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Non-methane hydrocarbons in the atmosphere of a Metropolitan City and a background site in South Korea: Sources and health risk potentials

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ABSTRACT

Hourly concentrations of non-methane hydrocarbons (NMHCs) were collected at a background monitoring site between April of 2004 and March of 2005 and at suburban and urban sites between March and December of 2006. The sources of NMHCs were identified and associated health risks through the inhalation pathway were evaluated. Positive matrix factorization (PMF) results showed that solvent sources account for the largest portion of the total NMHCs at suburban and urban areas in South Korea, and the risk assessment combined with the PMF results indicated that risk-weighted contributions of solvent sources were enhanced compared to the absolute contribution (from 52% to 68% in suburban areas and from 47% to 80% in urban areas). Carcinogenic risk due to benzene exposure exceeded the one-in-a-million (i.e., 10^{-6}) cancer benchmark at all three study sites, and the fractions of the population with greater than the benchmark level were 87%, 99%, and 98% in the background, suburban, and urban sites, respectively. Common benzene sources of three study sites were predicted to be Shandong in China based on the 120 h potential source contribution function (PSCF) analysis.

To prioritize management options for NMHC sources, risk term may give more meaningful information than amount term. This study suggests that controlling solvent sources would be better option for the mitigation of non-carcinogenic health risk from airborne NMHCs. In addition, the identification of benzene sources using PSCF can be used to assist policymakers in developing regional measures to reduce benzene.

1. Introduction

Many volatile organic compounds (VOCs) in urban air, such as benzene, toluene, ethylbenzene, and xylene are known to cause adverse health effects. Moreover, they are precursors of ground level ozone, which is also associated with health risks. The Republic of Korea announces the emission levels of non-methane volatile organic compounds (NMVOCs) every year, and the results show that the emission of anthropogenic NMVOCs has continuously increased, resulting in air pollution problems (Korean MoE and NIER, 2009).

In Korea, 37 species of VOCs are designated for regulation under the Clean Air Conservation Act. Entities that handle these VOCs are required to submit emission data as part of a Toxics Release Inventory (TRI) under the Toxic Chemicals Control Act. Due to growing concern among the public, carcinogenic VOCs such as benzene are subject to regulatory control. New regulations applying to annual ambient benzene (<5 μg m^{-3}) came into effect on January 1, 2010 under the Framework Act on Environmental Policy.

In general, exposure to VOC concentrations is highest under the category of personal exposure, with indoor and outdoor levels next highest. However, previous studies showed that outside air can infiltrate indoors, contributing to indoor air pollution (Lewis, 1991; Payne-Sturges et al., 2004). Loh et al. (2007) also noted that outdoor sources of organic hazardous air pollutants (HAPs) contributed to 50% of the total carcinogenic risk when infiltration was considered. Measured indoor and outdoor concentrations for VOCs, including carbon tetrachloride, ethylbenzene, and xylene, are positively correlated (Payne-Sturges et al., 2004). For example outdoor sources of benzene contribute to nearly 40% of total exposure levels (Wallace, 1996). Therefore, managing outdoor VOC concentrations would reduce indoor VOC levels and exposure rates as well. In particular, the identification and apportionment of outdoor VOC sources are crucial in reducing VOCs and associated ozone concentrations and hence health risks.

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Receptor models are used for identifying and quantifying sources of air pollutants based on concentration measurements at the receptor site. There are several different types of receptor model analyses. These include the chemical mass balance (CMB) and multivariate receptor models, with the most commonly being principal components analysis (PCA), UNMIX, and positive matrix factorization (PMF). CMB and PMF have been applied successfully to determine the contribution of non-methane hydrocarbon (NMHC) sources to ambient NMHC mixing ratios and ozone formation (Choi et al., 2010a,b; Na and Kim, 2007; Song et al., 2007; Xie and Berkowitz, 2006). Possible NMHC source areas have been explored using the potential source contribution function (PSCF) model with 6 h and 48 h back trajectories (Choi et al., 2010a,b; Xie and Berkowitz., 2007). Several studies using the CMB or PMF model identified the solvent source and vehicle exhaust in Busan and Seoul, South Korea, respectively, and petrochemical and gasoline sources in Beijing, China as major contributors to ozone formation (Choi et al., 2010a; Na and Kim, 2007; Song et al., 2007). In recent years, PMF has been used to apportion cancer risk related to air pollution to sources; large industrial sources and smaller point sources were identified as dominant contributors to cancer risk in and around Pittsburgh, PA, USA (Logue et al., 2009).

