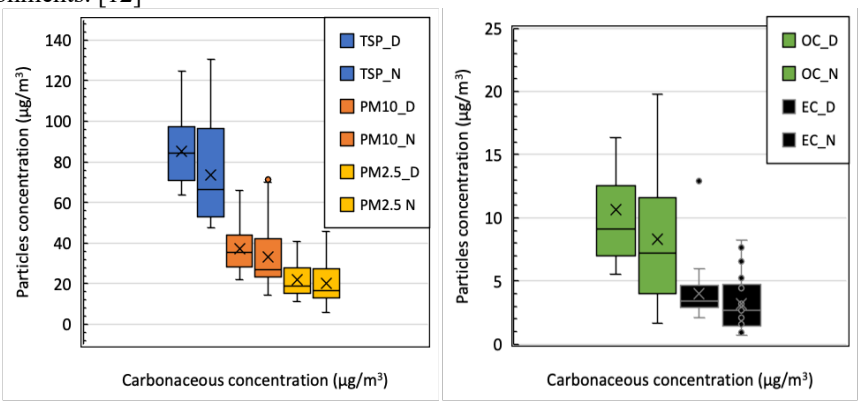

Figure 3. Daytime (D) and Nighttime (N) distributions of particulate mass concentrations (TSP, PM_{10}, and $PM_{2.5}$) and carbonaceous components (OC and EC) measured in Bangkok during the sampling period.

3.2 Temporal and Diurnal variability of light absorption and carbonaceous aerosols

Timeseries of the light absorption coefficient at 365 nm (Abs_{365}) along with OC and TSP mass concentrations is shown in Figure.4. The light absorption of both water and methanol extracts exhibited temporal variability, with several periods of enhanced absorption that were not consistently associated with changes in TSP mass concentration. These results suggested that variations in light absorption are not fully explained by particle mass alone. Instead, light absorption showed correspondence with variations in carbonaceous aerosol characteristics inferred from OC concentrations. Both water soluble and methanol soluble samples exhibited pronounced diurnal variability, suggesting that time-dependent atmospheric conditions may influence the abundance and light absorption characteristics of aerosols. Overall, the results show that aerosol light absorption exhibits temporal variation over the diurnal cycle, consistent with patterns reported in previous studies [9] [13][14][15].

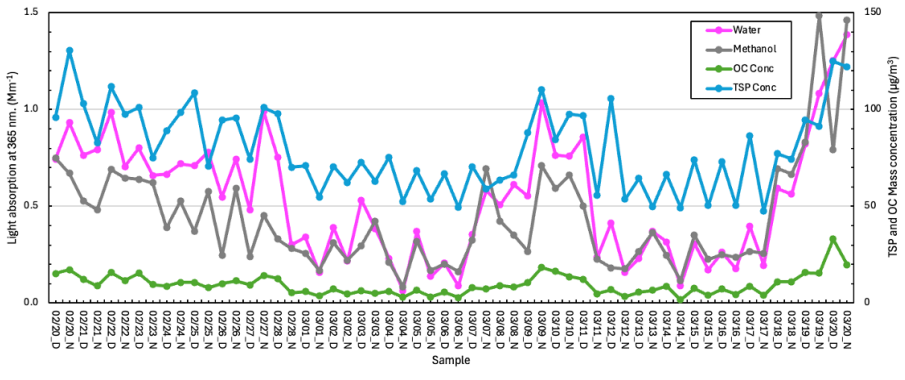

Figure 4. Time series of the light absorption coefficient at 365 nm for water and methanol extract, along with OC and TSP mass concentration during sampling period.

3.3 Light absorption coefficient

Figure.5 shows the average light absorption spectra of the soluble aerosol extracts over the wavelength range 300-700 nm, shown on both linear and logarithmic scales. For both extraction solvent and sampling periods, the spectra exhibit a common characteristic of light-absorbing atmospheric particles, with a sharp increase in absorbance in the ultraviolet region and weaker absorption toward the visible range. Across the entire wavelength, the absorption spectra of the water extract exhibited similar spectral shapes during both daytime and nighttime. Despite variations in absorption magnitude among samples, the overall wavelength dependent absorption behavior was comparable across extraction solvents and sampling periods. The logarithmic representation further highlights the consistent spectral dependence of absorption, with no pronounced divergence in spectral characteristics between solvents or between daytime and nighttime samples. The absorption Ångström exponent (AAE) values calculated over the wavelength range of 330-550 nm showed comparable magnitudes between daytime and nighttime samples. The mean AAE values for water extracts were 5.4 ± 0.6 during daytime and 5.4 ± 0.7 during nighttime, while those for methanol extracts were 5.8 ± 1.6 during both daytime and nighttime. These values fall within the range report in previous studies [10][16]. These results indicate similar wavelength dependent absorption characteristics across extraction solvents and sampling periods, within the observed variation.

