MECHANISM OF MITIGATION OF ATMOSPHERIC ENVIRONMENT BY A LARGE RESTORATION OF INNER-CITY RIVER (CHEONG-GYE STREAM IN SEOUL)

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Abstract

This study is to clarify the mitigation effect on atmospheric environment after the restoration (2003-2005) of the Cheong-Gye Stream which was a double-decked road in Seoul, South Korea. The main results are as follows: (1) Based on observed data with ultra-sonic anemometers in 2006, it is clarified that with the sea breeze from the Yellow Sea along the Cheong-Gye Stream, cool air masses are probable to reach around 80 m from the restored river. (2) As a result of comparing the observation data in 2006 with those in 2004 around the restoration zone, a decrease in air temperature and an increase in absolute humidity in 2006 were more remarkable than those in 2004 when the sea breeze was dominant.

Key words: river, mitigation, restoration

1. INTRODUCTION

This study is to clarify the mitigation effect on atmospheric environment after the restoration of the Cheong-Gye Stream which was a double-decked road in Seoul, South Korea (Fig. 1). The authors have started a total monitoring on thermal environment around the restoration zone in June 2003 (before the restoration processes). Especially the authors focus on some mechanisms of this mitigation. This paper is on a part of a collaborative project (Ichinose *et al.*, 2006) with many Korean partners including METRI/KMA (Kim *et al.*, 2008), Pukyong National Univ. (Kwon *et al.*, 2009), Keimyung Univ., etc. The authors would like to express their sincere thanks to them for their great assistances for our activities in Seoul.


Fig. 1 The Cheong-Gye Stream before and after the restoration (left: June 2003, right: August 2005)

2. METHOD

2.1. Study area

The Cheong-Gye Stream, which flows from west to east in the city center of Seoul, was an inner-city river with the length of around 11 km joining to the Han-Gang River (Fig. 2). The growth of Seoul at the beginning of the 20th century turned the area around the Cheong-Gye Stream into a populated area. As a solution, in late 1950's the river was placed into an underground channel. In the beginning of 1970's continued urbanization along this course resulted in the construction of the Cheong-Gye Double-Decked Road (mainly four lanes) with the length of about 6 km. More recently, an examination of urban infrastructure has revealed serious structural problems with this double-decked road. This occurred at a time when there was greater emphasis on environmental-friendly urban design. The Seoul Metropolitan Government, therefore, decided to remove several kilometer of this road and to restore the Cheong-Gye Stream. The operation term was from July 2003 to September 2005.

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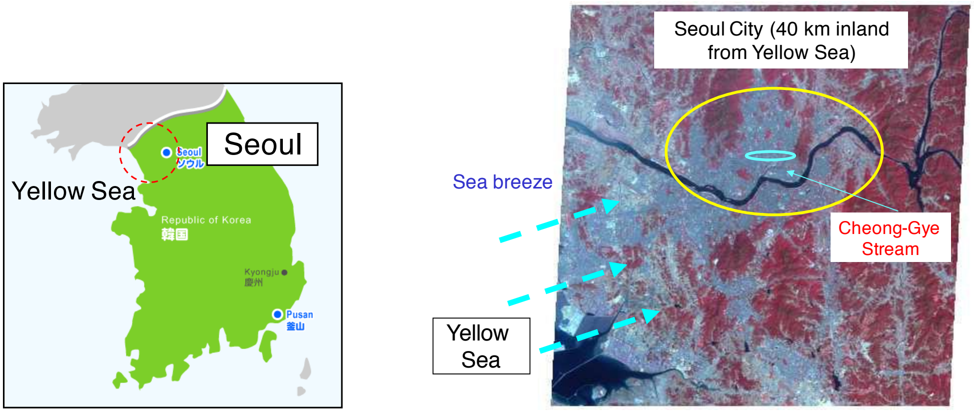

Fig. 2 Location of Seoul City and the Cheong-Gye Stream (Base map: ASTER)

