RELATIONSHIPS BETWEEN CARBON DIOXIDE CONCENTRATION AND PRESENCE OF TUNNEL SECTION OF THE HIGH-SPEED TRAIN PASSENGER CABIN IN KOREA

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ABSTRACT

In this study, we monitored the carbon dioxide (CO_2) concentration in a high-speed train passenger cabin by the *in-situ* non-dispersive infra-red (NDIR) method in order to investigate the effects of various factors, such as number of passengers and the presence of tunnels on the CO_2 concentration levels. We found that the CO_2 concentration was strongly related with the number of passengers and correlated with the presence of tunnel regions. The CO_2 concentration increased with increasing number of passengers and increasing tunnel residence time. This phenomenon could be observed in the most of high-speed trains in the world, since the flap of ventilation equipment is closed to avoid the ear-discomfort of passengers by pressure changes passing the tunnel section. As a result of this temporary stop in the supply of fresh air, the concentration of CO_2 in the passenger cabin increases drastically. We surveyed the tunnel information of the high-speed train in Korea, and divided the whole line into several sections in order to correlate it with the CO_2 levels of the passenger cabin. The carbon dioxide levels of the passenger cabin often observed to exceed 2,500 ppm in tunnel section. Some alternative ways to keep the carbon dioxide levels lower in the tunnel section were suggested.

KEYWORDS

Carbon dioxide, Tunnel, Ventilation, Passenger cabin, High-speed train

INTRODUCTION

With increasing concerns of indoor air quality, carbon dioxide (CO_2) concentration in the public transportation, such as train, bus, and subway, draws big interests since the CO_2 concentration in the indoor air is regarded as an index of ventilation status. In the guide line for indoor air quality of public transportation suggested by Korea Ministry of Environment (KME 2006), the CO_2 and particulate matters smaller than 10 μm (PM10) concentrations were selected as target materials for the management of indoor air quality in trains and buses. Before the Korean guideline, Hong Kong government set up the CO2 guidelines for public transportation (2004). Table 1 shows the guidelines of CO_2 and PM10 concentrations for normal operation time (Level 1) and rush-our time (Level 2). The guidelines are averaged values of whole line measurements, i.e. average of consecutive measurements from departing station to destination of a route. Those guidelines were suggested in order to improve the indoor air quality by enhancing proper ventilation of vehicles.

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Table 1. Management guidelines for indoor air quality of public transportation in Korea.

Index material	Type of transportation	Level 1	Level 2
CO_2 (ppm)	City trains (subway)	2,500	3,500
	Trains, Buses	2,000	3,000
PM10 ($\mu g/m^3$)	City trains (subway)	200	250
	Trains, Buses	150	200

EXPERIMENTAL METHODS

We measured the time-series of CO_2 concentrations in the Korea High Speed Train (KTX) cabin during the journey of Gyongbu-line (Seoul-Busan) and Honam-line (Yongsan-Mokpo) with recording the number of passengers on board. The sampling position was chosen at the center of passenger cabin with the height of passengers head on the seat. For the measurement of CO_2 concentration, the IAQ monitor (Wolfsence, model IQ410) was used. At the same time, the concentration of particulate matter (PM10), temperature, humidity and gaseous pollutants such as formaldehyde (HCHO) and volatile organic carbons (VOCs) were monitored to investigate the indoor air quality. The measurements were conducted on two consecutive days, 18~19 July 2006 for KTX Gyeongbu-line and 24~25 July 2006 for KTX Honam-line. On board measurements was performed at both inbound and outbound journey for each line. The outdoor air of 1200 m^3/h is supplied into KTX cabin during normal operation and the windows of cabin cannot be opened.

RESULTS

Figure 1 shows the correlation between CO_2 concentration and number of passengers of Gyeongbu and Honam lines. It is obvious that the high concentration of CO2 was observed at high number of passengers. The correlation (CO_2 = 23.8xN + 297, R^2=0.807) indicates that the increase of one passenger accumulates the CO_2 concentration by 23.8 ppm in the KTX cabin. In our previous study, the linear correlation between CO2 levels and number of passengers were observed at city trains of Seoul (Kwon et al., 2007).

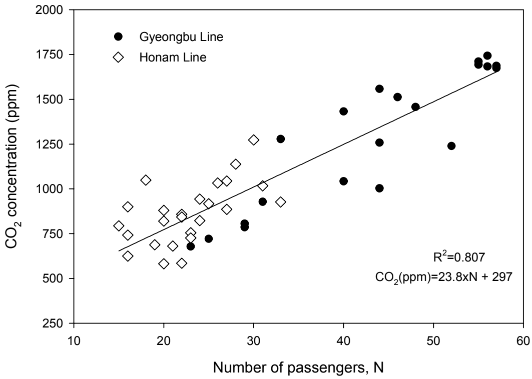

Figure 1. Correlation of CO_2 concentration with number of passengers on board.

