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Monitoring of black carbon concentration at an inland rural area including fixed sources in Korea

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HIGHLIGHTS

- BC concentration monitoring at a rural area including fixed sources.
- Diurnal variation of BC concentration on weekdays and weekends.
- BC concentration measured at night was higher than that measured during the day.
- Characteristics of a rural area with an urban-typed fixed source and agricultural burning.

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ABSTRACT

We monitored black carbon (BC) concentration for 6 months to understand the characteristics of atmospheric aerosols of an inland rural area in Korea. A multi-angle absorption photometer was used to continuously monitor the BC concentration, which was compared with elemental carbon (EC) concentration measured by an OC/EC Analyzer. For the atmospheric aerosols less than 10 μm, size distributions were measured using both an optical particle counter and a scanning mobility particle sizer. The diurnal variations for BC concentration show that the average BC concentration was 1.43 $\mu g\ m^{-3}$ and exhibited peaks in the morning rush hours. However, the BC concentration measured at night from 20:00 to 08:00 was higher than that measured during the day. The reason why the BC concentration at night was higher would be partly due to the regional characteristics influenced by the combination of local fixed sources and traffic condition. It is suggested that the traffic and transporting of pollutants from the west influenced the increase in the BC concentration at inland rural area including fixed sources.

1. Introduction

Black carbon (BC) has been studied for many years in the atmospheric sciences community since it was known to act as a positive radiative forcing (Andrea, 2000). Not only the environmental implication but also the effects of particles on illness (Nel, 2005) creates necessity for the research of the BC, which is prevalent in the ambient aerosol due to the soot generated in sources such as diesel engines. Korea has been suffering from Yellow Dust coming from the west during the spring season (Kwon et al., 2013). Recently, Korea has been suffering from PM2.5 transported from the west even during the winter season, so that the air pollution is ubiquitous at any time. In this situation, measurement of BC in a rural area is relevant in order to estimate the generation, transporting and fate of BC. In order to understand how the rural area is polluted, it is important to know the level of BC of pristine areas. The BC measured at Southern Himalayas was not higher than 0.6 $\mu g\ m^{-3}$ during the pre-monsoon season and less than 0.1 $\mu g\ m^{-3}$ during the monsoon season (Marinoni et al., 2010). BC measured at Harwell known as a rural background in the UK was reported to be around 0.5 $\mu g\ m^{-3}$ (Harrison et al., 2013). However, it is difficult to find BC data measured at inland rural area in Korea. Stimulated by this, we used a Multiangle Absorption Photometer (MAAP) to evaluate the BC concentration of a rural area, more specifically Byeongcheon area, which is located nearly at the center of South Korea. In this study, the ambient BC concentration of the inland rural area has been monitored for approximately 6 months. In addition, the BC concentrations were compared to the ambient EC concentrations. As far as the authors know, this study is the first attempt to measure BC concentrations and compare to the EC concentrations measured at a rural area in Korea.

2. Method

The BC concentration was measured by a MAAP (Multiangle Absorption Photometer, Thermo Scientific, 5012). MAAP is one of

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the filter-based instruments, which measures the BC concentration using the difference of transmitted signals from a clean filter (reference) and a particle-laden filter (probe). The filter-based technique intrinsically suffers from the issues regarding light scattering from the filter itself. Thus, most of the filter-based instruments should make a data correction for the scattering effect. However, MAAP does not require a data correction for scattering effects which is required for the analysis of PSAP or Aethalometer data (Petzold and Schönlinner, 2004). Data was recorded every 1 min and ordered from 00:00 to 23:59 each day. Then, we separated the weekday (from Monday to Friday) data and weekend (Saturday and Sunday) data for each month. After separation, the data ordered from 00:00 to 23:59 was arithmetically averaged every min for 16–20 d for weekdays and 8–10 d for weekends depending on the number of weeks included in the month, respectively. Finally, the monthly data was smoothed for better display using a "box averaging algorithm" supported by IGOR Pro (WaveMetrics). The size of the box was set to 60, meaning that the averaged data was equivalent to the data measured every 60 min. For maintaining the data quality assurance, we did not include the data collected on Korean national holidays into the weekday data.

The elemental carbon (EC) concentration was measured by a commercially available EC analyzer (Sunset Laboratory, Lab OC/EC Aerosol Analyzer) following a NIOSH 5040 protocol. The samples were collected for 8 h to compare BC and EC. To ascertain the effect of sampling time, the samples were collected for 12 h and compared with the samples collected for 8 h.

