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Analysis of Ambient Air Quality Level in Subway Area in Busan Metropolitan City

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The purpose of this study is to estimate the air quality of subway stations having underground platforms in Busan Metropolitan City, from September to November 2000, over seven times. The places of the investigation include Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station.

Samplings were conducted at three points in each station, i.e. gates, ticket gates, and platforms. CO, NO, NO_2, and O_3 were the main components of air for this analysis. In order to more fully understand station environments, we also measured an air temperature at each point.

The results showed that the O_3 average concentration of Yonsan-dong station was higher than others with 38~51 ppb.

The average concentration of NO was high at the ticket gate and platform at Somyon station (119 ppb, 122 ppb) and Nampo-dong station (102 ppb, 100 ppb). These results show that the air pollution of stations with underground shopping malls were higher than others.

At Somyon station having a junction station, NO and NO_2 concentration levels of platform-2 (noncrowded) were higher than platform-1 (crowded). This is most likely due to the accumulation of air pollutants and inadequate ventilation systems.

To find the relationship of the indoor (platform) and outdoor (gate), we analyzed the I/O ratio. The averages of CO and O_3 were both higher than one: 1.16 and 1.82, respectively.

In the correlations between each material and the others, NO vs NO_2 was the highest with R=0.63. In the correlations between indoor and outdoor, O_3 was the highest with R=0.64.

Key words : Ambient air quality, I/O ratio, Correlation, Underground

1. Introduction

With increasing city population densities, underground facilities and entertainment locations are proliferating at rapid pace in efforts to maximize the use of land. However, the administration of air quality control is not well integrated as air outdoor and indoor buildings are subject to two separate laws: outdoor air is subject to the Air Quality Preservation Act, and indoor air is subject to the Public Health and Sanitation Act.

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As underground subway stations and shopping centers, in particular, are excluded from either of these two laws, underground air pollution has emerged as a concern to the general public. People have different reactions when they are exposed to the same contaminants at similar concentrations. In order to protect the public from underground air pollution, the Ministry of Environment, Republic of Korea has conducted a study on the level of pollution and harmful trace substances in the air in underground areas. This study led to the establishment of recommended standards which were announced in September of 1989[1].

The underground pollution levels of advanced countries like the US and Japan were used as benchmarks in establishing the standards which are categorized by facility type, i.e. tunnels, shopping malls, subway stations, etc. However, recommended ambient air quality standards for underground space are insufficient, and their data help to resolve conflicts between different ministries responsible for controling underground air.

Although questions have been raised in Korea about ambient air quality in underground shopping arcades, subway stations and other public places, the available air quality monitoring data for those sites are not adequate for policy-makers to develop an accurate profile or to identify the major contributors to air pollution[2,3]. In particular, Busan Metropolitan City had few studies done on underground about air quality.

Park et al.[4] have studied about characteristics of heavy metal concentrations and indoor atmospheric environments in Busan Metropolitan Area.

Lee et al.[5] have studied about survey on air pollution in underground commercial floor of Busan area.

The purpose of this study is to estimate the ambient air quality level of Busan Metropolitan City subway stations with underground platforms, from September to November 2000, over seven times.

2. Materials and Methods

The stations selected for ambient air sampling were 5 stations, i.e. Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station, which have underground space such as platforms, shopping malls. Samplings were conducted at three points of each station: the gate, ticket gate and platform. At Somyon station, a junction station, air sampling was carried out at both platforms. The height of air sampling was at the respiratory level(i.e., 1.5m above the ground) and free from any direct obstructions. We regarded ticket gates and platforms as indoor and the gates as outdoor. The main air quality components under analysis were CO, NO, NO_2, and O_3.

The air was collected in a 10L Tedlar air sampling bag by Handy sampler(KIMOTO HS-7 Handy sampler)at 7:00 p.m. In order to understand the physical environments of subway area, we also measured an air temperature at each point.

The CO concentrations were measured with Thermo Environmental Model 48C, Nondispersive Infrared Method. The concentrations of NO and NO_2 were measured with Thermo Environmental Model 42C, Chemiluminescence Method. The O_3 concentrations were measured with Thermo Environmental Model 42C, Ultra Violate Photometric Method.

