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Incremental Concentration of Black Carbon Aerosol from Road Traffic in Inner Bangkok

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Abstract

Commonly referred to as soot, black carbon (BC) is a primary aerosol emitted from incomplete combustion of organic materials such as fossil fuels, biofuels and biomass. BC aerosol is a dominant anthropogenic solar radiation absorber, absorbing approximately 1 million times more radiation per unit of mass than CO_2. Recent research has found that BC is the second largest anthropogenic contributor to global warming. BC aerosol is not only a short-lived climate forcer (SLCF) but also an air pollutant that adversely affects human health. Emission sources of BC aerosol are mainly residential, industrial, transportation related and/or and open burning sources. In a large city with serious traffic congestion such as Bangkok, vehicles are the most significant source of BC aerosol.

The objective of this study is to determine BC concentrations in Bangkok's ambient air caused by road traffic. BC concentrations in the center of Bangkok city were measured using an aethalometer located on the rooftop of the Department of Environmental Engineering's five-story-building at Chulalongkorn University, Bangkok. Measurements were carried out in the dry season of January 2013, when atmospheric aerosol concentrations are high. BC concentrations were measured on a 24-hour basis for a continuous 7-day period. The results reveal diurnal variations that follow local traffic patterns. Except on Sundays, diurnal BC patterns were generally bimodal in both mornings and evenings. During weekdays, BC concentrations peaked in the morning at 4.01 µg per cubic meter and in the evening at 3.71 µg per cubic meter, with an average value of 3.08 µg per cubic meter. On Saturdays, BC concentrations peaked in the morning at 2.16 µg per cubic meter and in the evening at 2.24 µg per cubic meter, with an average value of 1.76 µg per cubic meter. On Sundays, BC concentrations showed only small variations throughout the day, ranging from about 0.93 to 1.41 µg per cubic meter, with an average value of 1.16 µg per cubic meter. It can be concluded that the baseline BC concentration in the inner Bangkok area is approximately 1 microgram per cubic meter. In the present case, contributions to ambient atmospheric BC concentrations from traffic were 3-4 times higher than the baseline concentration, indicating that green transportation is urgently needed to reduce SLCFs and air pollution in Bangkok city.

Keywords: Black carbon aerosol; vehicle emissions; short-lived climate forcers; Bangkok ambient air

Introduction

Commonly referred to as soot, black carbon (BC) is a primary aerosol emitted from incomplete combustion processes involving organic materials such as fossil fuels, biofuels, and biomass (IPCC, 2007). BC aerosol is a dominant anthropogenic solar radiation absorber (USAID, 2009), absorbing approximately 1 million times more radiation than CO_2 per unit of mass (USAID, 2009). However, despite recent findings that BC is the second largest anthropogenic contributor to global warming (Atlantic Consulting, 2009), BCemissions remain unregulated under the Kyoto Protocol. BC aerosol is not only a short-lived climate forcer (SLCF) but also an air pollutant that affects human health. BC aerosol emission sources are mainly residential, industrial, transportation related, but open burning is also a major contributor. In a large city with congested traffic such as Bangkok, vehicles are the most significant source of BC aerosol emissions.

The objective of this study is to determine the contribution of road traffic to ambient atmospheric BC concentrations in the inner Bangkok metropolis.

