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Contribution of Black Carbon Aerosol from Vehicles and Industries in Kathmandu –A Case Study

Sharma R.K.[1*], Bhattarai B.K.[1], Sapkota B.K.[1], Gewali M.B.[2], Amatya N.B.[1] and Kjeldstad B.[3]
[1]Pulchowk Campus Institute of Engineering, Tribhuvan University, Kathmandu, NEPAL
[2]Central Department of Chemistry, Tribhuvan University, Kirtipur, Kathmandu, NEPAL
[3]Depart of Physics Norwegian University of Science and Technology, Trondheim, NORWAY

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Abstract

Black carbon (BC) aerosol was measured at an interval of every five minutes at Pulchowk Campus, Lalitpur Nepal from May 2009 to 6th May 2010 using seven channels Magee Scientific AE-31 Aethalometer. In this paper, the data of six continuous strike days and working day are analyzed to identify the actual portion of BC contributed by vehicles and industries in the total concentration of BC aerosol. During six continuous strike days, 1-6 May 2010 all the industries were completely shut down and there were no vehicles plying on the road. Therefore, BC emission by vehicles and industries was considered as zero and only domestic activity was assumed as main source. In working day the mean value of BC aerosol was 10.91µg m^{-3} in a range between 5.45µg $m^{-3}$and 22.3 µg m^{-3} while on the first day of strike, it was between 3.03 and 11.9 µg m^{-3} with the mean value of 6.31µg m^{-3}. On the last day of the strike, the variation of BC aerosol from minimum to maximum was ranging between 1.90 µg m^{-3} to 11.59 µg m^{-3} having mean value as 5.07 µg m^{-3}. The contribution of BC aerosol by vehicles and industries was found to be about 50%. The diurnal trend of BC aerosol in one working day and strike days is nearly similar but the peak hour concentration of BC on a working day was nearly two folds of strike days. Further, a clear inverse relationship between BC and wind speed was also found.

Keywords: Aerosol, black carbon, aethalometer and diurnal.

Introduction

Black Carbon aerosol, an important constituent of airborne particulate matter, is a product of incomplete combustion of fossil fuel, biomass and coal. Increasing energy demand associated with a rapid industrialization and domestic uses has increased pollutant in the atmosphere thereby the concentration of BC aerosol. The automobile such as cars, scooters, motors, trucks and buses moving on the roads form the mobilesource of air pollution[1]. BC affects environment at local, regional and global levels. A black carbon aerosol absorbs solar radiation and is the second largest contributor to global warming, after green house gases[2]. The two most important sources of BC are combustion of fossil fuel and biomass burning[3, 4]. Solid bio-fuel combustion is the largest source of black carbon emission in India[5]. BC may also have regional climate impacts. High concentrations of BC over India and China are responsible for a trend toward increasing flooding in the south (India) and drought in the north (China)[6]. A significant amount of BC, if present, in the main clouds can lead to increased absorption of solar radiation that heats the atmosphere. The consequence of this is to burn off the clouds or to alter the cloud life time and precipitation patterns[6,7]. The atmospheric transparency reduced by high concentration of soot over India and China decreases agricultural productivity by 10-20 percent[8]. According to[9], black carbon strongly absorbs light and thereby degrades visibility. Studies by[3,10] have shown that BC can also alter the earth's radiation balance. The climate effects of BC aerosol depend strongly on its physical and chemical properties as well as on its residence time and distribution in the atmosphere[10]. Global warming due to black carbon may be as much as 0.3-0.4^{o} C[11,12].

In the present paper, an attempt has been made by comparing the concentration of BC on Strike days and ordinary working day respectively in Kathmandu to find out the actual mass of BC produced by industries and vehicles. Strike days suggest here, the typical days when there were no vehicles on the road. Schools, colleges, industries and most of the offices were not in operation. While on the ordinary working days, all the social activities of urban area were in full swing. Strike days were taken as an opportunity to find out the BC aerosol by domestic activity like wise, an effort has been taken to find out the possible emission of BC resulted from vehicles and industries. Simple strike event has been taken as an experimental basis for observation of BC aerosol by only domestic activity without using any complicated model and inventories.