2.2. Observations

The authors have started a total monitoring on thermal environment (meteorological observation) around the restoration zone before the restoration, began in 2003. The measured meteorological parameters were air temperature, relative humidity, solar radiation, mean radiant temperature (MRT), wind direction and wind speed, etc. Based on these data, the cooling effect, ventilation and thermal comfort index were evaluated. At points of M2, M3, M4, M5, M6 in Figure 4, the wind data were measured with ultra-sonic anemometers (Gill WindSonic etc.), and air temperature, relative humidity, and mean radiant temperature (MRT) were measured with AM-101 (Kyoto Electronics) etc. At N1-N5 and S1-S5 in Figure 4, air temperature and relative humidity were automatically measured with small thermometers (Hioki Electronics) placed in shelters. In addition, air temperature and relative humidity were automatically measured to estimate cooling effects in every 15 minutes on the riverside and at some city sites (Fig. 3). The measurements were performed using small thermometer (Hioki Electronics), which were set in shelters.

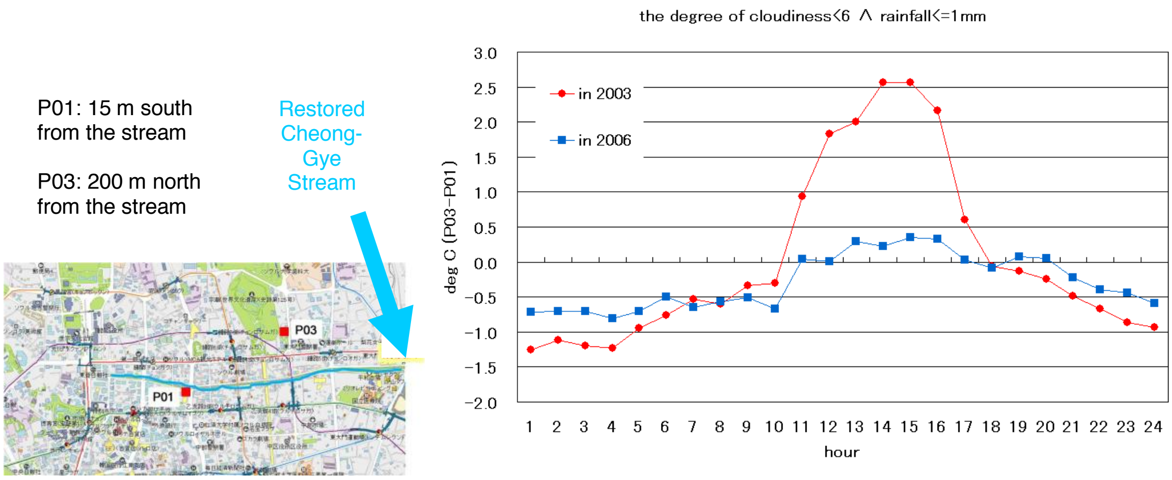

Fig. 3 The difference in temperature by hour on typical fine days in August in 2003 and 2006
Observation in 2003 was performed as collaboration with METRI/KMA etc.

3. RESULTS

3.1. The temperature before and after restoration

In order to compare a riverside and a city area on a large scale, the authors measured temperature, before and after restoring the stream. Figure 3 shows the difference in temperature by hour between two points P01 (Hanhwa) and P03 (Woongjin) on typical fine days in August 2003 and August 2006. At daytime in 2003 the difference was larger than in 2006, indicating that the air temperature after the restoration was higher than before the restoration. One of the possible explanations could be that after removing the double-decked road the sunshine increased, and hence, the cumulative effect of temperature also increased. On the other hand, at the night and the morning the situation is opposite. Near the stream the cooling effect was more pronounced after the restoration.