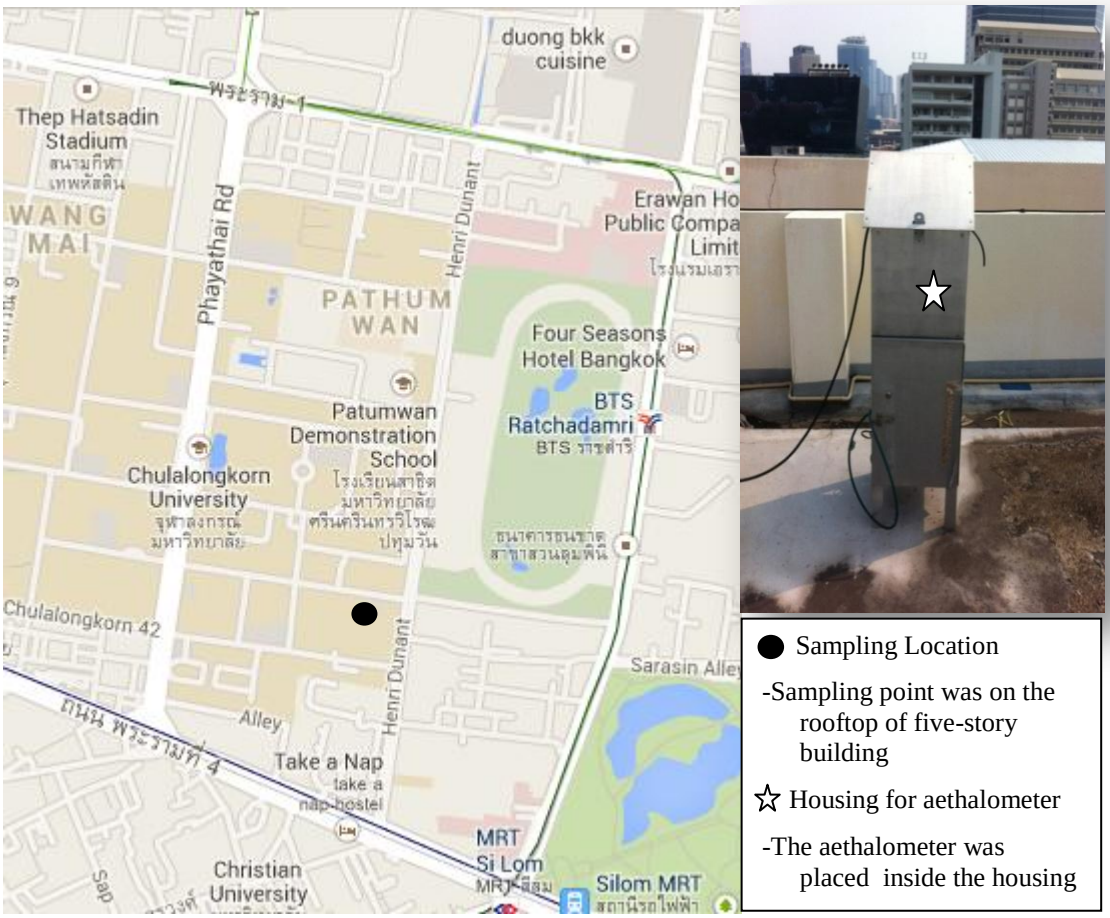

Figure 1 Sampling Location

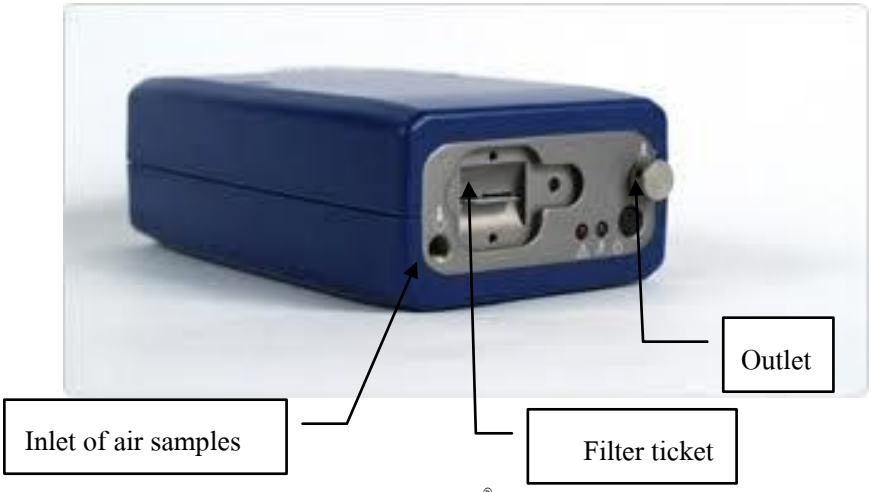

Figure 2 Aethalometer, MicroAeth® Model AE51, Magee Scientific

Material and Methods

BC concentrations were measured on a 24-hour basis over a continuous 7-day period, at the center of Bangkok city, on the rooftop of the 5-storey building occupied by the Department of Environmental Engineering, Chulalongkorn University, Bangkok (Figure 1). To more accurately determine the baseline concentration of BC and incremental BC concentrations due to traffic, the sampling location was located more than 50 meters from roads and other sources. Two mega shopping complexes, a large university, and numerous high-rise residential and commercial buildings are also located in this area.

