Design a Simple Experimental Setup for Measuring Light Absorption of Brown Carbon (BrC) in PM 2.5 Samples During "The Smoke Haze Season" in Chiang Mai

Siwat Kamepuang[1], Wan Wiriya[1,2]

[1] Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai , Thailand.

[2] Enviromental Chemistry Research Laboratoty, Faculty of Science Chiang Mai University , Chiangmai, Thailand.

ABSTRACT

This research aims to design a simple, cost-effective device using accessible materials and 3D printing to enhance durability in measuring Brown Carbon (BrC) absorption. Particulate matter less than 2.5 microns in diameter (PM2.5) samples were collected during March–April 2021. BrC was extracted by soaking in water and methanol to isolate the BrC dissolved in both solvents for analysis. The study compared measurement methods between a UV-Vis spectrophotometer and a self-developed spectroscopy device, using Beer-Lambert's law to calculate BrC absorption values. Preliminary tests showed that the BrC absorption value measured by the self-developed device was 0.640±0.317, while the UV-Vis spectrophotometer measured 0.6010±0.296. The BrC concentration from the self-developed device was 1.10×10^{-4} mg/L, compared to 1.04×10^{-4} mg/L from the UV-Vis spectrophotometer. Pearson correlation analysis indicated a strong positive correlation (r = 0.951) between the absorption values measured by the two methods. Performance evaluation revealed a limit of detection (LOD) of 0.083, a limit of quantification (LOQ) of 0.279, and a relative standard deviation (%RSD) of 1.99%. Statistical analysis showed no significant difference in variance between the two groups ($p > 0.05$). Continuous testing for 6 hours a day over 15 days confirmed the device's stability and accuracy in measuring light absorption.

INTRODUCTION

This work presents the development of a self-made spectrophotometer using 3D printing technology. It serves as an affordable and accessible alternative for measuring light absorption. The primary focus is on analyzing Brown Carbon (BrC) collected from PM2.5 samples. The core innovation of this project is the 3D-printed spectrophotometer. It is designed to measure light absorption and compare the results with those from a standard UV-Vis spectrophotometer. A 3D printer was used to create precise, durable, and customizable components for the experimental setup. This ensures easy assembly and cost-efficiency. The device facilitates the study of Beer-Lambert law principles. It offers

METHODLOGY

Preparation of Brown Carbon Solution

Punch the sample from PM2.5

Take 10 mL samples of both DI water and methanol extracts
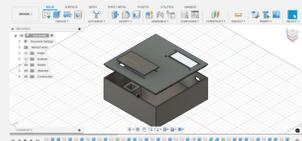

Extracts a simple in an Ultrasonic bath, No heat needed
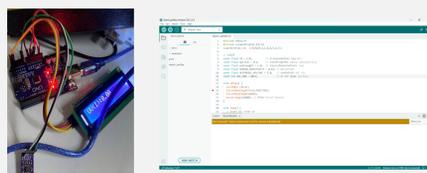

The pH adjust with a 0.1 M NaOH

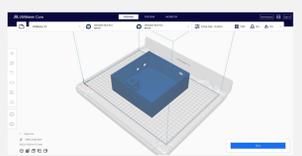UV-Vis Spectrophotometer, PerkinElmer

Create a simple 3 D light absorption device

Design the device with Autodesk Fusion 360

Arduino software for upload code program send to a board

Ultimaker Cura used for 3 D printing

A 3D Self made spectroscopy

Analyze — The determination of Brown Carbon (BrC) light absorption properties including ;

1. Measurement of Absorbance (A)

$$A = -\log_{10}\left(\frac{I_0}{I}\right)$$

Parameter:
- A : Absorbance.
- I_0 : Intensity of the light before it passes through the sample.
- I : Intensity of the light after passing through the sample.

2. The light absorption coefficient (b_{abs})

$$B_{abs} = \frac{A}{L}$$

Parameter:
- A: Absorbance
- L: Path length (cm)
- B_{abs} : Light absorption coefficient (cm^{-1}).

3. The mass absorption efficiency (MAE)

$$MAE = \frac{b_{abs}}{TOC}$$

Parameter:
- B_{abs} : Light absorption coefficient (cm^{-1}).
- TOC : Total Organic Carbon concentration (g/m^3).
- MAE : Mass absorption efficiency (m^2/g).

4. Calculation Brown carbon Concentration (C_{BrC})

$$C_{BrC} = \frac{b_{abs}}{MAE}$$

Parameter:
- B_{abs} : Light absorption coefficient (cm^{-1}).
- MAE: Mass absorption efficiency (m^2/g).
- C_{BrC} : BrC concentration (mg/L).

