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Article

Atmospheric Ultrafine Particulate Matter ($PM_{0.1}$) Bound Carbon Composition in Bangkok, Thailand

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Abstract: Seasonal variations in atmospheric ultrafine particulate matter ($PM_{0.1}$) were monitored in Bangkok, Thailand, from 2016 to 2017. $PM_{0.1}$ bound organic carbon (OC), and elemental carbon (EC) were collected by a cascade air sampler that can collect $PM_{0.1}$ and estimated by a thermal-optical carbon analyzer following the IMPROVE-TOR protocol. The annual average $PM_{0.1}$ in Bangkok was 14.5 ± 4.7 μg/m^3, higher than in large Asian cities like Shanghai and Hanoi. Biomass burning from neighboring areas was shown to increase the particle concentration. Apparent risings in carbon species as OC, EC, and OC/EC ratios in the wet and dry seasons were observed, and Char-EC/Soot-EC displayed that the $PM_{0.1}$ in the Bangkok atmosphere was influenced mainly by the vehicle exhaust, even though the influence of biomass burning was more sensitive during the dry season. The effective carbon ratio (ECR) displays that carbonaceous aerosol is light-absorbing; the dry season increase contributed to climate and air quality. The finding of this work is of great importance to air pollutants control policies in urban areas.

Keywords: $PM_{0.1}$; ultrafine particles; carbon; biomass burning; vehicle exhaust

1. Introduction

Air pollutants, particularly airborne particulate matter (PM), have been critical environmental pollution in many countries in recent decades [1,2,3,4]. Natural and anthropologic emission sources can release airborne PM [5,6]. The PM components are also classified as hazardous materials to human health [7] and induced to change global climate systems [8]. According to particle size criteria, PM is typically separated into coarse, fine, and ultrafine modes [9]. PM with an aerodynamic diameter of less than 10 μm belongs to coarse PM (PM_{10}). Those with an aerodynamic diameter less than 2.5 μm can be classified as a fine fraction ($PM_{2.5}$). Ultrafine particulate matter ($PM_{0.1}$) have diameters less than 0.1 μm, or 100 nm [10]. Thailand faces a severe air pollution problem, mainly by ambient PM, primarily released from industrial activities, biomass fires, and land transportation [11]. $PM_{2.5}$ average concentration during the dry season was reported to be exceeding the 24-hr standard for Thailand (50 μg/m^3) and more significant than the World Health Organization (WHO) standards (10 μg/m^3). Moreover, transboundary particulate pollutant has been an increasing concern recently [6,12].

However, the past decade has increased the study of ultrafine particles (UFPs) or $PM_{0.1}$ [9,13]. UFPs are recently more concerned with public health effects [10]. The physiochemical characteristics of UFPs continue to be lacking worldwide [9,10]. The Asian atmosphere is still limited in information on UFPs fraction, even though the Asian region has been the leading contributor to particulate pollution in the recent decade [14]. Several

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studies have deliberated the particulate pollution bound to the chemicals in several nations around Asia due to health effects and environmental damages [12,13,14]. Many studies are based on ground-based detecting, scientific modeling, and satellite image techniques [6,15,16,17]. Recent decades exposed that ambient PM plumes during haze episodes exceeded many countries' national standards, with an extreme value compared to WHO or other countries' standards [18]. Thailand and Southeast Asian (SEA) countries displayed that UFPs mass concentrations are around 15-20% of the total suspended particulate matter (TSP) in the ambient air [12,13,14,19].

Carbonaceous aerosols (CA) are typically separated into two broad classes based on their thermal-optical properties, and the total carbon (TC) is split into operationally defined elemental carbon (EC) and organic carbon (OC) [20]. Total carbon (TC) is the most composed of particles that occupy particle mass concentrations of approximately 20-50% [12,13]. The importance of PM in modifying the Earth's climate has been recognized for a long time [21]. Recently, the significance of the carbon fraction in aerosols to global radiative forcing, air quality, and human health has been stressed in several studies [22,23]. Information on carbon components in airborne PM is also essential to identify the emission sources and regular procedures for ambient particles and carbon material, the two leading causes of atmospheric particulate pollution and global warming [24].

Therefore, the general motivation of this study was to investigate the physicochemical characteristics of atmospheric $PM_{0.1}$ related to carbon that was conducted in Bangkok, Thailand, from 2016 to 2017. The main goal of this study was to investigate $PM_{0.1}$ and contained carbon compositions, and this information would be valuable for studying possible emission sources of atmospheric $PM_{0.1}$ in Thailand. The information from this work will provide facts about the chronological variation of atmospheric $PM_{0.1}$ in the typical cities in Thailand, which leads to a life-threatening global warming problem and adverse human health in urban areas. Moreover, this study may support future research and policy-making on air pollution control and environmental management in the case of developing countries.