It was found that the average concentrations of CO_2 were 1300 ppm for KTX Gyeongbu-line and 895 ppm for Honam line, which were quite lower values compared to current guide lines of Level 1(2000 ppm).

In order to analyze the effect of ventilation on the CO_2 levels in the KTX cabin, the tunnel region was investigated where the flap of ventilation was closed. Table 2 and Figure 2 indicate the location of tunnels according to the part of Gyoengbu line (Seoul-Cheonan-Daejeon-Daegu) heading for Busan station. Several tunnels in close distance was grouped as T1~T7. The compositions of tunnel ratio to total line were up to 29.3% for Seoul to Cheonan, 54.7% from Cheonan to Daejeon, and 59.3% from Daejeon to Daegu.

Table 2. Tunnels grouped by close distance on KTX Gyeongbu-line (Seoul to Busan direction).

Group	Tunnels Names	Starting(km)	Ending(km)	Total Length(km)
T1	Gwangmyeong ~ Jansang	14.742	28.110	13.368
T2	Unju ~ Sangbong	107.435	117.010	9.575
T3	Biryong ~ Moongok	128.990	135.350	6.360
T4	Daejeon ~ Daejeon-Station	146.490	153.630	7.140
T5	Hwasin1 ~ Hwanghak	192.935	212.400	19.465
T6	Oksan ~ Booksam2	227.845	240.296	12.451
T7	Daegu	260.940	281.101	20.261

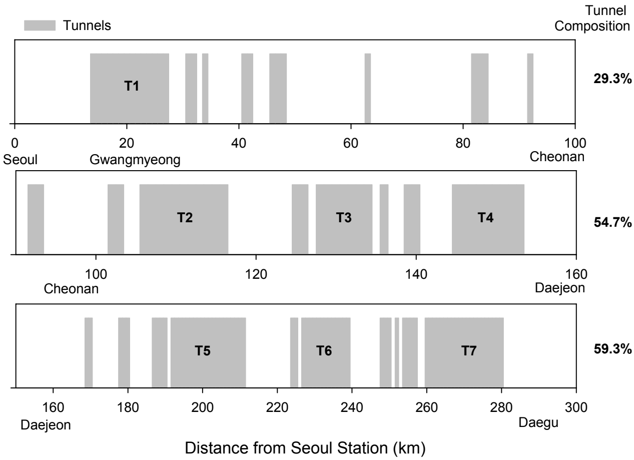

Figure 2. Primary tunnel regions between Seoul and Daegu station as marked grey colors (T1~T7).

Based on those classifications of tunnel regions, we correlated the CO_2 concentrations to tunnel groups (T1~T7). It was found that the peak of CO_2 concentrations were well matched with tunnel groups as shown in Figure 3. There was increase in CO_2 concentration when the train entered the tunnel regions and the peak concentration was observed during the tunnel passing. Highest concentration of CO_2 was observed at T7 for Seoul to Busan direction, while the highest CO_2 concentration was monitored at T5 for Busan to Seoul direction. It is interesting to note that the order of increase in CO_2 levels during T5 to T7 tunnel regions was T5<T6<T7 at Seoul to Busan direction, while the opposite order, T7<T6<T5 for Busan to Seoul direction.

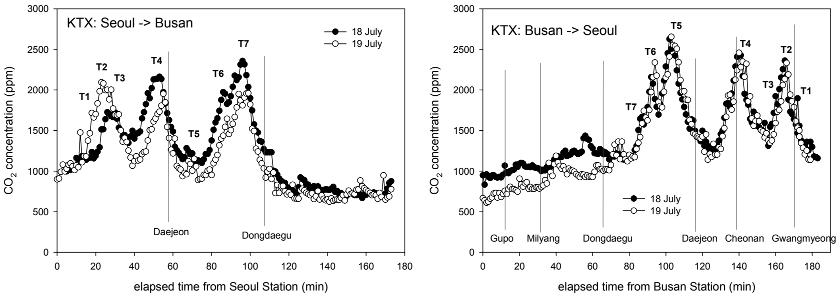

Figure 3. CO_2 concentration with elapsed time in KTX Gyeongbu-line related with tunnel regions.

CONCLUSIONS

The CO_2 concentration in a high-speed train passenger cabin was monitored in order to investigate the effects of number of passengers and presence of tunnel on the CO_2 concentration levels. It was found that the CO2 concentration was correlated linearly with number of passengers. For the tunnel effect which caused by stopping of ventilation, the variation of CO_2 concentration was well explained by the location of tunnel regions. The average levels of CO_2 in KTX were found to be below the guidelines for indoor air quality of public transportation suggested by Korea Ministry of Environment.

REFERENCES

Hong Kong Environment Protection Department (2003) Practice note for managing air quality in air-conditioned public transportation – Railways.

Korea Ministry of Environment (2006) Management guidelines for indoor air quality of public transportation.

Kwon et al. (2007) Assessment of indoor air quality of subway – CO_2 concentration and number of passengers, Spring Conference of Korea Society for Railway.