To find the relationship between indoor (platform) and outdoor (gate) positions, we analyzed the I/O ratio and the correlations of each pollutant concentration between indoor and outdoor points. To analyze the relationships between each pollutant at every platform, we correlated each material against the others.

3. Results

3.1 The average temperature of subway stations

Variations of average air temperature at the gates, ticket gates, and platforms were 11.0-31.2℃, 14.3-31.6℃, and 17.0-32.8℃, respectively. Generally, average temperatures were the lowest at the gates and the highest at platforms of each station. The temperatures in September and October were similar, but those in November was relatively low. These variations seem to be seasonally influenced.

3.2 Ambient air pollutant concentrations at each station and their points

3.2.1 CO

The concentration levels were measured at Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station, at 0.5-1.8 ppm, 0.6-3.7ppm, 0.6-2.3ppm, 0.6-2.4ppm, 0.4-1.6 ppm, respectively.

The concentration levels of CO are given in Table 1. The CO concentrations were generally high at gates. Particularly, the concentration of CO at Somyon station was the highest with 3.7 ppm over observation period.

At Yonsan-dong station, the concentration at the platform was higher than at the gate or ticket gate. We regard these result as influences from the ventilation system. The ventilation rate of each station in autumn are given in Table 2.

The variations between CO concentrations at each station not exceed the atmospheric environment standard in Korea(Average 9 ppm/8h below, average 25 ppm/h below)[1]. However, prolonged exposure to low levels of CO can cause headache, dizziness, and angina cordiale[6].

3.2.2 NO

The concentration levels were measured at Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station, at 23-336 ppb, 78-221 ppb, 37-229 ppb, 58-193 ppb, and 35- 132 ppb, respectively. The concentration levels of NO are given in Table 3. Somyon station had the highest concentration level with more than 100 ppb over most points.

At ticket gate of Somyon station, Nampo-dong station were the highest with 139 ppb, and 129 ppb, respectively. In the study of Satoru[7], the NO concentration was measured at an office, underground shopping mall, and kitchen a restaurant, at 33-69 ppb, 106 ppb, and 86 ppb, respectively. This demonstrated that the NO pollution of stations with underground malls at the ticket gates was higher than others.

Generally, NO concentrations were higher at the gate than other at points. These results are probably due to motor vehicle emissions at street.

3.2.3 NO_2

The concentration levels of NO_2 were measured at Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station, at 13-143 ppb, 12-55 ppb, 19-83 ppb, 20-77 ppb, and 14-39 ppb, respectively. The concentration levels of NO_2 are given in Table 4. NO_2 concentration levels not exceed the atmospheric environment standards in Korea (Average 80 ppb /24h below, average 150 ppb/h below)[1].

Generally, the outdoor NO_2 concentration levels was higher than those of the indoor. This is

Table 1. The concentration levels of CO at each station

Point / Site	Gate		Ticket gate		Platform	
	Average (ppm)	Range (ppm)	Average (ppm)	Range (ppm)	Average (ppm)	Range (ppm)
Yonsan-dong station	0.8	0.5~1.2	1.0	0.5~1.6	1.4	0.9~1.8
Somyon station	2.0	0.6~3.7	1.5	1.2~1.9	1.3	0.7~1.8
Busan station	1.4	0.8~2.3	0.9	0.6~1.5	1.3	0.9~1.9
Nampo-dong station	1.2	0.6~2.4	1.2	0.9~1.6	1.1	0.9~1.4
Dusil station	1.2	0.4~1.6	1.0	0.5~1.3	1.1	0.6~1.4

Table 2. The ventilation rates of each station in autumn

Site	ventilation rate(m³/min)
Yonsan-dong station	1,093,563
Somyon station	1,423,800
Busan station	1,306,542
Nampo-dong station	1,442,116
Dusil station	698,330

* Busan Urban Transit Authority, 18:00~20:00, Ticket gate, Platform

Table 3. The concentration levels of NO at each station

Point / Site	Gate		Ticket gate		Platform	
	Average (ppb)	Range (ppb)	Average (ppb)	Range (ppb)	Average (ppb)	Range (ppb)
Yonsan-dong station	140	72~336	67	23~121	80	66~97
Somyon station	187	150~221	119	86~139	122	78~183
Busan station	121	50~229	71	37~111	83	52~164
Nampo-dong station	103	69~193	102	74~129	100	58~181
Dusil station	94	35~132	79	51~123	81	54~102