BC concentrations were measured using an aethalometer (MicroAeth® Model AE51, Magee Scientific) (Figure 2). The instrument collected particulate matter via a filter and measured the infrared absorption value of this matter. The corresponding BC concen-trations were determined and were converted to µg per cubic meter.

The measurements were carried out in January 2013 during the dry season, when Bangkok's ambient air is known to contain high BC aerosol concentrations (Oanh et al, 2008; Suwattiga, 2012). BC concentrations were measured continuously on a 24-hour basis for 7 days.

Results and Discussion

Hourly BC concentrations during weekdays were found to range from 0.71-7.18 µg per cubic meter, with daily average concen-trations between 2.30 and 4.04 µg per cubic meter (Table 1). On Saturday and Sunday, hourly BC concentrations were 1.22-2.24 and 0.93-1.41 µg per cubic meter, with daily average concentrations of 1.76 and 1.16 µg per cubic meter, respectively.

Table 1 BC Concentrations on each day of the week

Day	Range of 1-hr BC Concentrations for 24 hours µg/m^3	24-hr BC Concentrations µg/m^3
Monday	1.15 - 4.95	3.00
Tuesday	2.28 - 7.18	4.04
Wednesday	0.76 - 6.32	3.37
Thursday	0.71 - 4.57	2.68
Friday	1.28 - 4.56	2.30
Saturday	1.22 - 2.24	1.76
Sunday	0.93 - 1.41	1.16

The results show distinct diurnal variations on weekdays, Saturday and Sunday (Figure 3). These variations correspond closely to normal daily traffic patterns (Figure 4). Except on Sunday, the diurnal BC patterns observed were generally bimodal in the morning and evening. On Sunday, only small variations in hourly concentrations were observed.

On weekdays (Monday to Friday), BC concentrations peaked in the morning between 08:00 - 09:00 h (with a maximum of 4.01 µg per cubic meter) and in the evening at about 19:00 - 22:00 h (with a maximum of 3.71 µg per cubic meter). On Saturday, BC concentrations peaked in the morning between 08:00 h and 13:00 h (with a maximum value of 2.16 µg per cubic meter)

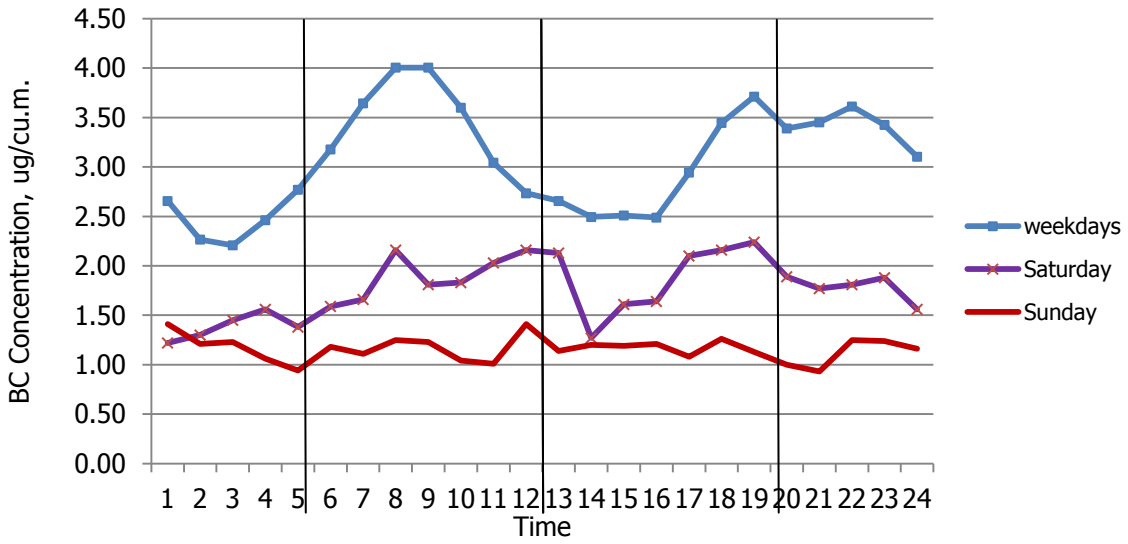

Figure 3 Diurnal BC Concentrations at Chulalongkorn University, Bangkok city center

