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The pollution status of sulfur dioxide in major urban areas of Korea between 1989 and 2010

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ABSTRACT

The pollution status of sulfur dioxide was analyzed using the datasets collected from seven major cities in Korea for the period of 1989–2010. Although there were moderate differences in SO_2 levels between the cities, the temporal trends were seen to be rather distinctive between seasons or across the years. The SO_2 levels consistently exhibited relative dominance during winter due to the combined effects of domestic heating and meteorological conditions. In contrast, the annual datasets underwent an abrupt decrease until the late 90s. As such, if the data are divided into two periods I (1989–1999) and II (2000–2010), the mean values were reduced considerably from a few tens of ppb (period I) to a few ppb levels (period II). This notable change is suspected to reflect the effect of gradual shift in fuel consumption patterns (e.g., from conventional fuels to cleaner renewal sources of energy). The results of the principal component analysis (PCA) indicated that emissions of SO_2 are affected by the incomplete combustion of fossil fuels. According to the health risk assessment, the SO_2 exposure to infants and adults should have decreased significantly from period I to period II (e.g., by 5–7 times).

1. Introduction

Sulfur dioxide (SO_2) in the ambient air is a pollutant of environmental significance. Like most pollutants, SO_2 has both natural and anthropogenic sources. Natural sources include volcanic eruptions, sea-salt emissions, and oxidation of other sulfur gases, while anthropogenic sources include burning coal, biomass combustion, and industrial combustion (Kawamoto et al., 2004; Speidel et al., 2007; Sun et al., 2013). Emissions of SO_2 from the latter occur predominantly as fossil fuel combustion at power plants (73%) and other industrial facilities (20%).

Sulfur dioxide is known to exert its influence on the earth's albedo and the earth's radiation budget (Bates et al., 1992). Through diffusion/dilution and chemical transformation into sulfate aerosols, SO_2 can contribute to the alteration of global and regional climate conditions and atmospheric chemistry (Kiehl and Briegleb, 1993; Mitchell et al., 1995; Ravishankara, 1997). An increase of sulfate particles can intensify the extent of solar radiation reflected back to space (Kaufman et al., 2002). As sulfate particles in the atmosphere can act as cloud condensation nuclei, scattering albedo can also be intensified by their increase (Manktelow et al., 2009).

SO_2 is a respiratory irritant and broncho-constrictor with the potential to cause cardiovascular abnormalities (e.g. decrease in heart rate variability) (Ott, 1985; Tunnicliffe et al., 2001). The short-term association between SO_2 and increased risk of cardio-respiratory mortality was assessed by multi-city analyses conducted in Europe (Katsouyanni et al., 1997; Sunyer et al., 2003) and Canada (Burnett et al., 2000). Because of strong toxic effects, regulation guidelines of sulfur dioxide have been established by numerous organizations to curb its pollution. Such guidelines are defined as the thresholds of concentrations (or dose of