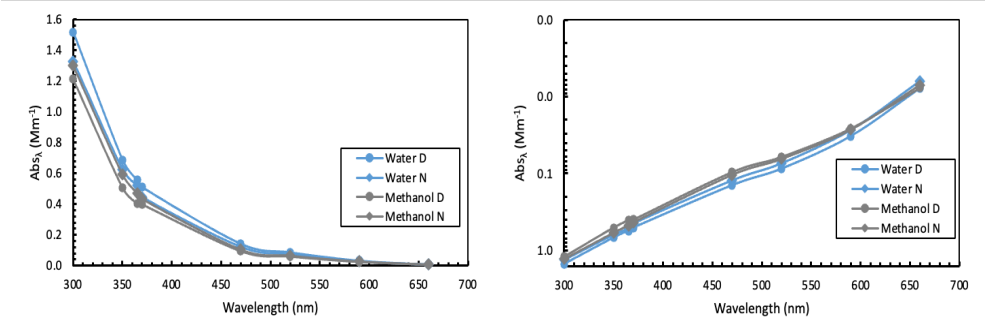

Figure 5. Average light absorption spectra of water-soluble and methanol-soluble aerosol components during daytime and nighttime, plotted on linear (left) and logarithmic (right) scales.

3.4 Relationship between light absorption and organic carbon in water and methanol extraction aerosols

The relationship between absorption efficiency at 365 nm (Abs_{365}) and both TSP mass concentration and organic carbon (OC) concentration for water and methanol extracted aerosol samples during daytime and nighttime in Figure.6. Abs_{365} exhibited weak to moderate relationships with TSP mass concentration across extraction solvents and sampling periods. These relationships were characterized by the considerable scatter and relatively low coefficients of determination (R). These results suggest that variations in light absorption are not well explained by changes in total particle mass alone. In contrast, Abs_{365} and OC concentration for both water and methanol extracts, with higher R values and more coherent trends compared to those with TSP mass concentration. These relationships were more pronounced during nighttime than during daytime. For both extraction solvents, the regression slopes were higher for OC than for TSP mass concentration, suggesting a closer correspondence between light absorption and organic carbon abundance. The linear regressions presented here are used as a descriptive approach to characterize the observed associations rather than to establish causal relationships. Visual inspection of the scatter plots did not reveal strong nonlinearity within the analyzed concentration ranges, and no systematic patterns were observed in the residuals. Overall, these results indicate that variability in aerosol light absorption is more closely associated with organic carbon concentration than with total particle mass, with differences evident between daytime and nighttime.

