Influences of Domestic and Foreign Anthropogenic Emissions on Atmospheric Fine Particulate Matter ($PM_{2.5}$) in Greater Tokyo

Background

The Ministry of the Environment of Japan has recognized health impacts of suspended fine particles below 2.5 μm in diameter in the ambient air (hereinafter, $PM_{2.5}$) in a report issued in April 2008. In Japan, about one-third of $PM_{2.5}$ in mass basis is occupied by sulfate and nitrate respectively formed by SO_X and NO_X emitted from automobile and large-point sources like factories and power plants. $PM_{2.5}$ is a trans-boundary air pollutant due to long retention time in the atmosphere. In order to consider mitigation strategies of $PM_{2.5}$ pollution, it is important to know how much $PM_{2.5}$ pollution in Japan is mitigated by reducing SO_X and NO_X emissions from domestic sources and what is the sensitivity of growing foreign emissions on $PM_{2.5}$ in Japan. To contribute to those issues, CRIEPI has developed an air quality model for East Asia[1)] to analyze atmospheric concentrations of $PM_{2.5}$ in Japan[2)].

Objectives

The purpose of this study is to assess influences of domestic and foreign emissions on $PM_{2.5}$ in Greater Tokyo by analyzing quantitative relationships between anthropogenic emissions and ambient concentrations of sulfate and nitrate in $PM_{2.5}$ by simulating $PM_{2.5}$ concentrations by the air quality model for East Asia.

Principal Results

Changes in $PM_{2.5}$ concentrations were estimated by changing SO_X and NO_X emissions by +20 % (which is equivalent to the growth rate in three years) in each of 12 source regions (Figs. 1 and 2). Below are the findings on sulfate and nitrate in $PM_{2.5}$ in Greater Tokyo.

(1) Concentrations of sulfate and nitrate varied most for the change in local emissions in Greater Tokyo and were relatively sensitive to emissions from domestic sources and sources in North Central China and Korean Peninsula. Changes in concentrations of nitrate to nearby emissions were larger than those of sulfate, because of faster formation (Fig. 3).

(2) For sulfate, concentrations were largely altered by local emissions in summertime when the monthly concentrations were the highest in the simulated year. The sensitivity of concentrations to foreign emissions was larger than domestic emissions in springtime. For nitrate to increases in local emissions, the increasing ratio of concentrations was larger than that of emissions in summertime (excess response) due to activated chemical formation and particulation of nitric acid, the precursor to nitrate. On the other hand in wintertime, the concentration decreased with increasing local emissions due to consumption of ozone, which was needed for the formation of nitric acid, by freshly emitted NO_X (Fig. 4). Those characteristic behaviors were caused by the complexity of nitrate formation and unproportional changes in nitrate concentrations to NO_X emissions (non-linearity).

From the above findings, it is concluded that sulfate and nitrate in $PM_{2.5}$ in Greater Tokyo are much influenced by local emissions. However, the influence of foreign emissions is also not negligible. It is importantly noted that non-linearity making the complexity in nitrate behavior should be taken into account when considering nitrate reduction.

Future Developments

Similar analysis will be carried out for ozone, another most concerned pollutant, in order to contribute to better quality of the atmospheric environment.

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Reference

H. Hayami, 2008, "Sensitivity of secondary particulate matter in Greater Tokyo to foreign and domestic emissions of air pollutants", CRIEPI Report V07020 (in Japanese)

＊1：Numerical models which compute temporal changes in concentrations of various materials in the atmosphere by considering processes like advection/diffusion, chemical reaction and deposition from inputs of meteorological conditions and emissions.

＊2：H. Hayami, 2007, "Sensitivity of secondary particulate matter in Greater Tokyo to foreign and domestic emissions of air pollutants", Journal of Japan Society for Atmospheric Environment, 42, 234-252 (in Japanese)