2. Methodology

2.1. Sampling Site

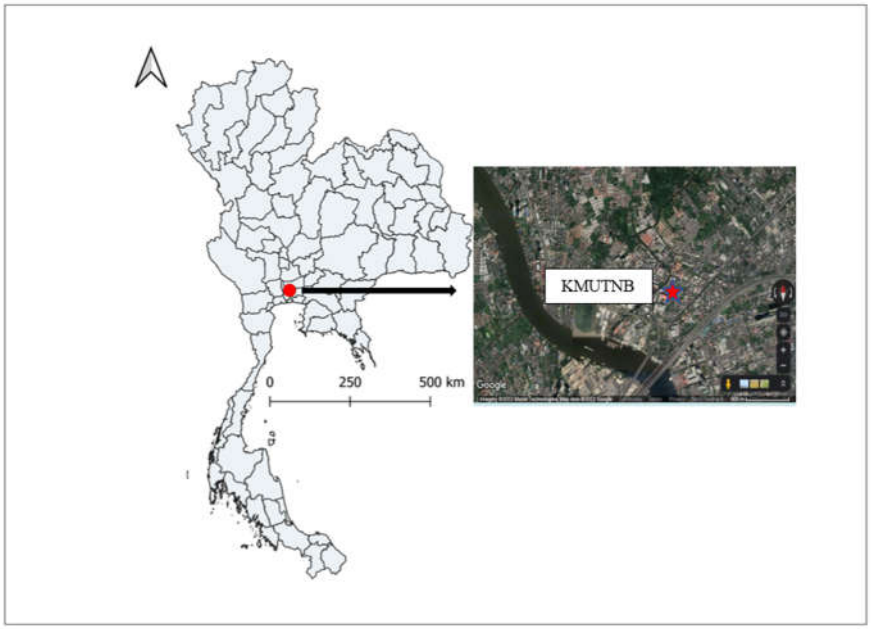

Figure 1. Location of monitoring site, in Bangkok, Thailand.

The monitoring campaign was conducted at King Mongkut's University of Technology North Bangkok (KMUTNB; 13.83 ºN, 100.51 ºE) (Figure 1). With a population of

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around 8 million in 2015, Bangkok is placed in central Thailand, with a daily average temperature ranging from 27.1 to 28.2 °C [25]. All of the thoroughfares were distributed southwest (SW), south (S), and southeast (SE) of the monitoring site, but the north (N) of KMUTNB is exposed to the cropland. The sampling site is located about 40 meters above ground level. A 24-hr sampling was conducted five times/month every six-day intervals from May 2016 to April 2017.

2.2. Cascade Sampler for ambient $PM_{0.1}$

A cascade air sampler for nanoparticles or ambient nano-sampler (termed here as ANS) was used to collect $PM_{0.1}$ at a flow rate of 40 liters per minute [26]. Quartz fiber filters (QFF) of diameter 55 mm were incubated at 350 °C for 1 hour to eliminate contaminants on the filter and then stored for 48 hours in a weighing chamber (Temperature 21.5 ± 1.5 °C and Relative Humidity 35 ± 5 %) and weighted by using a microbalance. The procedure followed one suggested by the Ministry of Environment of Japan. After collecting samples, the filters were kept in the chamber for at least 48 hours before being re-weighted and held at -20°C to preserve their chemical constancy until consequent analysis [27]. A total of 60 $PM_{0.1}$ samples were collected in this study.

2.3. Thermal-optical carbon analysis

The Sunset thermal-optical Carbon Analyzer equipped with Flame Ionization Detector (FID) sensors was used to analyze the OC and EC of $PM_{0.1}$. The thermal/optical reflectance (TOR) protocol was used to measure the OC and EC. The instruments estimated the carbon compositions in $PM_{0.1}$ samples, i.e., OC and EC, by stepwise heating the filter at different temperatures. In short, a 1.5 cm^2 area from QFF was heated in pure helium using a temperature of 120, 250, 450, and 550 °C set by the instrument program. Four OC fractions were separated and quantified as OC1, OC2, OC3, and OC4. Organic materials in the samples were converted entirely into CO_2. Following that, oxygen was passed through the instrument to maintain the condition of 2% oxygen and 98% helium. The temperature gradually increased to 550, 700, and 800 °C. This temperature program isolated and evaluated elemental carbon fractions (EC1, EC2, and EC3). Moreover, organic pyrolysis carbon (OPC) was generated during adding the oxidation state. OC1+OC2+OC3 +OC4+OPC defined OC while EC1+EC2+EC3-OPC defined EC. The analyzer was calibrated daily with a filter blank and a known concentration of CH_4. Moreover, EC can divide into char-EC (= EC1-OPC) and soot-EC (= EC2+EC3) [24].

2.4. Estimation of climate effect

Carbonaceous aerosol affects not only public health but also the global macroclimate since it could modify the global temperature by absorbing and scattering light. As Safai et al. (2014) [28] reported, the effective carbon ratio (ECR) was more susceptible to evaluating the carbonaceous aerosol effect of climate change, and ECR could be calculated from the ratio of SOC/(POC+EC). POC and EC could absorb the light commonly emitted from fossil fuel burning, crop residue burning, as well as domestic cooking. In contrast, the characteristic of SOC could scatter the light, mainly emitted from the oxidation of volatile organic compounds.

2.5. Quality assurance/Quality control (QA/QC)

The calibration of carbon analysis was analyzed by TC reference chemical, or sucrose ($C_{12}H_{22}O_{11}$). Blank filters (n=4) were used for the standardization. 10% of all samples were analyzed in duplicate, and a full calibration was performed every time a gas cylinder was changed. OC and EC repeatability in duplicates were 90 % and 95 %, respectively. The minimum detection limit (MDL) for OC and EC based on the estimation of the travel blanks were 0.37 and 0.01 μg/cm^2, respectively.