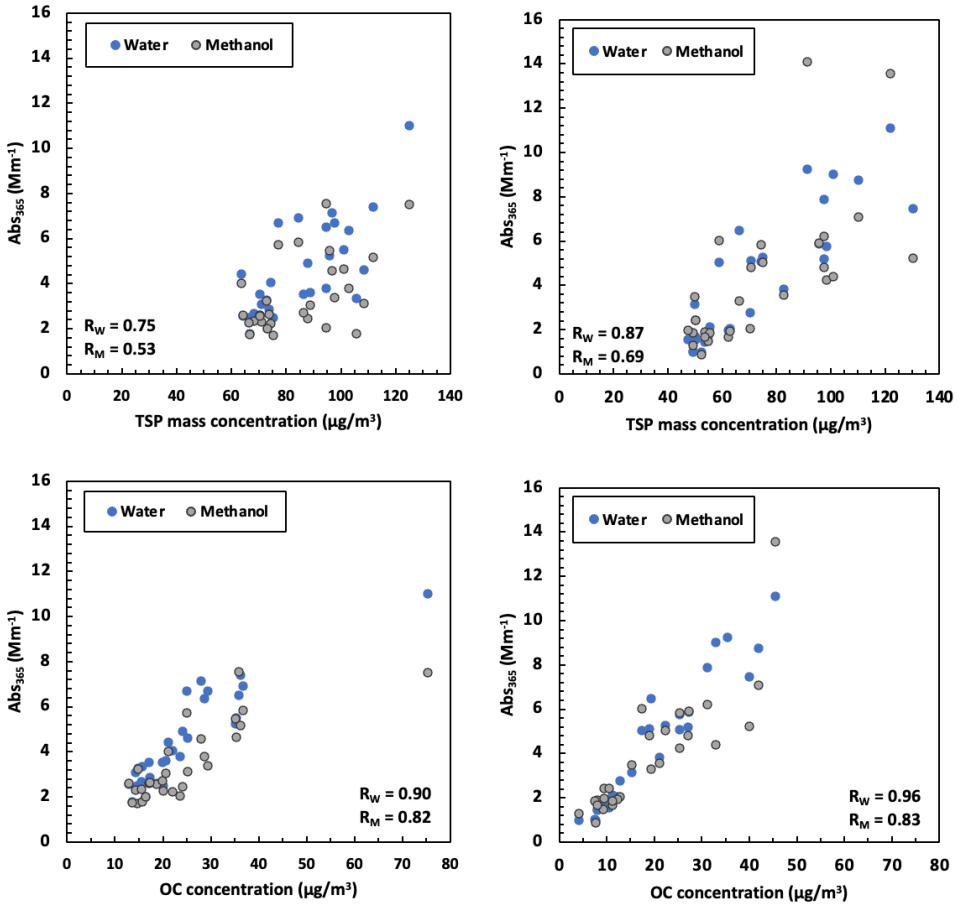

Figure 6. Relationship between Abs_{365} and TSP mass concentration (a,b) and OC concentration (c,d) for water and methanol extracts.

4 Conclusions

The analysis demonstrated a clear diurnal pattern in TSP mass concentration, with higher level occurring during daytime concentration. The comparison between carbonaceous components indicated that organic carbon (OC) consistently exceeds elements carbon (EC) and shows greater variability. These differences reflect time-dependent emission intensity, atmospheric mixing, and secondary formation processes in the urban environment.

Light absorption properties at 365 nm (Abs_{365}) exhibited diurnal variation and showed weak associations with TSP mass concentration, characterized by considerable scatter and limited explanatory power. In contrast, clearer associations were observed between Abs_{365} and OC concentration for both water and methanol extracts, particularly during nighttime. These results suggest that variations in light absorption are more closely associated with organic carbon abundance than with bulk particle mass alone. Overall, the observed patterns indicate that changes in carbonaceous aerosol properties are related to the variation in aerosol light absorption.

The absorption Ångström exponent (AAE) values for the water and methanol extracts were comparable between daytime and nighttime and fall within ranges reported in previous

studies, reflecting similar wavelength-dependent absorption characteristics across sampling periods within the observed variation. Overall, these results suggest that aerosol light absorption in Bangkok is linked to carbonaceous aerosol properties and exhibits clear diurnal variation. The observed difference between daytime and nighttime conditions may be influenced by time dependent atmospheric factors, such as emission patterns, atmospheric mixing, and secondary processes, although these processes were not directly examined in this study. These findings highlight the importance of considering carbonaceous aerosol characteristics and diurnal variability when assessing atmospheric light-absorbing components, rather than relying solely on total particle mass concentration.

The authors would like to acknowledge the Atmospheric Science Research Group (ASRG) and the Faculty of Environment, Kasetsart University, Bangkok, Thailand, for providing PM_{10} and $PM_{2.5}$, data.

