Effects of the Corona Pandemic on Indoor Fine Dust in Urban Schools

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Abstract. Corona pandemic restricted industrial activity of the country, influenced social activities of people, and changed students' school programs. PM10 and PM2.5 measured in National Air Quality Monitoring Systems were reduced from 36.1 μg/m³ to 34.5 μg/m³, and from 20.3 μg/m³ to 18.5 μg/m³, respectively. In particular, obvious decrease of indoor PM2.5 with high dependency on outdoor air quality was estimated. As a result of precise field tests in 179 classrooms of 53 schools, indoor PM2.5 showed a low average, 23 μg/m³, and PM10 also was lower 33 μg/m³ than before and after the pandemic (51 μg/m³ and 59 μg/m³ respectively). Due to a variety of class work, limited attendance, air purifier operation and frequent window opening, it was not easy to drive a consistent impact of the Corona pandemic at the indoor PM level. Consequently, the indoor and outdoor airborne fine dust concentrations became more similar than normal conditions, and indoor emission amount of PM10 in particular decreased.

1 Introduction

Corona pandemic has shrunk national the industrial activities, and has changed the social activities of the people. School students also have experienced different form of classes. Concerns about exposure of young students, who spend 6–8 h in classrooms, to indoor pollutants are increasing apparently in urban areas. One of the most significant indoor contaminants is particulate matters represented by PM10 and PM2.5 [1]. Since, elementary students are more vulnerable than adults to exposure to particulate matters due to their earlier developmental stage. Children inhale the air 3–5 times more than adults, and are exposed to a higher level of pollution per lung area. Thus, many studies on school air quality have been published [2,3].

The contraction of industrial scale due to a strict lockdown would have reduced air pollutant emission from point and mobile sources [4]. In addition to the reduction of domestic sources, inflow of foreign fine dust also decreased significantly [5]. The air quality improvement due to Corona has been observed even in large cities over the world [6,7].

Although the fine dust detected in the classroom are in part generated inside, outdoor air quality may directly affect the indoor air quality (IAQ) during this particular period. It also was expected that the decrease in PM2.5, which is highly dependent on the outside air, would appear much larger [8,9]. However, few studies on air quality in the most important indoor spaces have been conducted yet.

Considering the significance of school air quality, this study investigated the level of fine dust in classrooms before (year 2019) and after (2022) and during (2020 & 2021) the corona pandemic.

2 Experimental

2.1 Study sites

As depicted in Fig. 1, this study involved 53 schools in areas of South Korea. Selected test schools are located in areas of high population, near industry complexes, and with significant influences by long-distance transport pollution sources. Our investigation of indoor air quality required no intentional controls for the study. Samples were collected over 4 school days in three classrooms and playgrounds at each school from October, 2019 (fall semester) to June, 2022 (spring semester).

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2.2 Sampling and analysis

Sampling and analyses were carried out according to the standard method of National Guideline of the Ministry of Environment. Mini-volume air samplers (Model BMW 2500, Total Eng., Seoul, Korea) with an impactor classifying 2.5 μm or 10 μm -particles were used to collect the PM2.5 and PM10 at a height 1.2 – 1.5 m above the floor as shown in Fig. 2. Outdoor sampling was conducted in the vicinity of playgrounds. Excluding field blanks, the samples collected for PM10 and PM2.5 were 179 indoors and 61 outdoors.

Particle mass was determined gravimetrically by an electronic microbalance (Cubis II micro-balance, Seoul, Korea) with a resolution of 1 μg. The bulk carbonaceous content of the PM10 and PM2.5 such as organic carbon (OC) and elemental carbon (EC) was quantified with a Thermal/Optical Transmittance analyzer (Sunset Lab., USA). The precision of the OC and EC measurements was 0.95 or higher for each sample as a result of twice repeated analysis of the field samples. Accuracy was estimated as the amount of carbon in 50 μg of artificially prepared sucrose, and the difference was less than 5% when repeated seven times.

![Fig. 2 Indoor and outdoor sampling of PM2.5 and PM10.](image)

3 Results and discussion

3.1 Atmospheric concentration of fine dust

Annual average atmospheric concentrations of PM10 and PM2.5 for study areas and periods are summarized in Fig. 3. According to this official national data, Busan was lowest, and Gyeonggi showed mostly high levels. Nationally, the concentration of fine dust in the air revealed a decreasing tendency year by year. Nevertheless, these figures are higher than the annual average national guideline (30 μg/m³ and 15 μg/m³ for PM10 and PM2.5). The government is preparing the more stringent guidelines for PM10 and PM2.5 according to the air quality guideline (AQG) of world health organization (WHO). WHO advised 15 μg/m³ and 45 μg/m³ for annual and daily averages of PM10, and 5 μg/m³ and 15 μg/m³ for PM2.5, respectively. In accordance, it is true that the domestic condition is far short of the international level, and the IAQ for public spaces such as school classrooms is of concern.