Material and Methods

Kathmandu valley is located between 27 ^{o}37'30" N and 27^{o}45'0" N latitude and 85^{o}15' 0" E and 85^{o} 22' 30" E longitude. The base of valley is about 1350 meters above sea level and covers about 340 sq.km.area. The cross section of the valley is about 20 km north to south and 30 km east to west.

Kathmandu valley has a bowl like structure surrounded by four major mountains namely Shivapuri, Phulchowki, Nagarjun and Chandragiri at an elevation of more than 500m from its base. Figure 1 is showing Kathmandu valley surrounded by major mountains with the Himalayas in the north side and the three major cities Kathmandu, Bhaktpur and Lalitpur. At present, the population of the valley is 2.51 million [*CBS*, 2011]. It is the main political and administrative center, a major tourist gateway, and an economically strategic location in the country. High population growth, dramatic land use changes, and socioeconomic transformations have brought the paradox of rapid urbanization and environmental consequences to the valley.

An aethalometer AE 31 manufactured by Magee Scientific USA is a seven wave length instrument to monitor BC. It was placed for operation on the second floor of G block, Pulchowk Campus for continuous monitoring of BC. The aethalometer is an instrument that provides a real time read out of the concentration of BC or EC aerosol particles in air stream. The instrument was set into operation at a time interval of 5 minutes round the clock with a flow rate of 2 liters per-minutes (2LPM). It shows BC concentration in the display screen in an interval of five minutes. These data are automatically recorded in the flash card memory of the instrument. The instrument using its inlet tube aspirates ambient air from an altitude of ~8m above the ground level. Black carbon mass concentration is estimated by measuring the change in the transmittance of a quartz filter tape on to which particles impinge. This technique is reported to have shown good comparison with the other ones used for monitoring of BC particles, like coefficient of haze tape sampler, particle soot absorption photometer, thermal oxidation/reference technique[13, 14]. The detail of the working of aethalometer is found in the operation manual.

Results and Discussion

This is the first attempt to monitor BC aerosol in Kathmandu valley using aethalometer. Data were collected from May 2009. However this work analyzes data for six continuous strike days between 1- 6th May 2010. Just before the strike, 30th April 2010 was a regular working day and has been considered in the analysis to find out the contribution of BC aerosol by vehicles and industries in total BC. The daily average of BC concentration prior to working day for more than ten days was nearly same so, it has been considered as back ground concentration of BC in the discussion. During the strike days, no vehicles were on the road, all the industries were completely closed and only domestic activities like cooking, heating and so on were in progress. Therefore this period was taken in use to find out the mass of BC aerosol released by vehicles and industries.

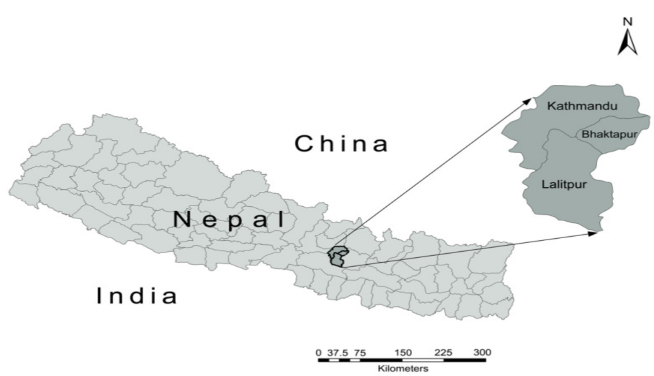

Figure- 1
Showing the valley and the surrounding area of Kathmandu

Table-1
Observed conditions of the monitored days

Conditions	30th April	1st May	2nd May	6th May
Working/Strike	Working Day	Strike day	Strike day	Strike day
Vehicles/Industries	Completely operated	Not in operation	Not in operation	Not in operation
School/Colleges/Offices	In complete operation	Not in operation	Not in operation	Not in operation
Domestic activity/Cooking heating	In complete operation	Same as working day	Same as working day	Same as working day
Rain	No rain	No rain	52.2mm rain	No rain
BC source	All the possible urban activities	Only domestic activities and some residual mass of previous day(working day)	Only domestic activities possibility of a small fraction of residual mass of working day	Only domestic activities no residual mass because of rain

