Measurement of NO_2 and aerosol in the atmospheric pollution using differential optical absorption spectroscopy (DOAS) with an obstruction flashlight

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Abstract

The Cheong-gye stream flowing from west to east in the city center of Seoul was functioned during about half a century as a busy highway after it had been covered with concrete in 1950's. However, the problem of safety by the aged deterioration was pointed out, and the conversion to the space of water and green was tried. The restored river was opened by the common people in October, 2005 after about two years of the restoration construction. During the execution of a large-scale city environmental improvement business that doesn't see the example in the world where an old river in the Seoul city is restored and a water and green space creates it, the purpose of this study is twofold. First, we compare the long-path result with the point data simultaneously measured at ground-based monitoring stations. Second, we analyze quantitative evaluation of the effect of Cheong-gye stream restoration on air quality.

We report on the atmospheric pollution monitoring in Tokyo of Japan and Seoul of South Korea during the summer 2007. By means of the differential optical absorption spectroscopy (DOAS), average concentrations of NO_2 particles in the atmospheric pollution have been measured. The air quality standards of NO_2 around Cheong-gye stream was more than 50 ppb during 2001 to June 2005. However, it is worth observing atmospheric pollutant species, since the value of NO_2 around Cheong-gye stream has been low after restored a Cheong-gye stream.

1. Introduction

In recent years, the atmospheric pollution in Japan, as a whole, has been improved as compared with situations couple of decades ago. However, we still have problems in places such as urban roadside areas, where the environmental standards have not been achieved. In this respect, efforts are required for monitoring anthropogenic air pollution, especially the combustion products such as nitrogen oxides and particulate matters.

The main pollution species in urban areas in Japan is the nitrogen dioxide (NO_2) and suspended particulate matter (SPM), usually referred to as PM_{10}. In the monitoring of such species, conventional point sampling at ground stations leads to concentrations for local environments. It is also valuable to obtain additional information of regional concentrations measured over a certain distance, e.g., several hundred meters to several kilometers. Differential optical absorption spectroscopy (DOAS) in the visible and near-UV region is more suitable to monitor horizontally averaged concentrations of pollutants (Edner *et al.*, 1993).

In the conventional long-path DOAS method, a continuously emitting light source is employed, and the source (or occasionally a retroreflector) is placed at a certain distance from the observation site. The use of aviation obstruction lights makes it possible to employ a simple detection system that consists of a telescope and a compact CCD spectrometer. Our group in Center for Environmental Remote Sensing, Chiba University (CEReS) reported

a novel DOAS method that is based on a white flashlight source and a compact CCD spectrometer.(Yoshii *et al.*, 2003). In Japan, it is mandatory for tall constructions (higher than 60m) to operate highly illuminant (more than 2×106cd) white flashlights during the daytime that are detectable in every direction from several kilometers away.

The purpose of this study is twofold. First, we compare the long-path result of DOAS measurement with the point data simultaneously measured at nearby ground-based monitoring stations. We report on the recent results in Tokyo and Seoul. Both measurements were performed as part of air-monitoring campaigns of a National Institute for Environmental Studies (NIES) team. Second, The aim of the Seoul measurement was to evaluate the effect of Cheong-gye stream (Cheonggyecheon) restoration on the regional air quality.

2. Study area and Experiment

2.1 Study area

Seoul City is composed of 25 administrative districts. The area of the city is about 605km^2. The scale of Seoul City is equal to Tokyo City that is about 621 km^2. The population of Seoul City is about 10 million, and which is more than the population of the Tokyo by 2 million in 2000. The highway over the Cheong-gye stream was removed and the stream was finally restored on October 1st, 2005. The study area located near Cheong-gye stream. In two years time from then, the total number of visitors to the restored Cheonggycheon area has exceeded 56 million. An average of 53,000 a day visited the stream on weekdays and 125,000 during weekends and holidays.