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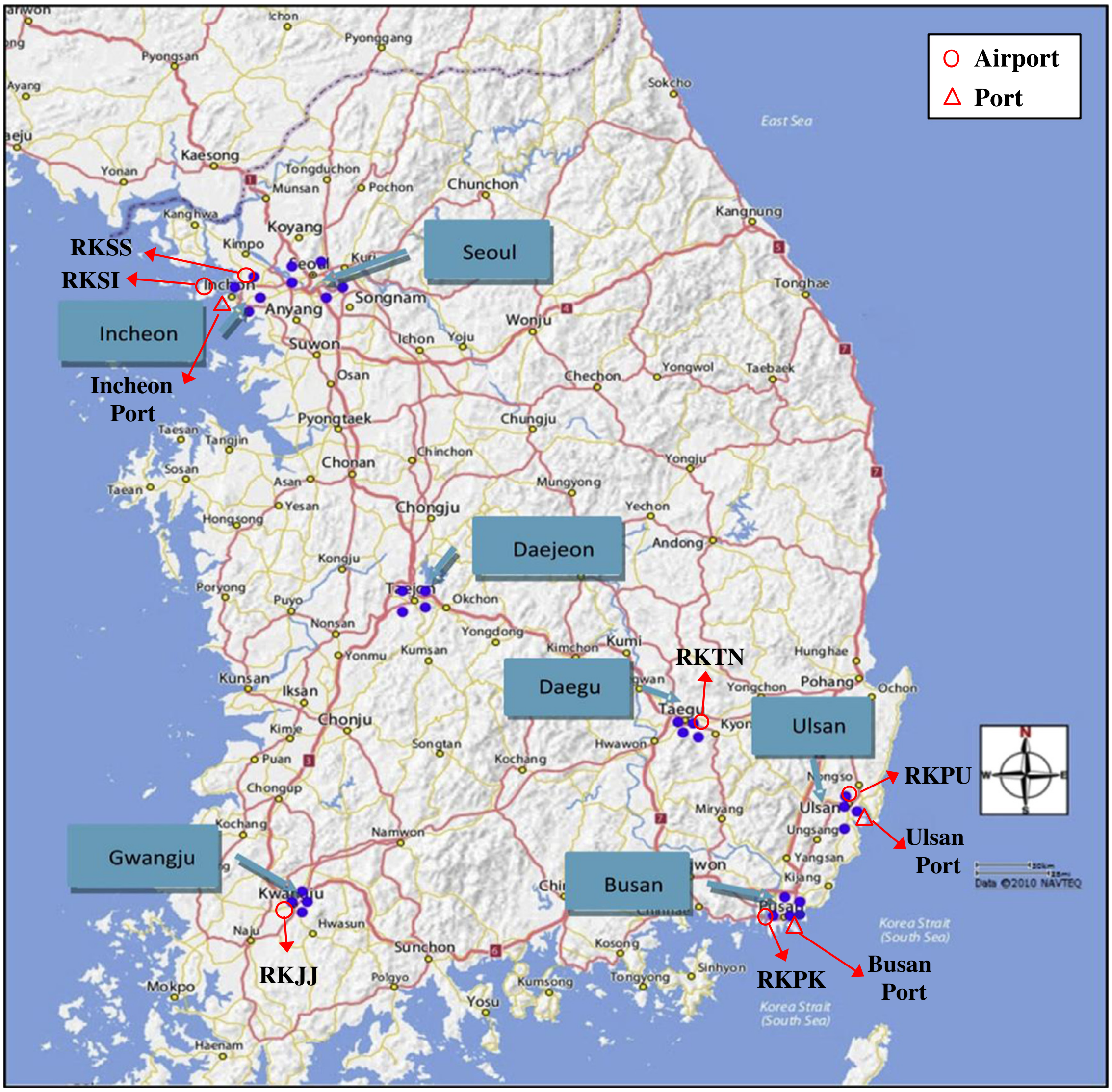

Fig. 1. Map showing the seven major Korean cities where SO_2 concentration levels were monitored.

pollutants) above which adverse effects can occur on plants or animal receptors. For instance, the guideline values for sulfur dioxide are set at 30 (annual average) and 100 μg/m^3 (24-hour average) (WHO, 2000).

The Korean Ministry of Environment (KMOE) has built and operated a number of monitoring networks since 1970 to assess the nationwide pollution status of criteria airborne pollutants (Nguyen and Kim, 2006). The analysis of the accumulated datasets from such a monitoring network allows us to have a better understanding of air quality change, source processes of airborne pollution, and the trans-boundary transfer of the pollutants. In this study, we focused on statistical analyses of SO_2 and relevant data collected from major cities in Korea over a two decadal period (1989–2010). Thus, the results of our analysis will help us implement a control strategy for SO_2 and other important pollutants in urban areas.

In the course of this study, we evaluated the spatial and temporal distributions of SO_2 in seven major cities. The analysis of SO_2 data was initially made to describe the factors controlling its behavior in relation to relevant parameters measured concurrently. Moreover, the potential sources of SO_2 were also assessed along with its exposure risk in target cities.

2. Materials and methods

2.1. Site characteristics of study area

To investigate the fundamental factors regulating the environmental behavior of SO_2, its concentration data were monitored continuously from seven major cities for the period of 1989–2010: Seoul (SL), Busan (BS), Daegu (DG), Incheon (IC), Daejeon (DJ), Gwanju (GJ), and Ulsan (UL). In