The study observation on 30th April working day shows that the mean value of BC was 10.9 µg m^{-3} with 95% confidence limit. The lower boundary for the mean was 8.1 µg m^{-3} and the upper boundary was 13.6 µg m^{-3}. The mean of BC corresponds to the contribution from vehicles, industries and domestic activities. On the first day of strike, 1st May the mean value observed was 6.3 µg m^{-3} with 95% confidence in the boundary between 4.8 µg $m^{-3}$and 7.7 µg m^{-3}. The BC concentration observed on that very day was the resultant of only domestic activities. However, some amount may have been contributed by residual mass of previous working day. On the second day of the strike, the mean value of BC observed was 2.7 µg m^{-3}. It was comparatively less than the first day value. This was due to rain fall of 52.2mm recorded on that particular day as well as the less amount of residual mass BC obtained from the working day. On the Last day of strike, 6th May 2010, the mean value of BC recorded were 5.0 µg m^{-3} within a boundary between 3.6 µg m^{-3} and 6.5 µg m^{-3} at 95% confidence. The trend of BC on these days is represented in figure 2.

From figure 2, it is clear that the diurnal variation of BC is pronounced on working day with two high peaks at about 8-9 O'clock in the morning and around 18-19 O'clock in the evening. During the strike days, the diurnal trend of BC is nearly same to that of working day but the peak hour values are two fold less than working day. This observation indicates that vehicular and industrial emission of BC aerosol in the valley gets maximum almost at the same time

There is a strong effect of wind with dispersion of aerosols in Kathmandu valley. The comparison of wind speed and BC aerosol clearly shows inverse relation between them. Figure 3 and figure 4 clearly represent that BC concentration is low when there is high wind speed.

Paired sample test has been carried out at 95% confidence level by comparing same time hourly data to know the actual pair difference in BC concentrations between i. working day and strike day, ii. strike day and strike day with rain and iii. working day and strike day assuming no any residual mass of earlier days respectively.

It has been observed that the mean difference of BC between working day and 1st day of strike is about 4.6 µg m^{-3} which is the contribution of BC by vehicles and industries only. The paired t value was 5.01 and p-value was 0.00 for the pair of 30th April and 1st May. It indicates that there was a significant effect of vehicles and industries for the contribution of BC in the atmosphere. Furthermore, at 95% confidence limit, the contribution of BC by vehicles and industries varies from 2.65 µg m^{-3} to 6.54 µg m^{-3}.

In the second pair analysis 1st day of strike having some residual mass of previous working day is compared with 2nd day of strike where it was influenced by different meteorological condition in comparison to than the fist day of strike. It has been observed that the mean difference of BC between strike day without rain and strike day with rain is about 3.6 µg m^{-3}. This is the mass of BC washed out by rain because 52.2mm of rain was recorded on that particular day. The paired t and p- values were 6.3 and 0.00 respectively for the pair of 1st and 2nd May. This indicates that there was a significant effect of rain in the removal of BC aerosol from the atmosphere. At 95% confidence limit, it can be stated that the removal of BC by rain was from 2.4 µg m^{-3} to 4.8 µg m^{-3}.

Similarly, in the third pair test a regular working day and last day of strike (the residual BC aerosol of previous days are assumed to be zero due to rain) were selected. The result infers that the mean difference of BC between these days was 5.8 µg m^{-3}. This is the contribution of BC by vehicles and industries. The paired t test and p- value for the last paired test was 5.4 and 0.00 respectively. Therefore there was a significant contribution of BC aerosol from vehicles and industries in the atmosphere. Moreover, at 95% confidence limit, the contribution of BC from vehicles and industries was from 3.5 µg m^{-3} to 8.1 µg m^{-3}. The detail of paired sample test is shown in table 2.