Table 4. The concentration levels of NO_2 at each station

Point / Site	Gate		Ticket gate		Platform	
	Average (ppb)	Range (ppb)	Average (ppb)	Range (ppb)	Average (ppb)	Range (ppb)
Yonsan-dong station	49	15~143	21	14~28	18	13~24
Somyon station	32	13~55	25	12~33	32	21~48
Busan station	46	28~83	31	43~23	33	19~50
Nampo-dong station	38	22~77	33	20~44	35	21~64
Dusil station	30	20~39	22	14~33	23	15~28

probably contributed by outdoor fuel burning from exhausted gases.[8)]

Exposure to NO_2 may act as a trigger for asthma in one of two ways[9)]. One possibility is that the pollutant causes a direct effect on the lungs by inflicting toxic damage. Another is that it may irritate and sensitize the lungs, making individuals more sensitive to allergic response upon contact with indoor allergens.

3.2.4 O_3

The concentration levels of O_3 were measured at Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station, at 8-88 ppb, 6-69 ppb, 1-19 ppb, 1-9 ppb, and 8-28 ppb, respectively. The concentration levels of O_3 are given in Table 5.

The concentration at Yonsan-dong station was the highest among the five stations over every point. O_3 concentration levels not exceed the ambient air quality standards in Korea (Average 60 ppb/8h below, average 100 ppb/h below)[1)]. However, the air quality standard of underground levels have not been established aside from unstable materials. According to the pollutant standard index, concentrations of O_3 between 100 ppb and 200 ppb are harmful to the human body. Those between 200 ppb and 400 ppb are also very harmful to the human body. Those over 400 ppb is fatal to the human body. Therefore, it is necessary for us to continuously study air quality in the underground.

3.3 Average air pollutant concentrations at each station and their three points

The average CO concentration was measured at the gates, ticket gates, and platforms, at 0.8-2.0 ppm, 0.9-1.5 ppm, and 1.1-1.4 ppm, respectively as shown in Table 1.

Table 5. The concentration levels of O_3 at each station

Site \ Point	Gate		Ticket gate		Platform	
	Average (ppb)	Range (ppb)	Average (ppb)	Range (ppb)	Average (ppb)	Range (ppb)
Yonsan-dong station	38	8~80	42	20~77	51	21~88
Somyon station	38	12~57	47	21~69	12	6~19
Busan station	3	1~5	7	3~15	10	3~19
Nampo-dong station	4	2~7	4	1~9	3	1~5
Dusil station	17	8~27	15	8~21	18	8~28

The CO concentration was the highest at the gates of every station except Yonsan-dong station. The highest level was at Somyon station at 2.0 ppm. The increase in traffic volume combined with crowded downtown.

However in the case of Yonsan-dong, the platform level was higher than that of the gate and ticket gate. The ventilation system seemed to influence these concentration levels.

The average NO concentrations were measured at the gate, the ticket gate, and the platform, at 94-187 ppb, 67-119 ppb, and 81-122 ppb, respectively. The concentrations at the ticket gate of Somyon station(119 ppb) and Nampo-dong station (102 ppb) were higher than at other stations. This result is because of the shopping malls, as in the study of Satoru[7)].

The average concentration at the platform of Somyon station was measured at 122 ppb. This level is due to the accumulation of pollutant concentration and an inadequate ventilation system.

The average NO_2 concentrations were measured at gate, ticket gate, platform, at 30-49 ppb, 21-33 ppb, and 18-35 ppb, respectively. The NO_2 average concentration was lower than NO, at the gate, the ticket gate, and the platform with 0.19-0.45 times, 0.21-0.50 times, and 0.23-0.42 times, respectively. NO_2/NO average ratio of indoor(0.32, platform) was lower than that of the outdoor(0.34, gate). This shows that it is difficult to do chemical reactions from NO to NO_2 under indoor circumstances[10)].

The average O_3 concentrations were measured at the gate, ticket gate, and platform, at 3-38 ppb, 4-47 ppb, and 3-51 ppb, respectively. The average concentrations were low at Busan station and Nampo-dong station, but Yonsan-dong station had the highest average concentrations at all three points. Therefore, We should make an effort to reduce the O_3 concentration at Yonsan-dong station.