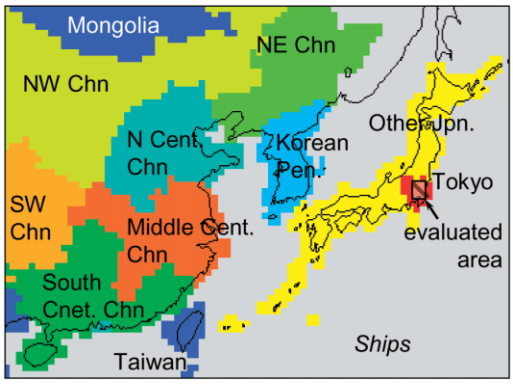


Fig.1 Source regions

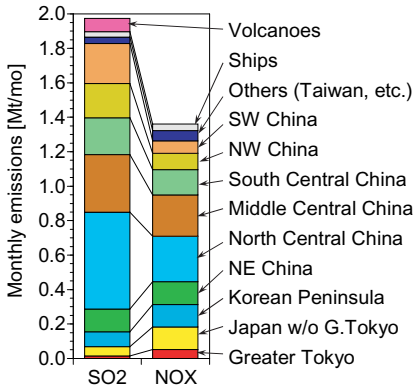
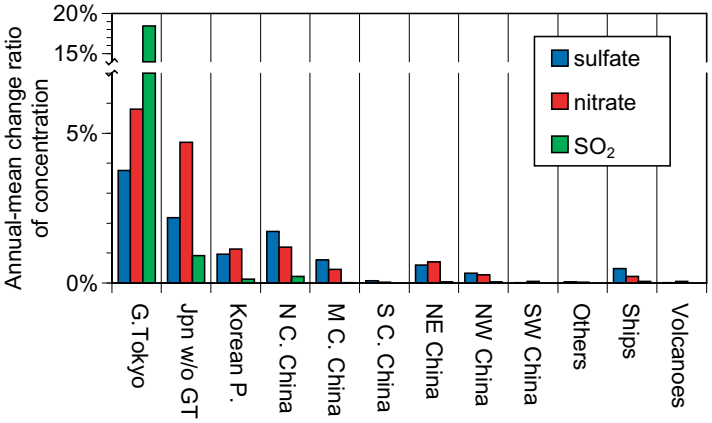
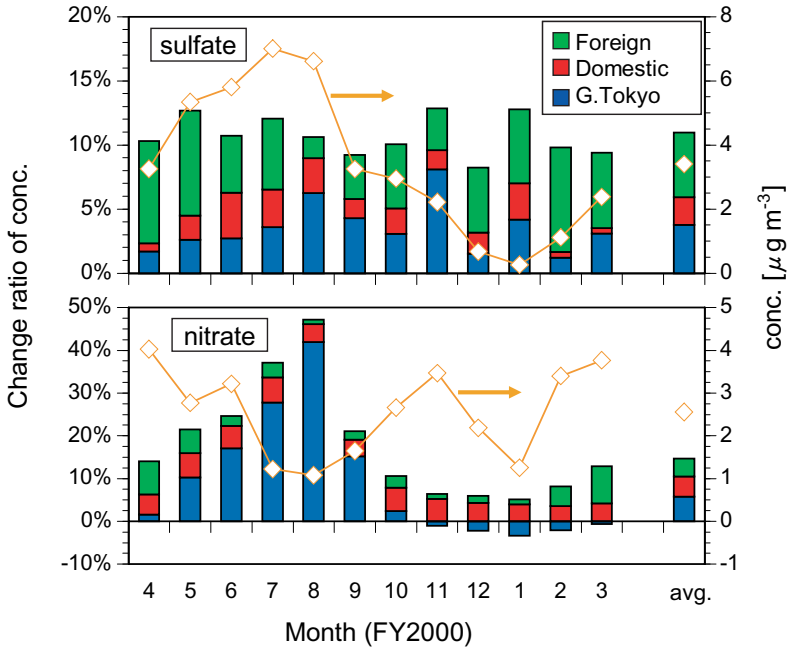


Fig.2 Monthly emissions from each source region



*The SO_2 concentration in Greater Tokyo increases by up to 20% with respect to +20% increases in local emissions, because SO_2 is a primary pollutant. However, sulfate and nitrate increase by only up to 5% with respect to +20% local emissions, because they are secondary pollutants and long-lived in the atmosphere. Over 1% increases of sulfate and nitrate concentrations to +20% emissions in North Central China suggest that influences from distant sources are not negligible.

Fig.3 Change ratio in concentration to +20% emissions of SO_x and NO_x in each source region



*The monthly sulfate concentration in Greater Tokyo is the highest in July and the lowest in January. The change ratio in concentration to +20% emissions varies with season, eg. 8% increase in concentration brought by +20% foreign emissions in April. The nitrate concentration in Greater Tokyo shows extreme responses to local emissions; excess changes (>20%) to +20% local emissions in summertime and negative changes in wintertime.

Fig.4 Change ratio of sulfate and nitrate concentrations along with their mean concentrations