Atmospheric concentrations have clearly decreased during the pandemic than before the outbreak. The decrease of PM2.5 was more obvious than PM10, probably because reduction of industrial activities might release less precursors for condensable particulate matters (CPM) such as nitrates, sulfates and VOCs as well as primary fine particulate matters. These secondary aerosols in general account for about 50% to 60 % of urban atmospheric PM2.5 [10,11]. Thus, while PM10 in 2021 showed a recovery compared to 2020, when a strict policy of exclusive lock-down took place, PM2.5 continued to reveal a declining tendency. Low levels in spring semester of 2022 reflect less inflow of outdoor pollutants, but since unofficially PM levels are rising in the second half of 2022, the current school air quality situation is presumed to be deteriorating.

![Fig. 3 Annual average local PM concentrations.](image)

3.2 Classroom fine dust with Corona pandemic

Fig. 4 shows the concentration of PM10 and PM2.5 detected during the sampling period. There may be discrepancies from the annual average data summarized in Fig. 3 due to certain distances between the school playgrounds and the location of the national AQMS, and also high concentration of particulate matters might have occurred in the area around the school during the actual sampling period.

Both indoor PM2.5 and PM10 levels appeared lower during the pandemic than the normal times. It is noted that indoor fine dust increased in the spring semester of 2021 due to increased outdoor concentration.

![Fig. 4 School PM concentrations during the study period.](image)
During non-period of a pandemic, the relative values for indoor versus outdoor (I/O) PM2.5 and PM10 were 0.59 and 0.72, respectively. Whilst they increased 0.68 to 0.99 for PM2.5 and 0.74 to 0.95 for PM10 during the pandemic period. The reason of higher concentration during the pandemic is probably due to frequent opening of windows. To prohibit the spread of the virus in the isolated classrooms, the government issued a guideline to open windows instead of operating air purifiers. The government determined that air purifiers could potentially increase the virus infections by promoting indoor airflow. This action plan consequently facilitated frequent air exchange by natural ventilation through windows.

As evaluating the indoor value (F/C) of fine (PM2.5) to coarse (PM10), the pandemic period shows a rather high level: 0.48 to 0.73, comparing to normal season: 0.47 to 0.48. A high level of indoor fine modes implies consistent exchange with outdoor air. At the same time, indoor emissions in coarse mode decreased. In practice, a fair amount of PM10 is known to be generated indoors [12]. However, the reduced student attendance and less activity during the pandemic have reduced the possibility of fresh generation of PM10 and resuspension from the flow and tables. In other words, it could be ascertained that the class operation policy and student activity status during the pandemic is one of key factors in determining the amount of fine dust generated in the classroom.

3.3 Carbonaceous materials

Fine dust found in urban atmosphere contains a large amount of carbonaceous materials such as organic (OC) and elemental (EC), which emitted from automobiles, open burning, industrial combustion and long range transport of petrochemicals. Not only is this carbon hazardous to our health, but it also provides clues to the pollutant's emission source.

Overall average concentrations of both carbonaceous materials for current study schools were 45% and 23% of PM2.5 indoors and outdoors, respectively.

A close examination on carbons indicates slightly lower levels during the pandemic as shown in Fig. 5. First point to note also is that OC, which are released from more various sources, is much higher than EC. EC of inside the classroom was less than 10% of OC; i.e. EC/OC varied 0.05 to 0.1; but no consistent relationship according to the pandemic was not found. Despite a similar amount of EC indoors and outdoors, there were no facilities or activities of combustion in schools for our study. It implies that there are some other emission sources for OC inside, probably such as organic aerosols from stationary, marker and synthetic fibers. It could be estimated that these tools were also used less during the pandemic.

Unlike OCs, since most ECs were introduced from outside, both spaces showed similar concentrations, but especially close 1.0 (more accurately 0.96 for IN/OUT) during the pandemic. The period except the pandemic showed 0.8 in average.

![Fig. 5 Concentrations of carbonaceous materials.](image)

4 Conclusions

Restricted activities of the people and industries due to COVID-19 lock-down improved urban air quality by decreasing the level of particulate matters. This study investigated the change in school air quality according to unusual social life patterns.

Decrease of atmospheric PM2.5 was more evident than PM10 during the pandemic period. In addition to improved air quality, limited attendance and class activity of the students has reduced both levels of PM10 and PM2.5 in school classrooms. As a result of comparing indoor and outdoor fine dust concentrations, the absolute amount decreased during the pandemic, but the relative value, I/O, rather increased. Among several measures for the school, window opening must have been a decisive factor in maintain a similar concentration of the classroom and outside.

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