3.4 Variations in air pollutant concentration at a junction station

Somyon station is a junction station. Therefore, the sampling was conducted at two points: the crowded platform (platform-1) and the non-crowded platform (platform-2) (The Fifth was

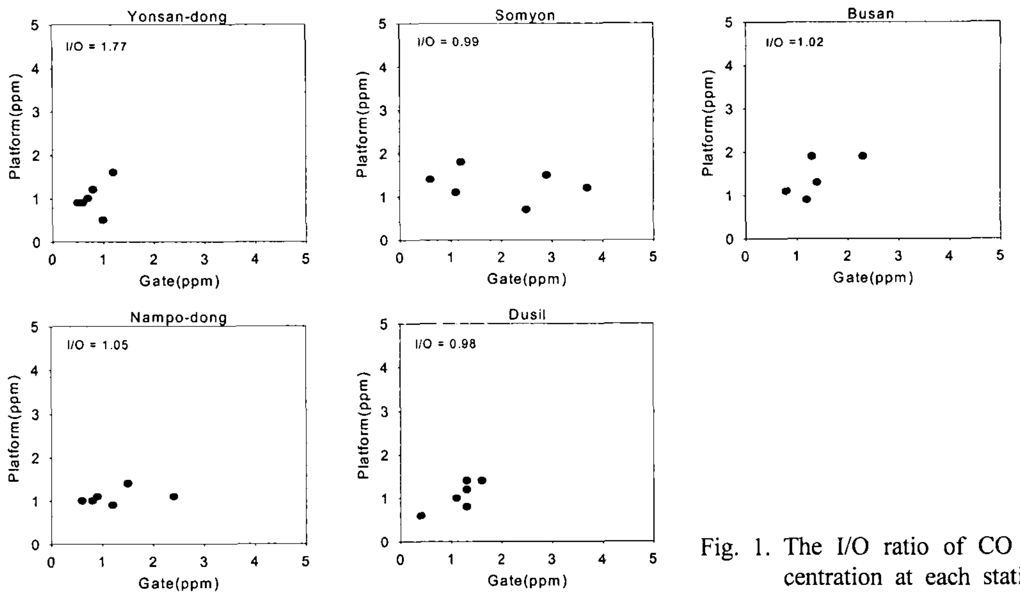

Fig. 1. The I/O ratio of CO concentration at each station.

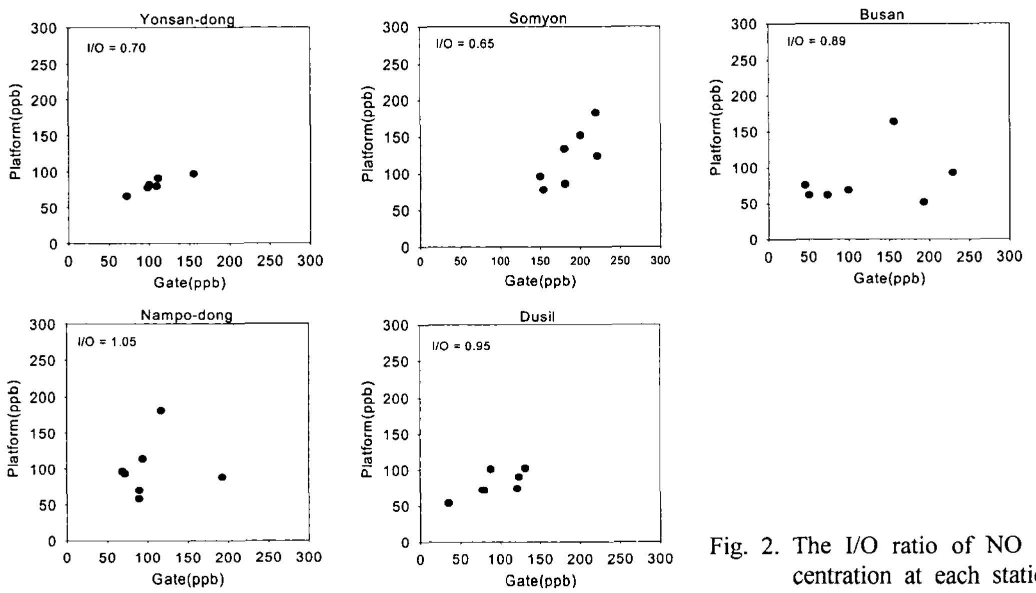

Fig. 2. The I/O ratio of NO concentration at each station.

excluded for omission of measurements).