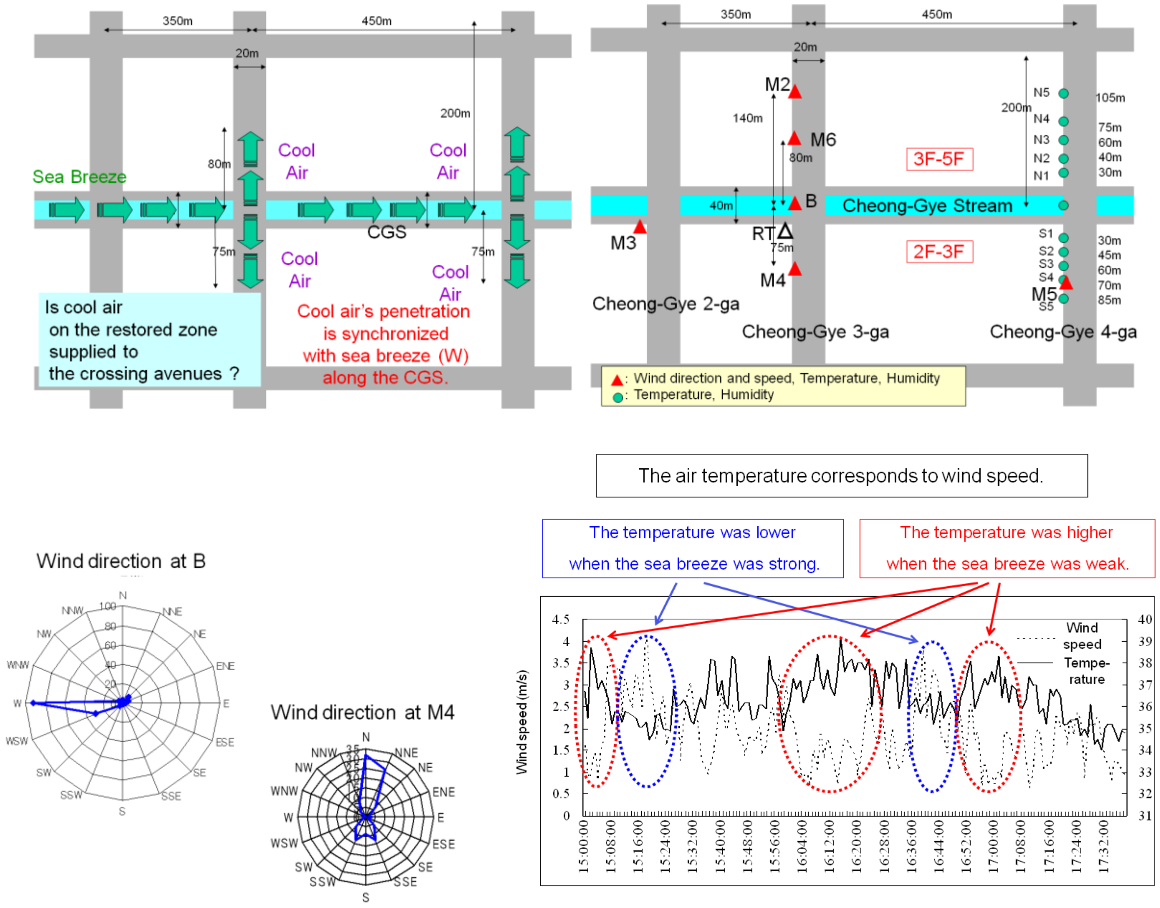

Fig. 4 Relationship between the wind speed at B and air temperature at M4 (13th of August, 2006)

3.2. Cooling effect supplied to the crossing avenues by wind from the stream

Seoul City is located 40 km inland from the Yellow Sea. In fine days of August, sea breeze flows in Seoul City westward (Fig. 2). Sea breeze along the inner-city river possibly has more pronounced higher cooling effect. The authors tried to find some evidence that the cool air is supplied to the avenues crossing the stream. Figure 4 shows the relationship between wind speed measured on the bridge (B) and the air temperature measured at the point M4 (75m south from the stream) on a fine day, 13th of August in 2006. At point B, the wind direction was mostly westward. At the same time, the wind direction at M4 was mostly northward. The results indicate that the temperature was lower when sea breeze was stronger. Then it is clarified that air on the restored zone is probable to be supplied to the crossing avenues. The authors compared the air temperature in 2004 and 2006 on the crossing avenues. Figure 5 shows differences in temperature on south side of the stream on a fine day, 13th of August in 2004 and 2006. During the sea breeze in 2006 air temperature decreased more than during the sea breeze in 2004, especially at points S1 and S2.

3.3. Air pollution

Figure 6 shows an annual change in NO_2 and PM10 concentrations beside the stream. NO_2 value in 2006 has been decreasing in comparison to 2003 for the same period of time. On the other hand, PM10 value has not changed significantly between the restoration times.