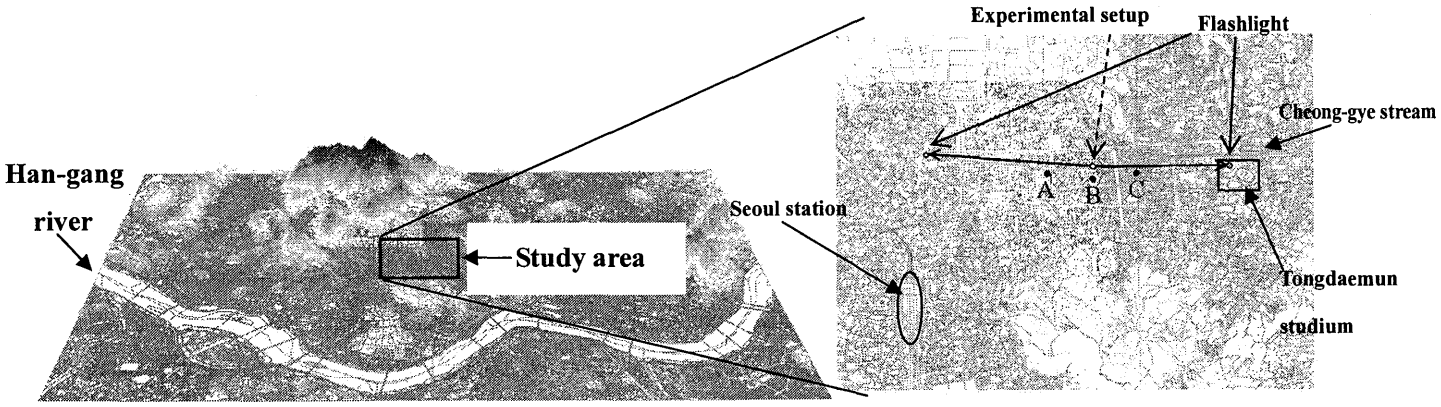

Fig. 1 Study area (Seoul city)

2.2 Experimental method

Fig. 2 shows a schematic of the experimental setup in the central Tokyo. An astronomical telescope (Meade, DS-115), with an aperture diameter of 115 mm and a focal length of 910 mm, is employed to focus the image of a point light source located at a far distance. The image is formed near the eyepiece location (the eyepiece itself is removed from the telescope) where the entrance slit (1 mm high and 5 μm wide) of a CCD spectrometer (Ocean Optics, USB2000) is placed. The CCD consists of 2048 elements and is sensitive in a wavelength range of

200-800 nm, resulting in an average resolution of 0.3 nm/pixel. This CCD spectrometer is composed of a fixed grating and a linear CCD array with a mechanically stable, crossed Czerny-Turner design. No moving parts are incorporated, resulting in high reliability and compactness (89 mm wide × 63 mm deep × 34 mm high). The CCD gate duration is set at 300 ms in the experiment. Between successive gate periods, there exists a time lag of 7 ms, in which each spectral data is sent to a personal computer (PC) through the universal serial bus. The data acquisition can be attained successfully even when no trigger (synchronous with the flashlight) is applied to the CCD spectrometer, though this relatively long gate time as compared with the flashlight duration causes somewhat increased amount of the background skylight.

We automatically achieved the discrimination of data with and without the flash event by comparing the light intensity integrated over a wavelength region of 400 – 450 nm, used for the present NO_2 detection. The spectral difference between the flash and the no-flash events exhibits the net strobe intensity after the long-path transmission in the urban atmosphere. Fig.2 shows optical thickness of each component detected by the DOAS spectrometer. The absorption of NO_2 gas species gives a structure of the order of 0.2 in terms of the optical thickness. In order to extract the NO_2 concentration, contributions from molecules and aerosol particles can be subtracted by simply applying a linear fit to the back-ground. Another important aspect from this figure is that, by measuring the light intensity, it becomes feasible to evaluate the aerosol contribution in the DOAS signal itself.

For the measurement in the central Tokyo, we made use of a xenon strobe install at a steel tower in Jujyo as a light source. The lamp height is about 130m above the ground level. According to the regulation, the light intensity is diminished at dusk and dawn, and during the nighttime blinking red lights replace the flashlights. Thus, the DOAS measurement is limited to the daytime, around 5 a.m. to 7 p.m. during the summer. In the north direction 4.8km from the source, a DOAS system was installed in Four Seasons Hotel Tokyo at Chinsan-so. For the measurement in Seoul, we made use of projector as a light source. The lamp height is about 70m above the ground level. The DOAS measurement with the light source of projector is used during the daytime to nighttime. In the east direction 1.4km from the source, a DOAS system was installed in a Cheong-gye stream at Cheongae-3ga (Fig .1).

