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Evaluation of SO_2 pollution levels between four different types of air quality monitoring stations

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Abstract

In order to assess the spatiotemporal distribution patterns of sulfur dioxide (SO_2), its concentration data sets measured from four different types of air quality monitoring (AQM) stations in Korea were analyzed for the period 1998–2003. The target AQM stations were selected to represent both highly urbanized locations in seven major cities (i.e., urban traffic (A) and urban background (B)) and relatively remote locations in nine major provinces (suburban background (C) and rural background (D)) in Korea. As such, the mean concentrations of SO_2 were clearly distinguished both between the A- and B-type stations and between the C- and D-type stations. The mean concentration levels of SO_2 in the A-type stations were approximately 18% higher than those of the B-type stations; it was found that the concentration of the former ranged from 7.94 ppb (Seoul) to 14.2 ppb (Ulsan), and the latter from 5.43 ppb (Gwangju) to 12.8 ppb (Ulsan). Likewise, there were many distinctions between the C-and D-type stations. The mean concentrations of the C-type stations varied from 3.88 ppb (Jeju) to 8.50 ppb (Jeonnam), while those of the D-type stations from 1.47 ppb (Jeju) to 4.76 ppb (Gangwon). Comparison of seasonal patterns indicated that the SO_2 values tend to peak consistently during the winter (or spring) months, regardless of station types. When the SO_2 data were compared on a long-term basis throughout the whole study period, the patterns generally exhibited a gradual and systematic decrease for most study sites. However, the patterns for such annual changes tended to differ between major urban (A and B) and suburban station pairs (C and D). It was found that such decreasing trends were more clear in the former pair than in the latter. The overall results of our analysis from diverse AQM station types indicate that the distribution characteristics of SO_2 may have been controlled rather sensitively through time by social and environmental changes which forced the reduction of SO_2 emissions.

Keywords: Sulfur dioxide; Ambient; Roadside; Background; Korea

1. Introduction

The aftermath of rapid industrialization is often found in enhanced emissions of undesirable and harmful pollutants such as sulfur dioxide (SO_2). The potential role of sulfur dioxide is well known, for it can contribute to the degradation of air quality in both spatial and temporal scales (e.g., Tegen et al., 1997). SO_2 is emitted into the atmosphere mainly from anthropogenic sources such as the combustion of sulfur-containing fossil fuels (e.g., coal, oil, and natural gas: Reddy and Venkataraman (2002a, b)). In the US, over 65% of SO_2 released into the air, or more than 13 million tons per year, comes from

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electric utilities, especially those which burn coal (US EPA, 2000). In the case of Asia, emissions of SO_2 are predicted to grow continuously according to the Regional Air Pollution INformation and Simulation—Asia (RAINS—ASIA) model; the trend is estimated to vary from 34 Tg ($= 10^{12}$ g) in 1990 to 110 Tg by the year 2020 (Foell et al., 1995).

It is known that large quantities of pollutants including SO_2 are emitted from coal burning and other industrial activities. Many studies confirm that the amount of sulfur released by the emissions of coal combustion process is higher than that of other fossil fuels (e.g., Isobe et al., 2005). The acid deposition resulting from such source processes is currently considered as a potential damage; transformation of such chemicals into more stable end products, sulfuric acid, while posing a threat to vegetation and aquatic life in ecologically sensitive areas (Park et al., 2000), can also cause human-organ damages (Pandey et al., 2005).

Rapid economic growth made in Korea has brought out an increasing demand of fossil fuels, leading to the substantial release of major airborne pollutants. Acquiring a better knowledge of their distribution and behavior is hence a prerequisite to develop pollutant-control tactics. In our previous work, the SO_2 data obtained from two air quality monitoring (AQM) station types (i.e., urban and suburban background areas) have been investigated to evaluate the SO_2 pollution patterns of each station type (Nguyen and Kim, 2005). In this study, we extended the scope of our study by examining the SO_2 data sets acquired from four different types of AQM stations; these four types are selected to represent: (1) urban traffic, (2) urban backgrounds, (3) suburban backgrounds, and (4) rural backgrounds. Through an application of diverse statistical analysis, we attempted to describe the pollution patterns of SO_2 that can represent such diverse environmental settings in relation with the related source processes. In addition, the temporal distribution patterns of SO_2 were also evaluated after grouping the data sets into varying time scales such as monthly, seasonal, and annual terms.

2. Materials and methods

In this study, to investigate the fundamental factors regulating the environmental behavior of SO_2, its concentration data monitored continuously from four different types of AQM stations in Korea were analyzed for the period 1998–2003 (Table 1). For readers' reference, South Korea is divided into 16 administrative areas, 9 provinces and 7 major cities, with about half of approximately 48 million population living in each. A geographical map of the major cities and provinces is shown in Fig. 1. To allow a simple evaluation of SO_2 distribution patterns, its data measured from all those 16 administrative areas (the sum of up to 220 monitoring stations) were analyzed in this study. For the purpose of the present study, all stations were classified into the following four categories: urban traffic (A), urban background (B), suburban background (C), and rural background (D) types.

Detailed information on these AQM stations is provided in our companion article on NO_2 pollution in Korea (Nguyen and Kim, 2006). It should be noted that the SO_2 data sets for both A/ B and C/D pairs were selected from identical city and province areas, respectively. However, there are differences in the selection scheme for those two pairs. For instance, the B-type stations are distributed fairly abundantly throughout the whole city, while most of the A-type stations are located rather selectively near roadside areas. Likewise, the C- and D-type stations in provincial areas were also selected to examine the SO_2 distributions for both ambient and background concentration levels. The SO_2 concentration data obtained from all AQM station types dispersed all across major locations in Korea can hence be used to explore the spatial and temporal distribution patterns of SO_2 in relation with varying environmental and/or source conditions.

The raw data sets of SO_2 from all stations were measured using the pulse UV fluorescene method. All of those data are then quality-controlled in the data management network system operated by the Korea Ministry of Environment (KMOE). The number of these AQM stations, in fact, changed gradually through the study years from as little as 143 (1998) to as many as 220 stations (2003). It should be emphasized more specifically that the abundance of the AQM stations differs greatly between A/D and B/C station pairs. The sum of all A station types increased from 10 (1998) to 17 stations (2003), while that of D stations from 5 (1998) and to 14 stations (2003). In the meantime, the number of B stations increased from 64 (1998) to 91 stations (2003), and that of the C station type from 64 (1998) to 98 stations (2003).

A detailed analysis of SO_2 data was made after converting initial data sets recorded at hourly intervals into monthly scales. Hence, monthly