The results show that the average concentrations of NO and NO_2 were higher at platform-2 than those of platform-1: 122 ppb, 82 ppb and 33 ppb, 21 ppb. Because platform-2 is located inside corner, the ventilation system does not influencing to every where. To be comfortable indoors, the influx of air from outdoor needs to be cleaned with an air cleaner system[11].

3.5 I/O ratios comparison of every station

We defined indoor as platform, outdoor as gate, calculated the I/O ratios. Figs. 1, 2, 3, 4 present the I/O ratios of CO, NO, NO_2, O_3 concentrations at each station.

The I/O ratios of CO concentration at Yonsan-dong station, Somyon station, Busan station, Nampo-dong station, and Dusil station varied from 1.50 to 2.20, 0.28 to 2.33, 0.75 to 1.46, 0.46 to 1.67, and 0.62 to 1.50, respectively.

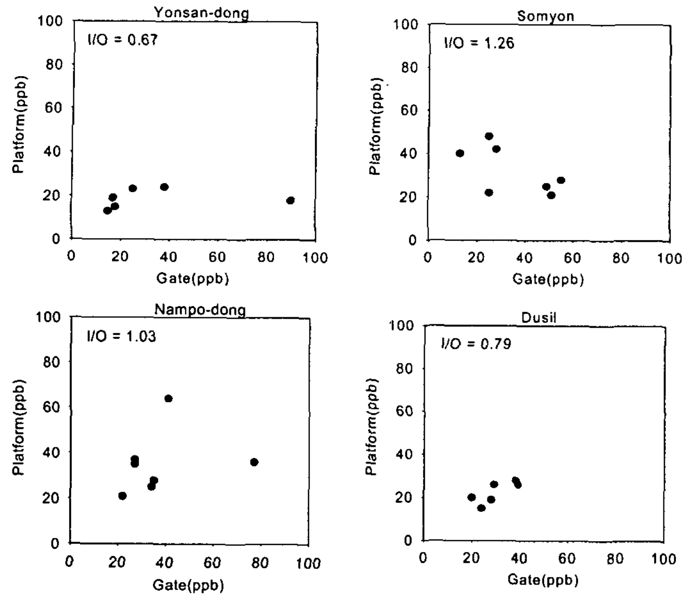

Fig. 3. The I/O ratio of NO_2 concentration at each station.

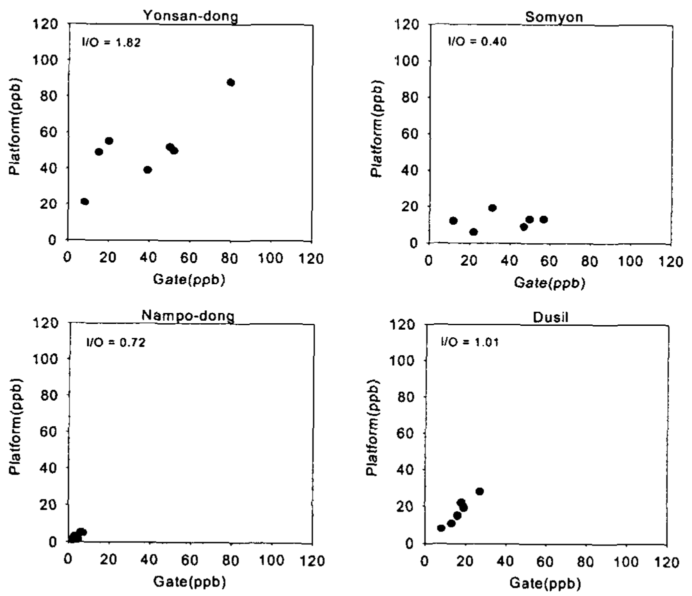

Fig. 4. The I/O ratio of O_3 concentration at each station.