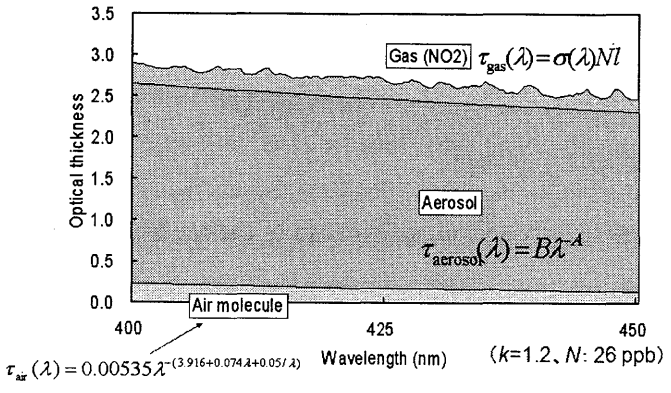

Fig. 2 Optical thickness of each component

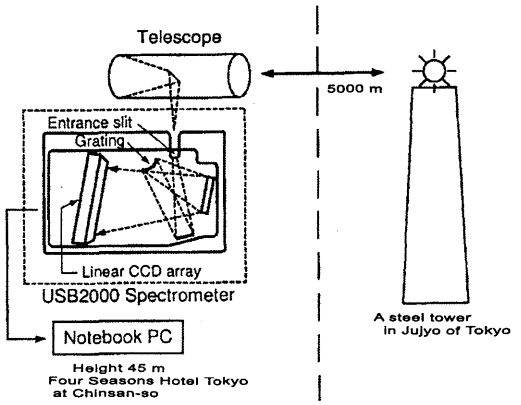

Fig. 3 Experimental setup for measuring NO_2 in the central Tokyo

3. Result

3.1 DOAS measurement with an obstruction flashlight in the central Tokyo

In Tokyo, the obstruction flashlight was used as a light source. The distance was 4.8 km from the observation site. The diurnal change of NO_2 concentration was measured during 10-13 August 2007 (Fig .4). A reasonable correlation is found between the result of the long-path measurement and the data from a ground station below the optical path. The ground data obtained every hour. The temporal resolution of the DOAS data is five minutes, much shorter than the sampling measurements. The DOAS measurement was limited to the daytime, and the resulting NO_2 concentration is obviously lower than that from the sampling measurement. Since the measurement was during hot, sunny days in August, we had expected a well-mixed boundary layer in the urban atmosphere. The present results, however, suggests that the concentration of pollution can exhibit local inhomogeneity, particularly when the exhaust from motor vehicles was the dominant cause of the pollutants. From the ground sampling measurement, it is also noteworthy that the NO_2 concentration was much higher during the nighttime. This is presumable because of the rush hour on the regional highways due to the family reunion in this particular season.