PMF is a very effective tool capable of analyzing a wide range of environmental data (Paatero and Tapper, 1994). It apportions NMHC sources using only measured data without an emissions inventory (Choi et al., 2010a,b; Kim et al., 2005; Song et al., 2007; Xie and Berkowitz, 2006). PMF requires pollutant concentrations and associated uncertainties as input data, and the solution provides the number of sources, the chemical composition profiles of the sources, and the source contributions.

In the present study, we determined the sources of non-methane hydrocarbon (NMHC) employing PMF at three study sites (background, suburban, and urban sites in South Korea) and compared the sources to those of the South Korean national inventory. Potential health risks from exposure to ambient NMHCs including benzene, toluene, ethylbenzene, and xylene were estimated by deterministic or probabilistic risk assessment. In addition, the major contributors to NMHC-related health risks were identified via the PMF results and common source regions of benzene were examined according to PSCF plots. The results of this study can assist in the prioritization of anthropogenic NMHC sources and the development of proper management options for the NMHC sources based on adverse health effects.

2. Methods

2.1. Sampling sites

Detailed descriptions of three sampling sites in South Korea can be found elsewhere (Choi et al., 2010a,b). NMHC samples at Sukmo, the background monitoring site, were collected between April of 2004 and March of 2005. The data on NMHCs at Gijang and Jin sites were collected between March and December of 2006. Sukmo is located in the northwestern tip of South Korea and has limited anthropogenic sources of contamination and low population density. Gijang is a newly developed suburban site in Busan, Korea. Gijang is approximately 20–28 km from large industrial and petrochemical complexes in Ulsan. Jin is an urban site situated in the center of Busan that is characterized by heavy traffic and proximity to industrial complexes in the western and southwestern regions. Fig. 1 illustrates the locations of the three monitoring sites.

2.2. NMHC samples

Sampling and measurements of 55 NMHCs were conducted in accordance with the Photochemical Assessment Monitoring Stations (PAMS) Technical Assistance Document (TAD) (USEPA, 1998). Air samples were analyzed every hour using a combined gas chromatograph with a flame ionization detector (PerkinElmer

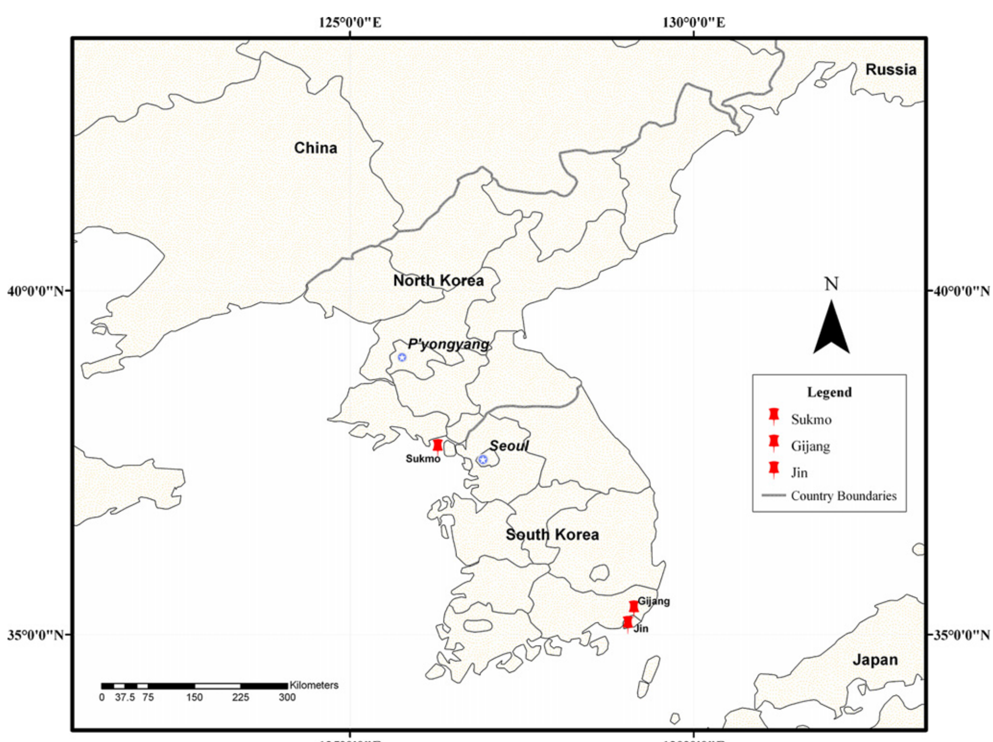

Fig. 1. Locations of the study sites.