References

1. M. O. Andreae and A. Gelencsér, “Black carbon or brown carbon? The nature of light-absorbing carbonaceous aerosols,” *Atmospheric Chem. Phys.*, vol. 6, no. 10, pp. 3131–3148, 2006, doi: 10.5194/acp-6-3131-2006.
2. A. Laskin, J. Laskin, and S. A. Nizkorodov, “Chemistry of Atmospheric Brown Carbon,” *Chem. Rev.*, vol. 115, no. 10, pp. 4335–4382, May 2015, doi: 10.1021/cr5006167.
3. G. Wu *et al.*, “Light absorption, fluorescence properties and sources of brown carbon aerosols in the Southeast Tibetan Plateau,” *Environ. Pollut.*, vol. 257, p. 113616, Feb. 2020, doi: 10.1016/j.envpol.2019.113616.
4. D. A. Lack and J. M. Langridge, “On the attribution of black and brown carbon light absorption using the Ångström exponent,” *Atmospheric Chem. Phys.*, vol. 13, no. 20, pp. 10535–10543, 2013, doi: 10.5194/acp-13-10535-2013.
5. X. Zhang, Y.-H. Lin, J. D. Surratt, and R. J. Weber, “Sources, Composition and Absorption Ångström Exponent of Light-absorbing Organic Components in Aerosol Extracts from the Los Angeles Basin,” *Environ. Sci. Technol.*, vol. 47, no. 8, pp. 3685–3693, Apr. 2013, doi: 10.1021/es305047b.
6. N. Chuersuwan, S. Nimrat, S. Lekphet, and T. Kerdkumrai, “Levels and major sources of $PM_{2.5}$ and PM_{10} in Bangkok Metropolitan Region,” *Environ. Int.*, vol. 34, pp. 671–7, Jul. 2008, doi: 10.1016/j.envint.2007.12.018.
7. W. Phairuang, P. Suwattiga, S. Hongtieab, M. Inerb, M. Furuuchi, and M. Hata, “Characteristics, sources, and health risks of ambient nanoparticles (PM0.1) bound metal in Bangkok, Thailand,” *Atmospheric Environ. X*, vol. 12, Dec. 2021, doi: 10.1016/j.aeaoa.2021.100141.
8. M. Li et *al.*, “Abundance and Light Absorption Properties of Brown Carbon Emitted from Residential Coal Combustion in China,” *Environ. Sci. Technol.*, vol. 53, no. 2, pp. 595–603, Jan. 2019, doi: 10.1021/acs.est.8b05630.
9. A. Hecobian, X. Zhang, M. Zheng, N. Frank, E. S. Edgerton, and R. J. Weber, “Water-Soluble Organic Aerosol material and the light-absorption characteristics of aqueous extracts measured over the Southeastern United States,” *Atmospheric Chem. Phys.*, vol. 10, no. 13, pp. 5965–5977, 2010, doi: 10.5194/acp-10-5965-2010.
10. R.-J. Huang *et al.*, “Brown Carbon Aerosol in Urban Xi’an, Northwest China: The Composition and Light Absorption Properties,” *Environ. Sci. Technol.*, vol. 52, no. 12, pp. 6825–6833, Jun. 2018, doi: 10.1021/acs.est.8b02386.

11. W. Kliengchuay *et al.*, "Seasonal Analysis of Indoor and Outdoor Ratios of $PM_{2.5}$ and PM_{10} in Bangkok and Chiang Mai: A Comparative Study of Haze and Non-Haze Episodes," *Heliyon*, vol. 11, p. e42261, Feb. 2025, doi: 10.1016/j.heliyon.2025.e42261.
12. L. K. Sahu, Y. Kondo, Y. Miyazaki, P. Pongkiatkul, and N. T. Kim Oanh, "Seasonal and diurnal variations of black carbon and organic carbon aerosols in Bangkok," *J. Geophys. Res. Atmospheres*, vol. 116, no. D15, Aug. 2011, doi: 10.1029/2010JD015563.
13. P. Uttamang, P. Choomanee, J. Phupijit, S. Bualert, and T. Thongyen, "Investigation of Secondary Organic Aerosol Formation during O_3 and $PM_{2.5}$ Episodes in Bangkok, Thailand," *Atmosphere*, vol. 14, no. 6, p. 994, 2023, doi: 10.3390/atmos14060994.
14. Y.-C. Ting, Y.-R. Ko, C.-H. Huang, Y.-H. Cheng, and C.-H. Huang, "Optical properties and potential sources of water-soluble and methanol-soluble organic aerosols in Taipei, Taiwan," *Atmos. Environ.*, vol. 290, p. 119364, Dec. 2022, doi: 10.1016/j.atmosenv.2022.119364.
15. B. Zhang *et al.*, "Seasonal changes in water-soluble brown carbon (BrC) at Nanling background station in South China," *Front. Environ. Sci.*, vol. Volume 12-2024, 2024, doi: 10.3389/fenvs.2024.1360453.
16. J. Li *et al.*, "Optical properties and molecular compositions of water-soluble and water-insoluble brown carbon (BrC) aerosols in northwest China," *Atmospheric Chem. Phys.*, vol. 20, no. 8, pp. 4889–4904, 2020, doi: 10.5194/acp-20-4889-2020.