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2.6. Hot Spots and Backward Trajectories

Active fires or hot spots representing open fires are derived from a moderate resolution imaging spectroradiometer (MODIS). The back-trajectories were calculated using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model, which was initially advanced in the 1980s by National Oceanic and Atmospheric Administration (NOAA) and then launched at https://www.ready.noaa.gov/HYSPLIT.php website. The model was initialized with two seasons. Three-day backward trajectories were simulated for twelve individual months arriving at sampling hours (0800 UTC) at three different elevations of 100, 500, and 1000 m above ground level.

3. Results and Discussion

3.1. $PM_{0.1}$ mass concentrations

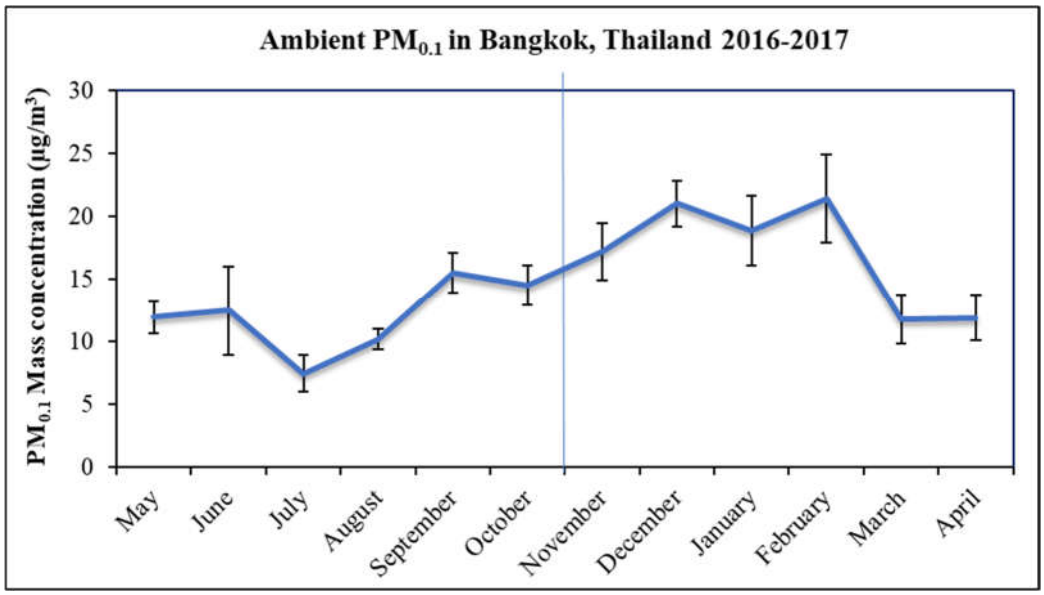

Figure 2. Monthly average variation in $PM_{0.1}$ concentrations in Bangkok, Thailand.

The annual average of $PM_{0.1}$ in Bangkok, Thailand, from May 2016 to April 2017 was 14.5 ± 4.7 µg/m³ (Figure 2). The concentration of $PM_{0.1}$ during the wet season from May to October ranged from 7.5 to 15.5 µg/m³ with an average concentration of 12.0 ± 3.2 µg/m³, while during the dry season from November 2016 to April 2017 ranged from 11.8 to 21.4 µg/m³ with a mean of 17.0 ± 4.6 µg/m³. The monthly concentration of $PM_{0.1}$ during the wet season was less than during the dry season. The lowest $PM_{0.1}$ was found at 5.1 µg/m³ during 18-19 July 2016, while the highest $PM_{0.1}$ was found at 27.0 µg/m³ during 27-28 February 2017. The mass concentration in Bangkok, Thailand, from 2016 to 2017 was lower than the levels in Chiang Mai, Thailand, from 2014 to 2015 (25.2 ± 4.7 µg/m³) during forest fires episode [24] and in tunnel measurement by Chen et al. (2010) [29] in Hsinchu, Taiwan (33.2 ± 6.5 µg/m³). Nevertheless, the concentrations of $PM_{0.1}$ were mainly more significant than those in large cities in Asian countries, e.g., Hat Yai (2018), Thailand (10.2 ± 2.2 µg/m³) [23], Hat Yai (2019), Thailand (10.4 ± 1.2 µg/m³) [12], Shanghai, China (13.4 µg/m³) [30] and Hanoi, Vietnam (6.1 ± 2.7 µg/m³) [4] (Table 1). The $PM_{0.1}$ in this study was also higher than those in cleaner zones, for instance, in North Sumatra, Indonesia (7.1 µg/m³) [13], 2.2 ± 0.6 µg/m³ in the traffic area in Hsinchu, Taiwan [29], 1.4 ± 0.6 µg/m³ in New Taipei, Taiwan [31] and 4.7 µg/m³ in Kanazawa, Japan [32]. The predictable $PM_{0.1}$ portion in PM_{10} in each emission source in the United Kingdom is this way; waste burning (4%), manufacturing boilers (7%), energy in industrial (8%), cropland (9%), off-road transport (9%), other non-road vehicles (14%) and manufacture process (15%) [33]. In addition, the information on $PM_{0.1}$ mass concentration is still limited in western countries due to a small mass concentration. Most studies of UFPs worldwide use particle number concentration (PNC)

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[34]. In the United States of America, Venecek et al. (2019) [34] calculated $PM_{0.1}$ mass concentration in 39 towns and found that $PM_{0.1}$ levels are relatively low on an annual average (under 1 μg/m³).