The average I/O ratios were higher than 1 at Yonsan-dong station, Busan Station and Nampo-dong station. Those of Yonsan-dong station were highest with 1.77. It means that indoor pollution is higher than outdoor. But they were close to 1 at Somyon station and Dusil station with 0.99 and 0.98, separately. This indicated that the pollution of indoor and outdoor was similar. Average I/O ratio of CO was 1.16 in this study. This implies that the level of CO pollutants was high at subway platforms. It suggests that air quality of subway station should be improved.

The I/O ratios of NO concentration at Yonsan-dong station, Somyon station, Busan Station, Nampo-dong station, and Dusil Station varied from 0.20 to 0.92, 0.48 to 0.83, 0.27 to 1.69, 0.46 to 1.55, and 0.61 to 1.54, respectively.

The average I/O ratios at Nampo-dong were higher than 1, those at other stations were lower than 1. This means that Nampo-dong station platform was more polluted than other

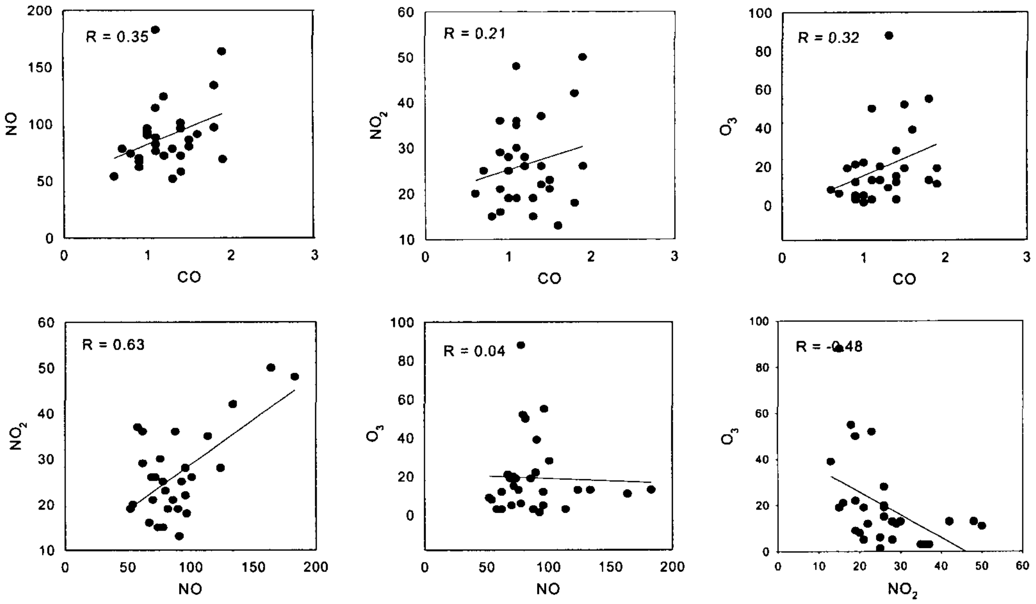

Fig. 5. The correlation diagram between two pollutant gases.

stations.

The I/O ratios of NO_2 concentration at Yonsan-dong station, Somyon station, Busan Station, Nampo-dong station, and Dusil station varied from 0.11 to 1.12, 0.41 to 3.08, 0.30 to 1.07, 0.47 to 1.56, and 0.63 to 1.00, respectively.

The I/O ratios Somyon station and Nampo-dong station were higher than others with 3.08, 1.56, each. The average I/O ratios at Somyon station and Nampo-dong station were 1.26 and 1.03, each.

The study of Toshiro demonstrated that the underground I/O ratio was also 1.2[12]. This implies that stations with shopping malls are more polluted than other stations.

The I/O ratios of O_3 concentration at Yonsan-dong station, Somyon station, Busan Station, Nampo-dong station, and Dusil station varied from 0.96 to 3.27, 0.19 to 1.00, 1.50 to 19.00, 0.30 to 1.00, and 0.85 to 1.22, respectively. At Yonsan-dong station, Busan station, and Dusil station, the average I/O ratios were high with 1.82, 5.15, and 1.01. Yonsan-dong station was high both concentration and I/O ratio, but Busan Station was low concentration with high I/O ratio.