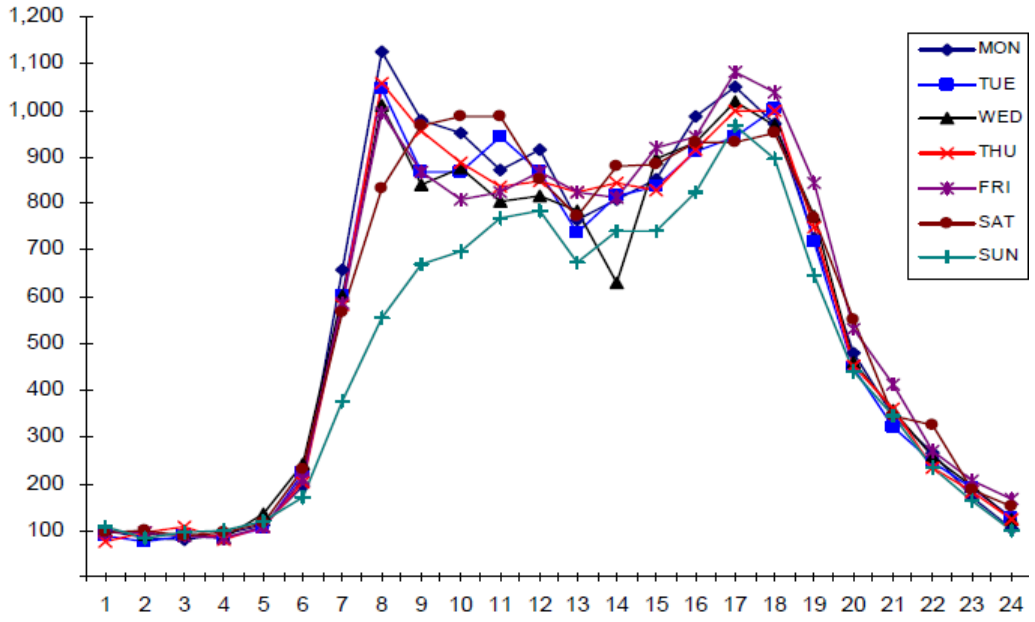

Figure 4 Diurnal Variation of Traffic Volume in a Week
Source: Department of Public Works and Town and Country Planning, n.d.

and in the evening at about 18:00 -19:00 h (with a maximum value of 2.24 µg per cubic meter). On Sunday, BC concentrations were about 0.93-1.41 µg per cubic meter, with an average value of 1.16 µg per cubic meter. The BC concentrations did not peak on Sunday. The city's baseline BC concentration was determined to be approximately 1 µg per cubic meter. Therefore, incremental BC concentrations from traffic on weekdays amounted to 2-3 times the baseline concentration or about 2-3 µg per cubic meter.

Results from previous BC studies in Bangkok are summarized in Table 2. Garivait and Chaiyo (2006) used an aethalometer to measure BC aerosol concentrations at King Mongkut's University of Technology Thonburi (KMUTT), located just south of Bangkok, and also in a remote area of Pimai district, NakornRatchasima, approximately 300 kilometers northeast of Bangkok. This study found that at KMUTT, BC aerosol concentrations ranged from 2.284 to 7.079 µg per cubic meter, with those in Pimai district ranging from 0.0843 to 2.345 µg per cubic meter (Table 2). Oanh et al (2008) studied 6 Asian cities (in Thailand, China, India, Indonesia, the Philippines and Vietnam) from 2002 to 2008 and found that, at the Asian Institute of Technology campus (a suburban area 49 km north of Bangkok) EC concentrations in $PM_{2.5}$ ranged from 4 to 11 and from 2 to 10 µg per cubic meter in the dry and rainy seasons, respectively. Suwattiga (2012) studied elemental carbon (EC) in PM_{10} at King Mongkut's University of Technology North Bangkok (KMUTNB) and found that EC concentrations ranged from 2 to 22 µg per cubic meter, with an average value of 9 µg per cubic meter. During the dry season, BC emissions ranged from 4 to 22 µg per cubic meter, with an average value of 11 µg per cubic meter. This was significantly higher than