The size distribution of atmospheric aerosols smaller than 0.1 μm was determined by the combination system of a DMA (Differential Mobility Analyzer, homemade) and a CPC (Condensation Particle Counter, TSI, 3775). The size distribution of the aerosols between 0.3 μm and 10 μm was measured by the OPC (Optical Particle Counter, Labco, MDL-125). The size distributions were scanned 5 times at typical time both in the afternoon and at night. Averaged values were displayed in Section 3.

Windrose diagrams were obtained from the data openly accessed website of KMA (Korea Meteorology Administration). The diurnal pattern of monthly average wind speeds were also obtained from the KMA website which announces meteorological data on hourly basis.

Traffic densities were measured from the numbers of vehicles which passed through the main gate of the campus. Therefore, the traffic density is an important indicator of moving sources that directly affect the BC concentration. We separated the traffic data into weekdays and weekends. Then, we accumulated the numbers of vehicles every hour and averaged to display the traffic density per hour. BC concentrations were monitored at the Korea University of Technology and Education (KOREATECH) located in Byeongcheon, Cheonan. Fig. 1 shows the sky view of the monitoring site. As can be seen in Fig. 1, the site is surrounded by rice fields, mountains and farming fields. At the left side of the monitoring site, there is a factory where automotive brake pads are mass produced. A stream flows near the southern part of campus and there is a 2-lane road near the northern part of campus. Thus, the monitoring site represents the combination of rural characteristics and urban characteristics.

3. Results and discussion

3.1. Diurnal variation of black carbon

We measured the BC concentrations for 6 months from April to September, 2012. Diurnal patterns of the BC concentration of both weekdays and weekends are shown in Fig. 2. The variation of BC concentrations for hourly average lies between 1.12 μg m^{-3} and

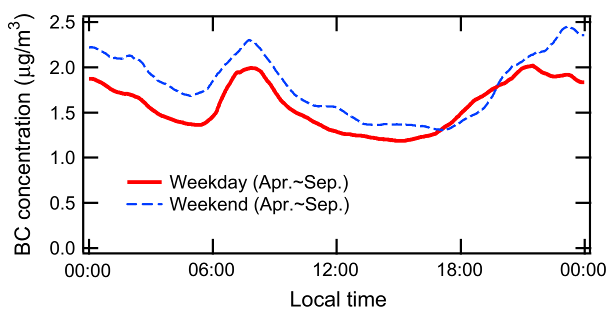

Fig. 2. Diurnal patterns of BC concentration calculated from hourly means for 6 months (April–September, 2012).

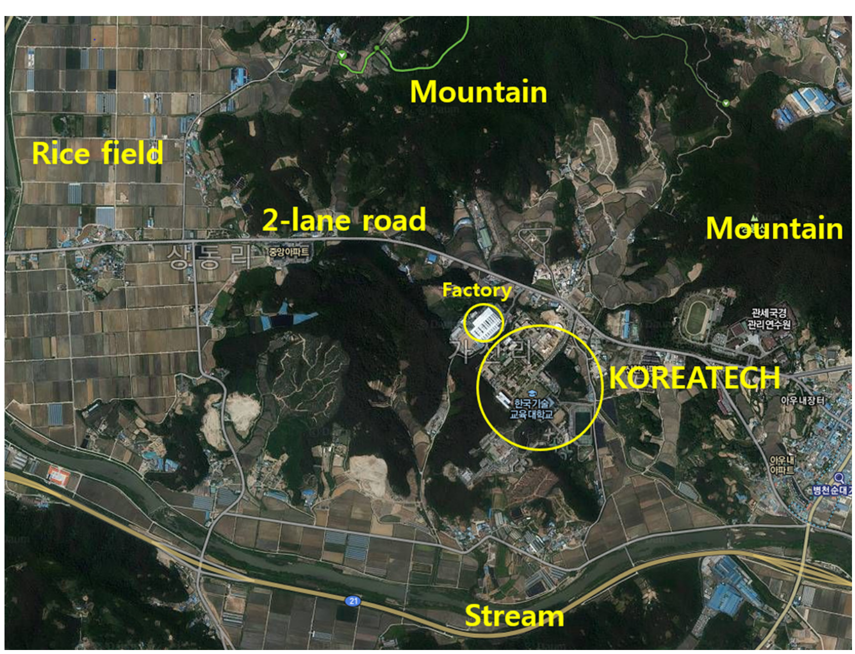

Fig. 1. Geographical condition near the monitoring site.

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