Table 1. $PM_{0.1}$ concentrations (μg/m³) at different locations in Asian Countries.

Location	Site Description	Concentration	References
Bangkok, Thailand	Urban	14.5 ± 4.7	This study
Bangkok, Thailand	Urban	14.8 ± 2.0	[24]
Chiang Mai, Thailand	Suburban	25.2 ± 4.7	[24]
Hat Yai, Thailand	Suburban	10.2 ± 2.2	[23]
Hat Yai, Thailand	Suburban	10.4 ± 1.2	[12]
Pathumtani, Thailand	Suburban	16.9 ± 4.2	[23]
North Sumatra, Indonesia	Rural	7.1	[13]
Hanoi, Vietnam	Urban	6.1 ± 2.7	[4]
Shanghi, China	Urban	13.4	[30]
Hsinchu, Taiwan	Traffic	2.2 ± 0.6	[41]
Hsinchu, Taiwan	Tunnel	33.2 ± 6.5	[42]
New Taipei, Taiwan	Urban	1.4 ± 0.6	[31]
Kanazawa, Japan	Suburban	4.7	[32]

3.2. The analysis of eight carbon fractions of $PM_{0.1}$

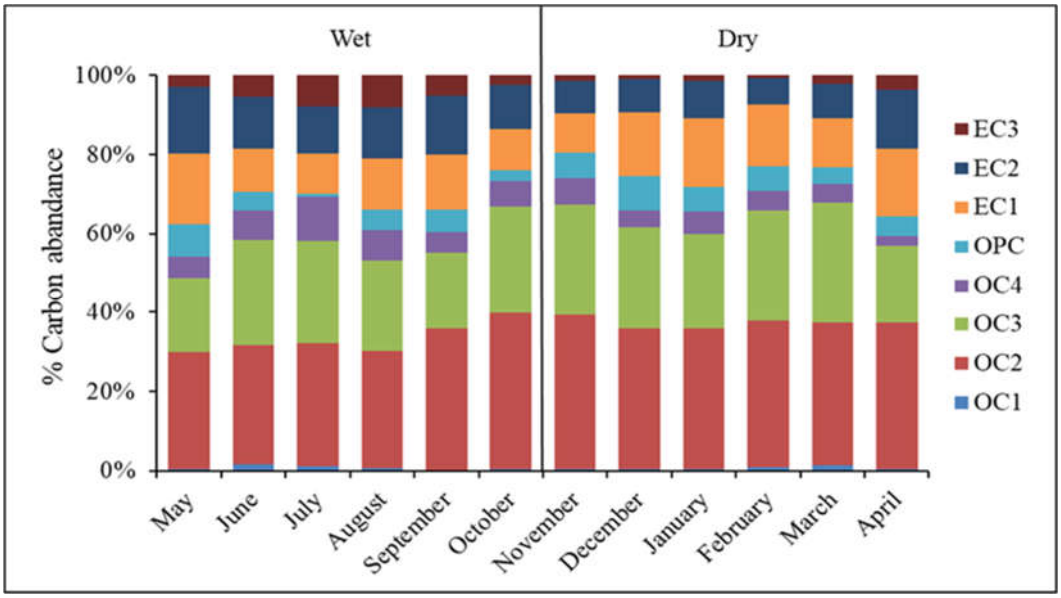

Figure 3. The percentage of eight carbon fractions in $PM_{0.1}$.

The thermogravimetric EC-OC study produced information for OC1-OC4, OPC, and EC1-EC3 fractions. These fractions were divided based on volatility and contained information regarding possible EC and OC sources in the Bangkok atmosphere. Figure 3 illustrates the percentage contributions of eight carbon fractions (OC1, OC2, OC3, OC4, OPC, EC1, EC2, and EC3) to total carbon in eight stages. Because each fraction differs in its source, it is often used in the source apportionment of CA investigations [23]. Biomass combustion contributes to OC1. OC2 is an indicator for coal combustion and might be derived from secondary organic carbon (SOC) and biomass fires [35]. OC3 and OC4 are found at higher concentrations in the road dust profile. EC1-OPC, also known as char-EC, is generated by biomass combustion and specifies lower temperature combustion processes (550°C). EC2 and EC3, also identified as soot-EC, result from a high-temperature combustion process and are created through gas-to-particle conversion [20]. The OPC

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fraction may be due to highly polar organic compounds. There was a noticeable monthly variation in eight carbon fractions in the $PM_{0.1}$ particle range. OC2 and OC3 were the most abundant species during the wet, while OC2, OC3, and EC1 established a place with 60-80% during the dry season. Soot-EC was detected higher than the char-EC and depicted seasonal variation. Char-EC also characterized seasonal dependence. Han et al. (2009) [20] claim that char-EC/soot-EC ratios are better for identifying sources and comprehending the radiative effect. Both are naturally absorbent; soot-EC absorbs lighter than char-EC [36].