RESULTS AND DISCUSSION

The result of absorbance comparing between Ultraviolet-Visible Spectrophotometer. And A Self made spectroscopy device

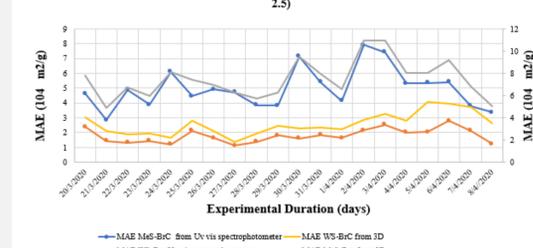| Peridos sampling	Extraction	Absorbance from Uv-vis Spectrophotometer		Absorbance from a Self-made device	
		Average	S.D.	Average	S.D.
Non smoke haze season (n=20)	WS-BrC	0.991± 0.282		0.994+0.284	
	MeS-BrC				
Smoke haze season n=20	WS-BrC	0.124±0.102		0.127± 0.103	
	MeS-BrC				
Smoke haze season (high PM 2.5) n=20	WS-BrC	0.157± 0.076		0.1624 ± 0.075	
	MeS-BrC				

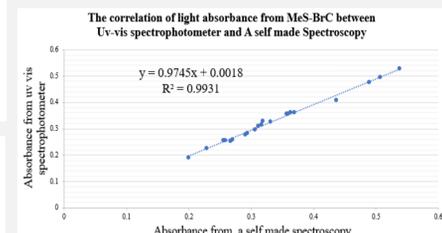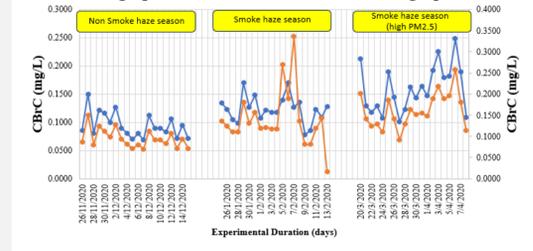The graph of light absorption (babs) during Smoke haze season (High PM 2.5)
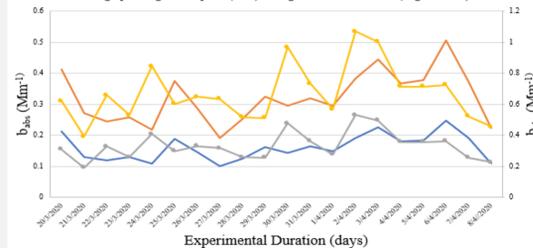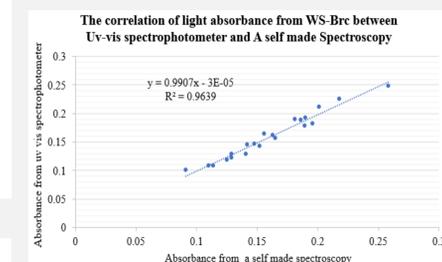

The graph of concentration of MeS--BrC during 3 periods
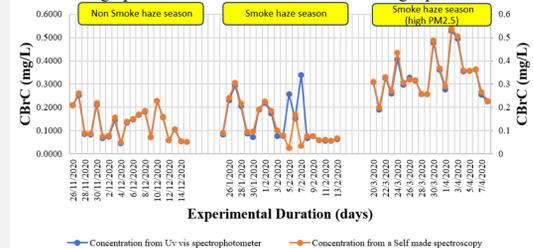
The graph of Mass Absorption Efficiency (MAE) during Smoke haze season (High PM 2.5)

The graph of concentration of WS-BrC during 3 periods

The correlation of light absorbance from MeS-BrC between Uv-vis spectrophotometer and a self made Spectroscopy
y = 0.9745x + 0.0018
$R^2 = 0.9931$
Methanol solution Brown carbon

The correlation of light absorbance from WS-Brc between Uv-vis spectrophotometer and a Self made Spectroscopy
y = 0.9907x - 3E-05
$R^2 = 0.9639$
Water solution Brown carbon

ACKNOWLEDGMENT

REFERENCES

[1] Smith, J., & Doe, A. (2024). Study on light absorption properties in urban environments. Journal of Environmental Sciences, 105(2), 123-135.

[2] Kasetsart University. (n.d.). Facilities - Department of Mechanical Engineering. Kasetsart University.

[3] Thai Science Journal. (n.d.). Study on manufacturing technology. Thai Science Journal, 15(2), 45-60.

CONCLUSION

1. BrC absorption from the self-developed device (0.640±0.317) closely matches with UV-Vis spectrophotometer results (0.6010±0.296) with strong correlation (r = 0.951).

2. The device has a LOD of 0.083, LOQ of 0.279, and low %RSD of 1.99%.

3. No significant difference ($p > 0.05$) between devices, confirming reliability.