According to the total average I/O ratios, CO and O_3 were greater than 1, with 1.16 and 1.82, each. This indicates that CO and O_3 sources are indoors. We should study further to inquire the reason continually. The average I/O ratios for NO and NO_2 were lower than 1, with 0.85, 0.91.

3.6 Correlation

A number of studies have demonstrated that outdoor air quality can have a significant impact on indoor air.[13~15]

Because platforms represent indoor locations of subway stations, we analyzed the correlation between each material and the others. The correlation analyses are given in Fig. 5.

The correlation analyses were NO vs O_3, CO vs NO, CO vs NO_2, CO vs O_3, NO vs NO_2, and NO_2 vs O_3, where R=0.04, R=0.35, R=0.21, R=0.32, R=0.63, and R=-0.48, respectively. The highest correlation was between NO and NO_2. This indicates that the origins of NO and NO_2 air pollutant have related. The negative correlation between NO_2 and O_3 is due to the transition from NO_2 to O_3.

To obtain relationships between indoor and outdoor air quality, correlation analyses were carried out on indoor (platforms) vs outdoor (gates) concentrations of each pollutant at every station.

The correlation analyses are given in Fig. 6. The correlation analyses revealed CO, NO, NO_2,

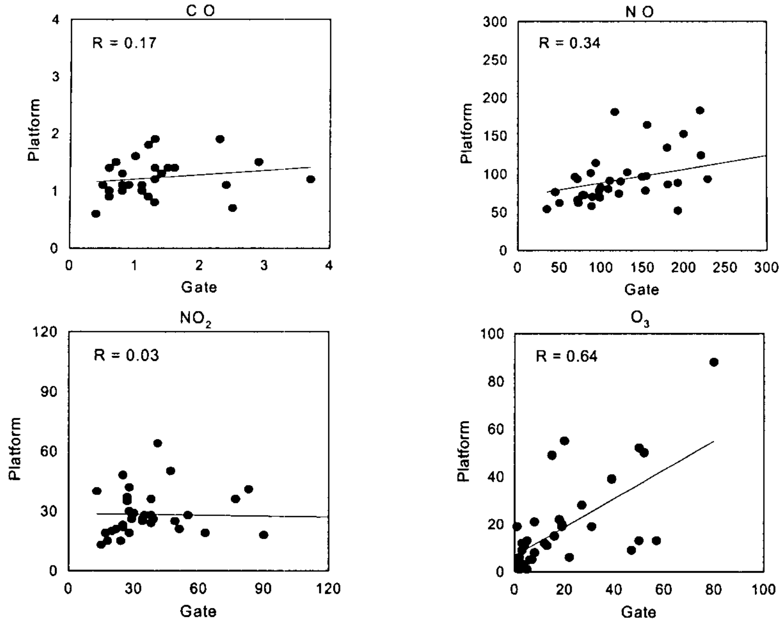

Fig. 6. Correlation diagram CO, NO, NO_2, and O_3 concentration between the platform and the gate.

and O_3, with result of R=0.17, R=0.34, R=0.03, and R=0.64, respectively. The highest O_3 correlation indicates that the O_3 concentration of platforms (indoor) increases as that of gates (outdoor) also increases. It is expected that the correlation will rise in the summer when O_3 alarm system is proclaimed frequently. This is due to its influence of people in the subway stations. To clarify the characteristics subway stations, it is necessary for us to do continuous experiments during the spring, summer, autumn, and winter.

4. Conclusions

From this study of air quality of Busan Metropolitan City subway stations with the underground platforms, we have reached several a conclusions.

O_3 concentration at the platform of Yonsan-dong station was higher than others. This is regarded as a result of an inadequate ventilation system.

The concentrations of NO at Somyon station and Nampo-dong station were higher than others. This showed that the air pollution of stations with underground malls were higher at the ticket gate than others.

With the I/O ratios of pollutants, CO and O_3 were higher than 1 at Yonsan-dong station. In the correlation of each pollutant at the platforms, the relationship between NO and NO_2 was the highest. In the correlation between indoor and outdoor, O_3 was the highest.

This study has confirmed the need for improvement of air quality at subway stations with underground platforms in Busan Metropolitan City. The accomplishment of this study will attribute to the elevation of ambient air quality in underground living spaces in Busan Metropolitan City.

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