3.3. Carbon characteristics

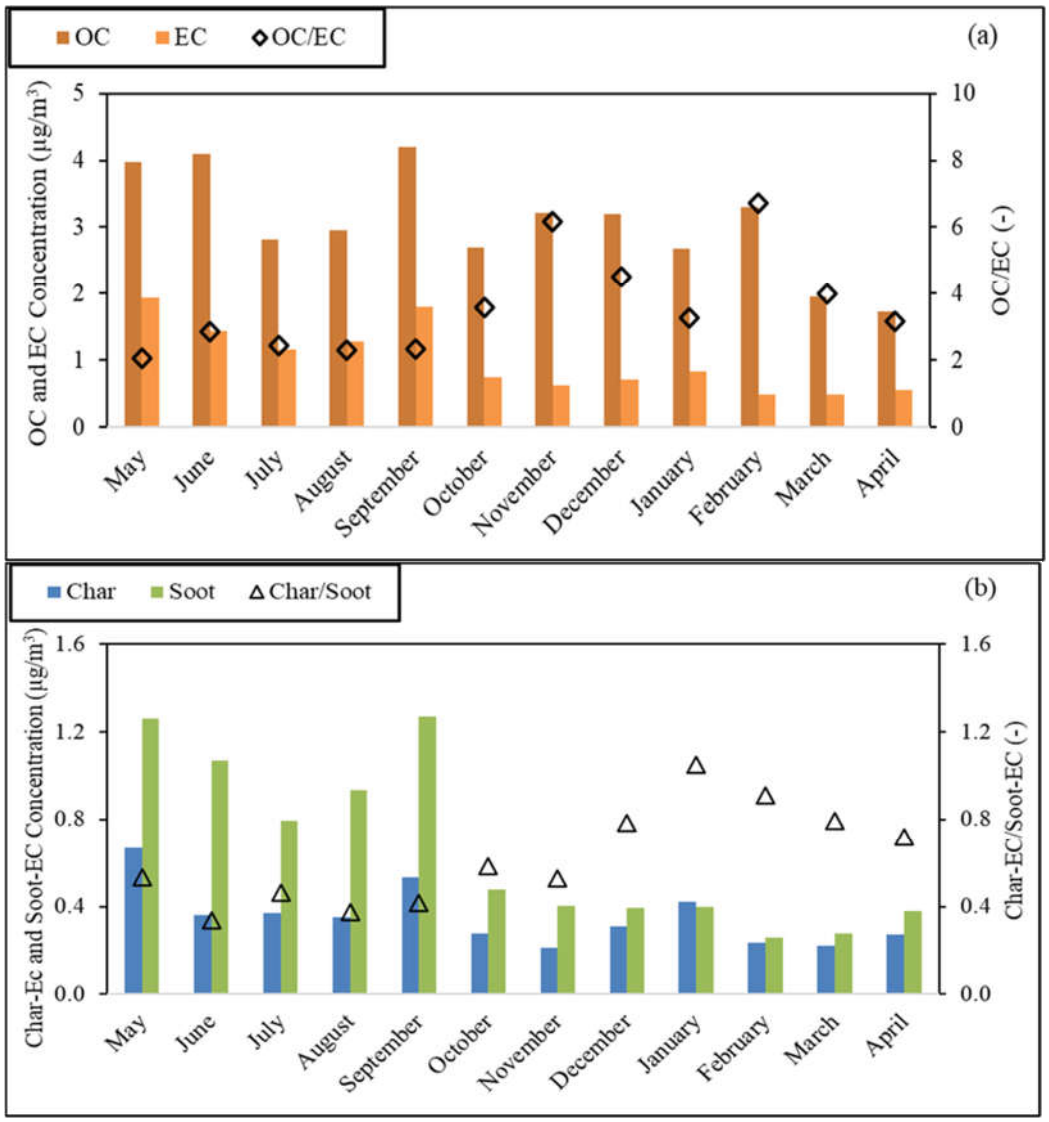

Figure 3. (a) OC, EC, and OC/EC ratios (b) Char-EC, Soot-EC, and Char-EC/Soot-EC ratios.

The carbonaceous components in ultrafine particles, including OC, EC, Char-EC, and Soot-EC, from May 2016 to April 2017 at KMUTNB are presented in Figure 3a-b. The OC and EC concentrations in the wet season were slightly higher than in the dry season, with the highest OC in September being 4.2 µg/m³ and EC in May at 1.9 µg/m³. The lowest OC was found in OC for April (1.6 µg/m³) and EC in February and March to be 0.5 µg/m³. In Bangkok, the ambient $PM_{0.1}$ also dominates the total TC concentration (OC and EC), occupying around 16.1-53.1 % of the total $PM_{0.1}$ mass concentration with, on average, around 30.3%.