Table-2
Representation of Paired Sample Test

Paired Samples Test									
Pair	**Month and Year**	**Paired Differences Mean**	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**p value**
					Lower	**Upper**			
Pair 1	April30 - May1	4.60	3779.5	916.7	2.65	6.54	5.0184	16	0.00
Pair 2	May1 - May2	3.61	2344.3	568.6	2.40	4.81	6.3532	16	0.00
Pair 3	April30 - May6	5.84	4446.8	1078.5	3.55	8.12	5.4172	16	0.00

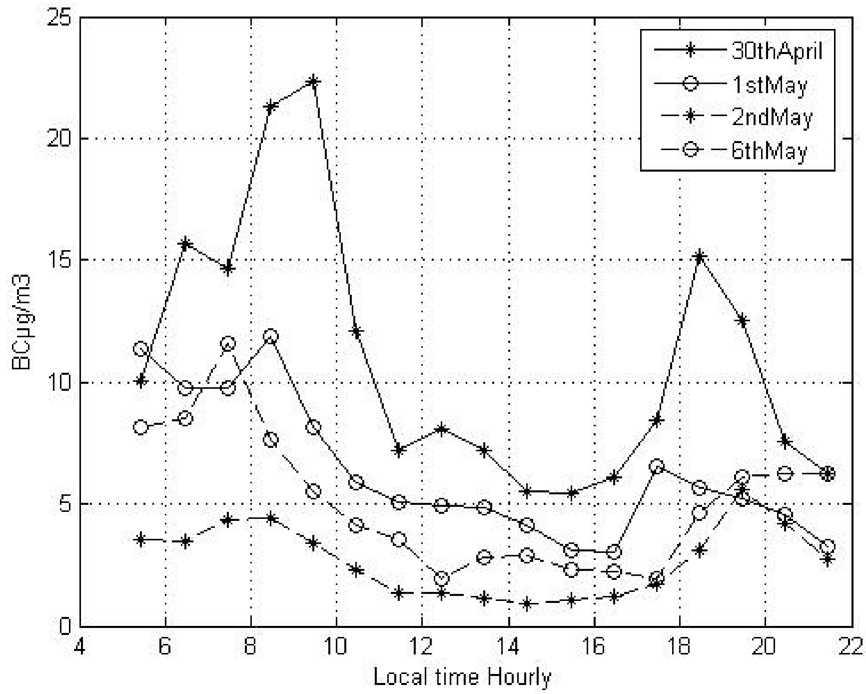

Figure- 2
Trend of BC aerosol on different days in Kathmandu

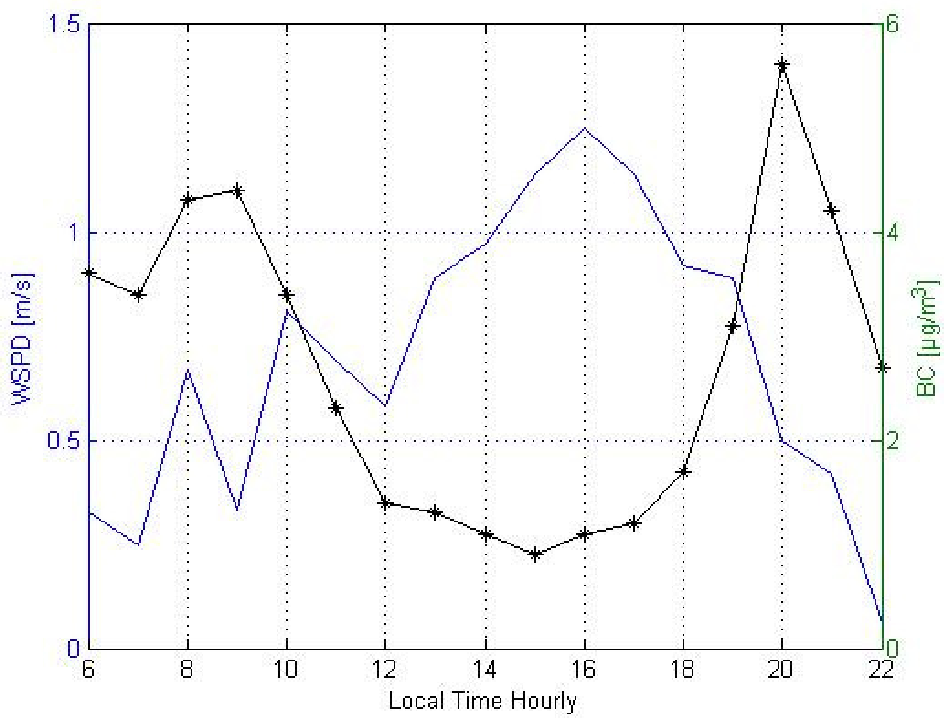

Figure- 3
Diurnal BC aerosol and Wind speed pattern on 2nd May 2010(BC –black line with asterisks; wind speed –blue solid line)

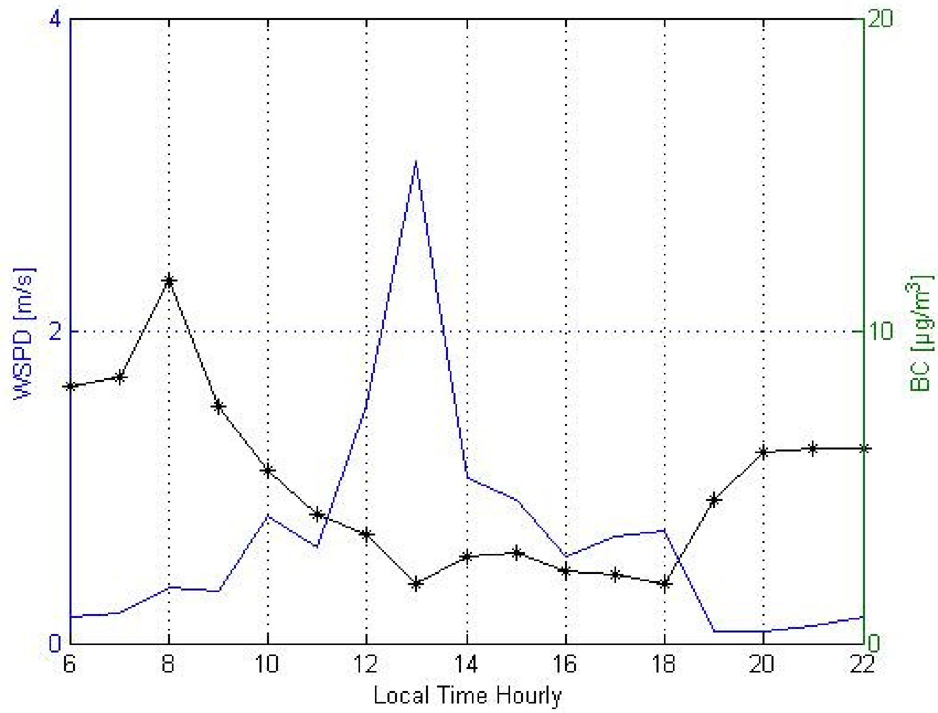

Figure-4
Diurnal BC aerosol and Wind speed pattern on 6th May 2010(BC- black line with asterisks; wind speed- blue solid line)

Conclusion

The diurnal variations of BC aerosol in working and strike days are nearly similar but the high peak values in working days are about two folds higher than the strike days. It indicates pronounced anthropogenic emission of BC aerosol on regular days. The average BC aerosol recorded on 30th April. 1st May, 2nd May and 6th May 2010 (within 6-22hrs) are 10.9, 6.3, 2.7 and 5.0 µg m^{-3}respectively indicating an average of 10.9 µg m^{-3} BC aerosol for working day. The result shows that vehicular and industrial emission contributes about 50% to the total BC aerosol produced in the valley. A distinct inverse relationship between BC aerosol and wind speed was observed. Therefore, in addition to wind, rain also plays a significant role in the reduction of BC aerosol from the atmosphere. The amount of BC aerosol observed during the strike days may not be the actual back ground BC by domestic activity of the valley because domestic activities of additional people from outside the valley (commuters) also included in the observation. Moreover, domestic activity contributes less amount of BC aerosol in the valley than vehicles and industries.

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