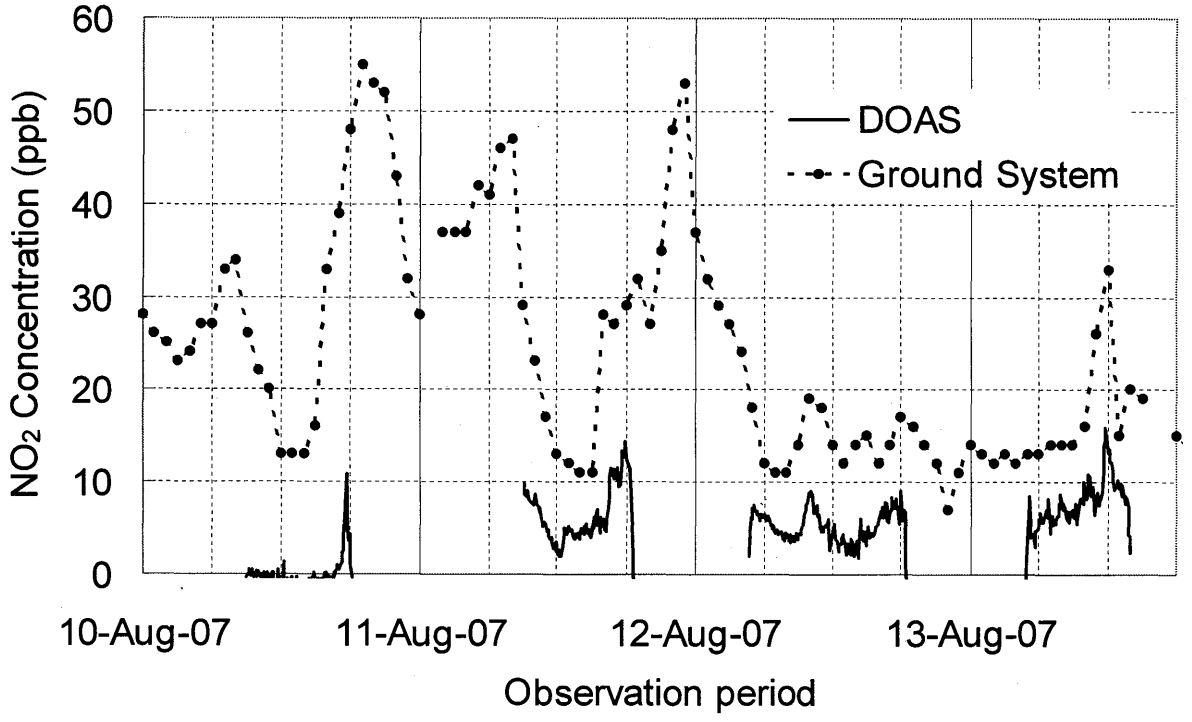

Fig. 4 The DOAS measurement in comparison with the ground sampling data in the central Tokyo

3.2 DOAS measurement with a projector flashlight in the restoration zone, Seoul

The projector flashlight was used as a light source and the distance of the light source and observation was 1.4km. Power consumption of the projector is 220 W, and the emission covers the visible wavelength. Fig. 5 shows the data from nearby ground stations (operated by the municipal environmental department and available on the Internet). The value of NO_2 is more than 50 ppb during 2001 to 2005. However, the value has decreased after the restoration of stream in October 2005.

For the observation in Seoul measurement was set up at about 30 m height. The projector flashlight was used as a light source and the distance of the light source and observation was 1.4km. The projector flashlight was set up at about 70 m height. The ground data obtained every hour. The temporal resolution of the DOAS data is five minutes. Therefore, the value of DOAS and Ground system data were same (Fig. 6).