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The OC/EC ratios can practice identifying specific sources of carbonaceous particles. Ratios for diesel exhaust, biomass fires, and coal burning have different levels. The higher ratio comes from biomass fire, whereas fossil burning produces lower OC/EC ratios [2]. The OC to EC ratio for biomass fires is higher (~6-8) [2,20], and that from fossil fuel combustion is lower (~0.2-1) [37]. Characteristic carbonaceous species include diesel consumption (OC/EC ~ 0.06-0.8) [38]. biomass fires (OC/EC ~ 3.9-4.2) [39], and distant transportation/aged aerosol (OC/EC ~ 12) [40]. In this study, OC/EC ratios account for generally agreed with others. The OC/EC ratios for ambient $PM_{0.1}$ range from 1.9 to 6.2, with an average of 3.0 is lower than those cities in Thailand of ambient $PM_{0.1}$ in Chiang Mai during haze episodes (3.5), Bangkok (3.4), and slightly higher than Hat Yai (2.9) [23,24]. Moreover, this result is comparable with Hanoi, Vietnam, which fluctuated from 3.8 to 5.7 [4], but higher than those from Taiwan, which ran from 0.2 to 1.7 [29]. The OC/EC ratio during the wet season is less than during the dry season. The OC/EC ratio of land transportation ranges from 1 to 2, and the higher about 4 may be from biomass fires [4].

The OC/EC ratios were as follows; land transportation (1.2-1.3), manufacturing (1.6-2.3), and biomass combustion (3.9-4.2) in PM_{10} from near sources in Thailand [39]. These results displayed that the higher OC/EC of $PM_{0.1}$ ratios at the KMUTNB site could be attributed to mixed sources dominating carbonaceous particles above Bangkok, Thailand. OC domination, particularly in $PM_{0.1}$, may be primarily derived from biomass fires. In contrast, the OC to EC ratios hangs on the above three factors to acceptably categorize the emission source. The three factors are involved primary emission sources, wet deposition, and secondary formation in the atmosphere [16].

Unlike the OC to EC ratio, Char-EC/Soot-EC ratio is diverse from different primary sources and can use to classify the origin sources [20]. The direct emission source and the wet deposition are the two influences interrupting the char-EC/soot-EC ratio. Higher Char-EC/soot-EC specifies the dominance of biomass combustion linked to char-EC contributions to the total EC contents [12]. At the same time, ratios less important than 1.0 suggest that soot from the diesel exhaust significantly contributes to the total EC concentrations [16]. The ratio of char-EC/soot-EC in $PM_{0.1}$ is almost constant during the wet season, around 0.58 ± 0.45. Char-EC/soot-EC is an index of fossil fuel burning (< 1.0 for diesel soot) [23]. This proposes that fossil energies in local transportation, e.g., diesel exhaust, influence atmospheric $PM_{0.1}$ above Bangkok. However, the char/soot increases during the dry season by around 1.0. The impact of biomass fires is vital for increasing Char-EC, representing biomass burning emissions in this area [24]. Considering the carbon indices, both OC/EC and char-EC/soot-EC ratios differed in size distribution [2,23]. Other size-segregated PMs and carbon components are crucial to forthcoming studies in a more detailed investigation into developing carbonaceous aerosol studies.

3.4. Estimation of secondary organic aerosol concentrations

Because observed OC concentrations include both POC released directly from emission sources and SOC generated in the ambient air by photochemical reactions, an assumption is required to determine secondary OC contribution to measured OC concentrations. A simplified technique was adopted in some circumstances, where OC/EC > 2.0 was presumed to imply a substantial SOC contribution [41]. However, a more complicated method known as the EC tracer method is more commonly employed to assess SOC contribution to quantity OC concentrations. SOC concentrations can be estimated using Equation in the EC tracer method [42].

$$SOC = POC - EC \times (OC/EC)_{min}$$

Where POC is the primary organic carbon, SOC refers to secondary organic carbon, $(OC/EC)_{min}$ is the value of the lowest OC/EC ratio each season. We calculated the carbon species for the wet and dry seasons in this study. The contribution of POC, SOC, and EC are presented in Figures 4a-b.

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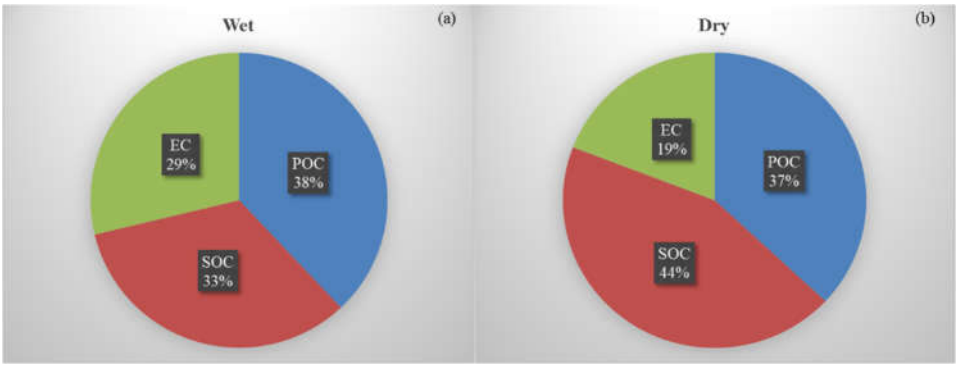

Figure 4. Carbon distribution of each species for wet and dry seasons in $PM_{0.1}$. EC: elemental carbon POC: primary organic carbon SOC: secondary organic carbon