4. CONCLUSION

The main results are summarized as follows: (1) Based on observed data with ultra-sonic anemometers in 2006, it is clarified that with the sea breeze from the Yellow Sea along the Cheong-Gye Stream, cool air masses are probable to reach around 80 m from the restored river. (2) As a result of comparing the observation data in 2006 with those in 2004 around the restoration zone, a decrease in air temperature and an increase in absolute humidity in 2006 were more remarkable than those in 2004 when the sea breeze was dominant. Therefore, it is clarified that the mitigation effect for atmospheric environment exists after the restoration of the Cheong-Gye Stream. The authors express their thanks to Dr. Victoria Likhvar (NIES) for her great assistance on data analyses.

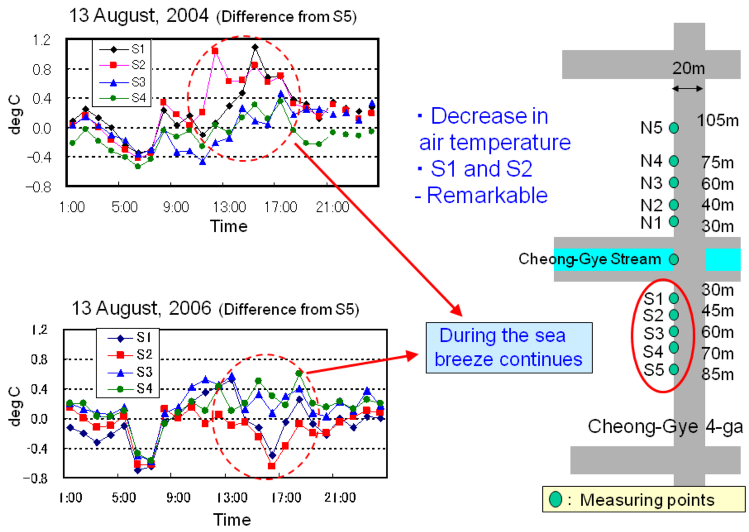

Fig. 5 Comparison of air temperatures in south side from the stream in 2004 and 2006
<u>Observation in 2004 was performed as collaboration with METRI/KMA etc.</u>

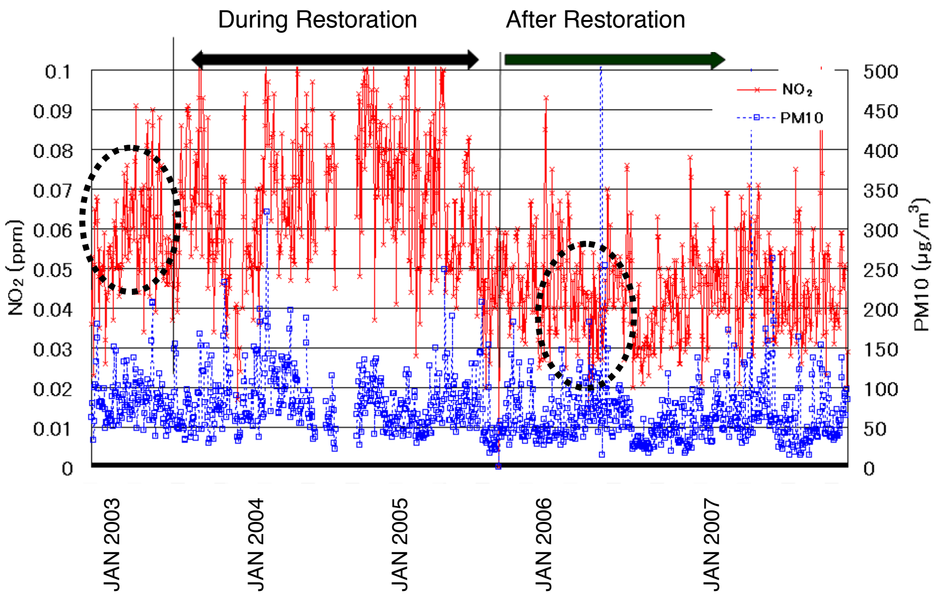

Fig. 6 The interannual change in NO_2 (red line) and PM10 (blue line) concentrations beside the stream
(in "Cheong-Gye 4-ga" monitored by Seoul Metropolitan Government)

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