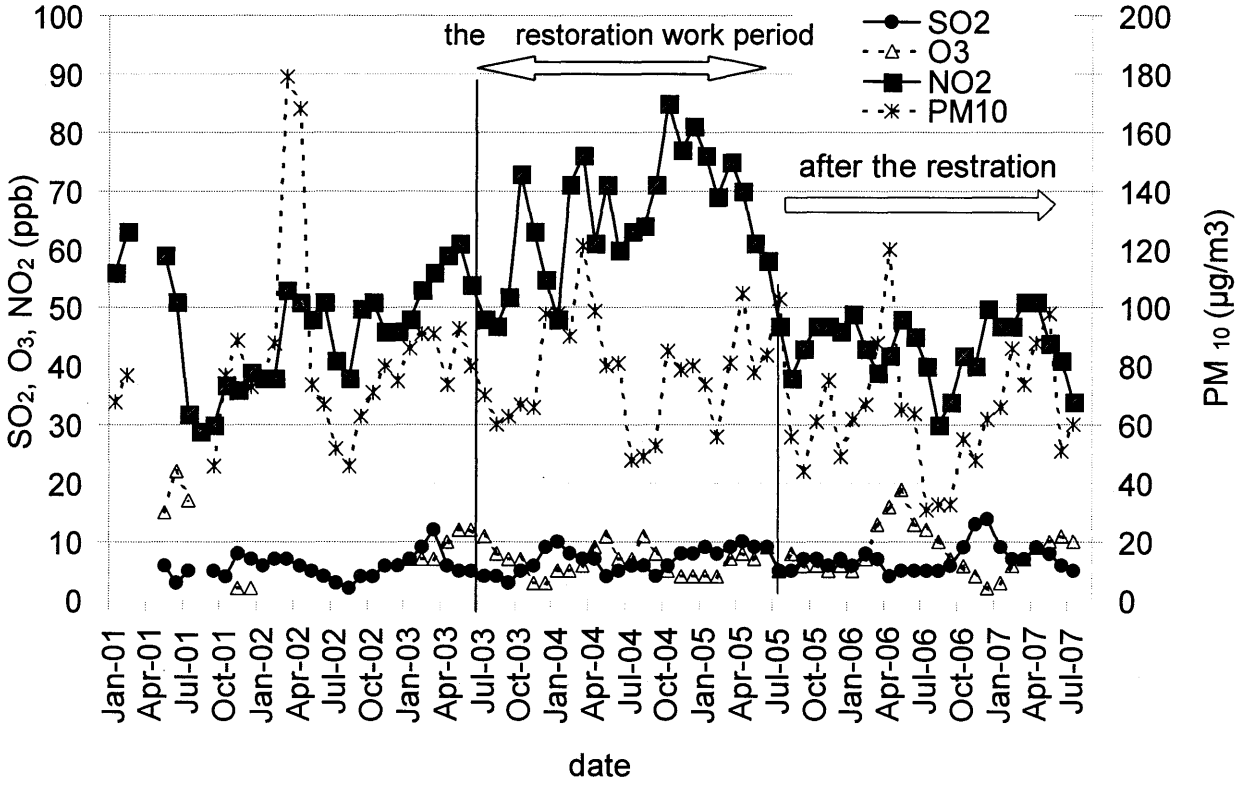

Fig. 5 Monthly average of atmospheric pollutant species around the restoration zone (Cheonggye 4ga of Ground system)

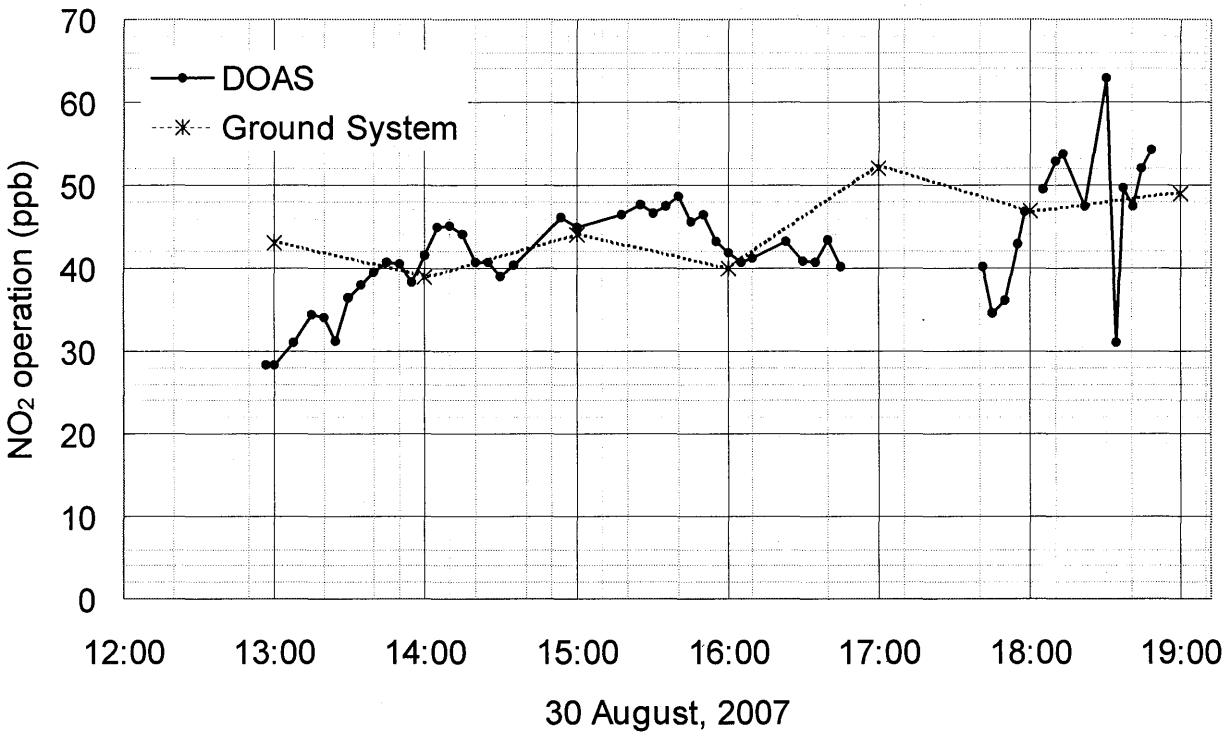

Fig. 6 The DOAS measurement in comparison with the ground sampling data in Seoul

4. Conclusions

For the observation in Tokyo, the NO_2 concentration from the DOAS measurement was much lower than the ground sampling result, though the temporal behavior of the concentration was similar between the two methods. We need further studies to elucidate the local or vertical inhomogeneity of the pollution distribution in the city areas. For the observation in Seoul measurement, we have obtained a reasonable agreement between the DOAS and ground-sampling measurements. The projector light provides a favorable light source for the DOAS measurement for both daytime and nighttime.

Further long-term monitoring is planned to study the effect of restoration.

References

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