The averaged proportion of SOC presented the contribution of $PM_{0.1}$ to be 33% and 44% in the wet and dry seasons, respectively (Figure 4). In Thailand, secondary atmospheric $PM_{0.1}$ has a limited study. This is the semi-direct attempt to estimate the SOC in $PM_{0.1}$ each season. The average SOC in Bangkok, Thailand, agreed with the corresponding values for Hanoi, Vietnam, and Hat Yai, Thailand [4, 23]. Thuy et al. (2018) [4] reported that smaller SOC particles were dominant compared to coarser particles; the SOC in $PM_{0.1}$ pays up to 42.7% of the carbon level in Hanoi, Vietnam. The meteorological conditions during the cold dry season play a vital role in increasing the level of organic species in ambient particles. During the dry season, stable atmospheric conditions may strengthen atmospheric oxidation, and the low temperatures could increase the condensation of volatile secondary organic components (VSOC) [43].

3.5. Effective carbon ratio (ECR)

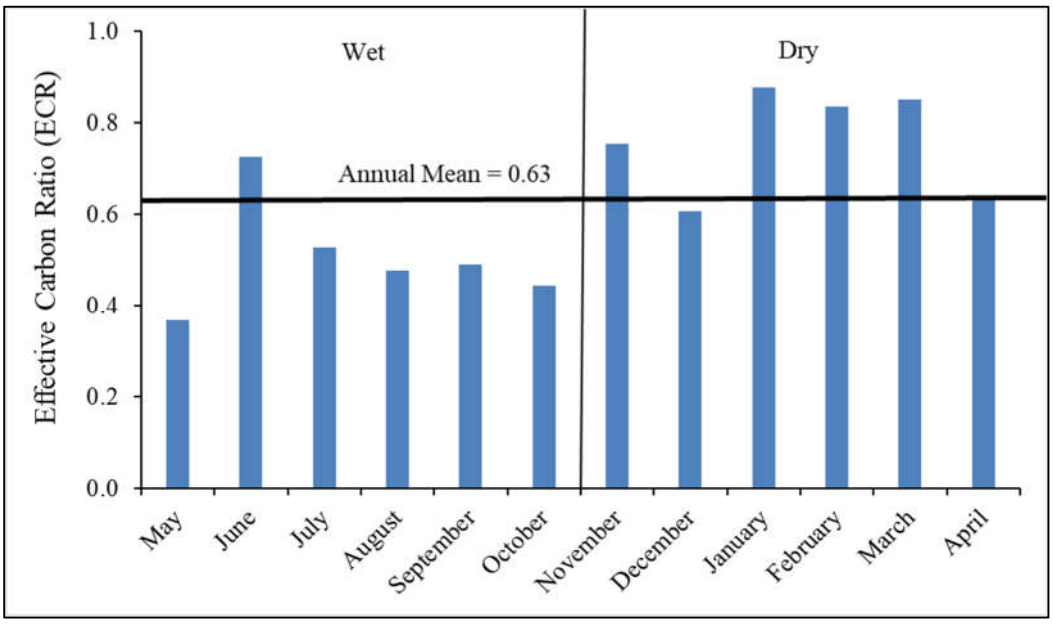

Figure 5. Effective carbon ratio (ECR) during the wet and dry seasons in Bangkok.

The OC/EC ratios play an essential role in the CA in the climate models. However, the OC to EC ratio does not provide comprehensive data on the radiative impact of CA or its sources. Since OC contains both primary OC and secondary OC, each has different source mechanisms and different behaviors to interact with solar radiation. The Effective carbon ratio (ECR) can represent the ambient warming effect of combustion CA [28]. A lower ECR ratio during the wet season has implications for more absorbing type CA. During the rainy season, low ECR values (≤ 0.50), primarily due to the high level of POC

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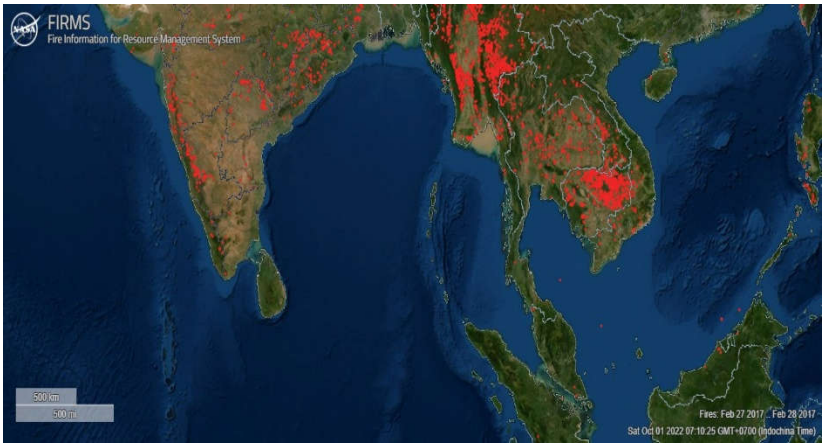
and EC, were detected. POC and EC could absorb the light commonly emitted from fossil fuel combustion, agricultural residue burning, and domestic cooking. On the other hand, during hot and cold dry seasons, high values (ECR ≥ 0.60) show in the direction of scattering-type CA. The formation of secondary organic carbon (SOC) during smoke aging in Bangkok, Thailand, was attempted to estimate by the semi-direct method of the SOC in $PM_{0.1}$. The averaged proportion of SOC showed that the contribution of $PM_{0.1}$ is 57.1% in the dry season, while in the wet season, only 46.3% of SOC was found in $PM_{0.1}$. The higher SOC/OC in the dry season indicates the high level of secondary sources to form smaller particles from the combustion sources in Bangkok and increase the light-absorbing during the dry season [4]. The characteristic of SOC could scatter the light, mainly emitted from the oxidation of VOC. Consequently, the concept of ECR is strengthened to estimate the effect of CA on the global climate system.