Table 2 BC concentrations determined in current study, compared with other studies

Sites	Land use	BC aerosol, µg/m^3	Analysis method	Reference
KMUTT	Suburban South of Bangkok	2.284 - 7.079	Aethalometer	Garivait and Chaiyo (2006)
Pimai District	Rural	0.0843 - 2.345	Aethalometer	Garivait and Chaiyo (2006)
AIT Dry season Wet season	Suburban North of Bangkok	In $PM_{2.5}$ 4-11 2-10	EC concentration	Oanh et al. (2008)
KMUTNB Dry season Wet season	Suburban North of Bangkok	In PM_{10} 4-22 (11) 2-13 (8)	EC concentration	Suwattiga, (2012)
Chulalongkorn University	Urban Inner Bangkok	In PM_{10}: 3.79 In $PM_{2.5}$: 3.03 BC = 0.50 - 10.58 (2.72)	EC concentration Aethalometer	Duangkaew (2012)
This study Dry season	Urban Inner Bangkok	0.71-7.18 (2.62)	Aethalometer	

Note: Average values in parentheses

the concentrations measured during the wet season, when black carbon emissions ranged from 2 to 13 µg per cubic meter, with an average value of 8 µg per cubic meter. Duangkaew (2012) analyzed EC concentration in PM_{10} and $PM_{2.5}$ and measured BC using an aethalometer at Chulalongkorn University (CU). Their results indicated that, during the dry season, average concentrations of EC in PM_{10} and $PM_{2.5}$ were 3.79 µg per cubic meter and 3.03 µg per cubic meter, respectively. BC concentrations (measured by an aethalometer) were 0.50-10.58 µg per cubic meter, with an average value of 2.72 µg per cubic meter.

These studies indicate that BC concentrations north and south of Bangkok are higher than BC concentrations in inner Bangkok. Atmospheric BC concentrations in the city are mostly from vehicular sources. On the other hand, BC concentrations in suburban areas north and south of Bangkok appear to be from multiple sources, including vehicles, trucks and biomass burning. It is likely that BC concentrations in rural area are low because there are no significant sources in these areas. BC concentrations vary from place to place depending on their sources at any given time. Husain et al (2007) studied BC concentrations in Lahore, Pakistan, which uses (at least at that time) a considerable amount of fossil fuels and biomass fuels and found that BC concen-trations ranged from 6 to 110 µg per cubic meter. Rehman et al (2011) studied BC concentrations resulting from cooking using bio-fuels in rural India and found that BC concentrations in ambient air reached up to 30 µg per cubic meter during cooking hours.

Conclusions

The present study found that BC concentrations in the inner Bangkok area during weekdays ranged from 2.21 - 4.01 µg per cubic meter, with an average value of 3.08 µg per cubic meter. On Saturday, BC concentrations ranged from 1.22 - 2.24 µg per cubic meter, with an average value of 1.76 µg per cubic meter. On Sunday, BC concentrations ranged from 0.93 - 1.41 µg per cubic meter, with an average value of 1.16 µg per cubic meter. On average, BC concentrations on weekdays were 3-4 times higher than for Sunday. The baseline BC concentration in the inner Bangkok is approximately 1 microgram per cubic meter. In this case, BC contributions from traffic were 2-3 times higher than the baseline BC concentration, indicating that green tran-sportation is urgently needed in Bangkok city center to reduce BC aerosol emissions. Reducing atmospheric BC can reduce short-lived climate forcers (SLCFs) and air pollution simultaneously.

Acknowledgements

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