3.6. Possible Local and Long-Range Transport of PM

(a) Hot Spots during the wet season (July 2016)



(b) Hot Spots during the dry season (Febuary 2017)

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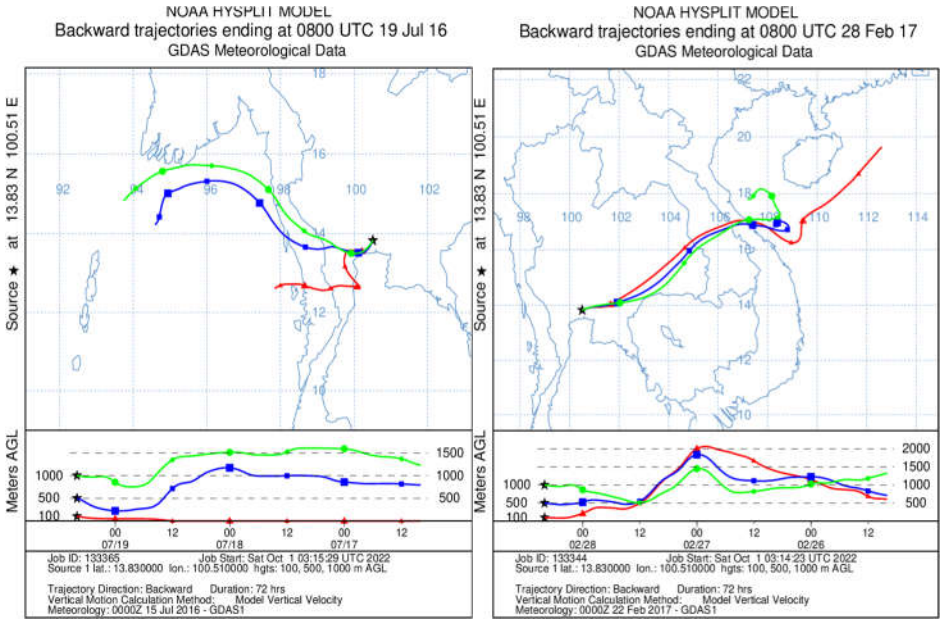

(c) Backward trajectory at KMUTNB over 18-19 July 2016

(d) Backward trajectory at KMUTNB over 27-18 Febuary 2017

Figure 6. Hot spots and air mass trajectories.

The HYSPLIT model was used to study the potential long-term transport of PM-bound carbon at the sampling site. We performed a backward air mass trajectory simulation for two seasons, wet and dry, in this study. The source coordinate is 13.83 ºN and 100.51 ºE. PM-bound carbon, with a lifetime of around one week, can travel for long distances in the atmospheric system [44]. Figure 6a-b displays the hot spot distribution in Thailand and neighboring countries. During the wet season, a few hotspots in this area compared to the dry season that a dense active fire in upper Southeast Asian countries where several researchers have reported biomass fires, including pre-and post-harvesting season of the agricultural crop as well as forest fires [6, 23, 24]. In the wet season, most of the air mass movement originated from a westerly direction (Figure 6c). It was under the influence of the southwest monsoon, in which clean air masses from the Indian Ocean brought a low PM level to Thailand. On the other hand, in this study, high levels of $PM_{0.1}$ were detected on a few sampling days during the dry season (27-28 February 2017) (Figure 6d). These high concentrations could be either contributed by domestic sources or from cross-border countries through the long-range transport of particulate pollutants. Moreover, all of the 72-hr air mass originated from the northeast and central part of Thailand and some parts of neighboring countries, including Vietnam and Laos, where open fires have been observed.

4. Conclusions

Seasonal variations of ultrafine particles ($PM_{0.1}$) in Bangkok, Thailand, were investigated based on cascade air sampling in 2016-2017. The annual average $PM_{0.1}$ in Bangkok was 14.5 ± 4.7 μg/m^3, higher than in large cities in Southeast Asia. Char-EC/Soot-EC values for the $PM_{0.1}$ particle were a lesser amount of 1.0 both in the wet and dry seasons. A higher Char-EC/Soot-EC ratio indicates the dominance of biomass burning associated with Char-EC contributions to total EC contents; ratios < 1.0 suggest that Soot-EC from fossil fuel combustion largely contributes to the whole and is a significant contributor to total EC. The authors also recommend that more research be conducted related to how local sources and transboundary pollution affect not only the $PM_{0.1}$ mass level but also the chemical components of these fractions to make available a more comprehensive and reliable understanding of $PM_{0.1}$ profiles emitted from an urban area, particularly during a haze

episode in Thailand. These findings emphasize the importance of focusing emission control strategies on ultrafine particle sizes in Thailand and elsewhere.

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