Comparison of personal exposures to gaseous pollutants under public transportation modes during and after the SFTR

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Abstract: During the Spring Festival Travel Rush (SFTR) in China, many people travel and public vehicles are always full. This research studies the air pollutant exposure of commuters under five transportation modes: China railway high-speed train (CRH train), subway, bus, car, and walk. The routes are selected between Nanjing and Xuzhou. The volatile organic compounds (VOCs), carbon dioxide (CO2), and formaldehyde (HCHO) levels are compared in five different transportation modes. The results indicate that personal exposure level to VOC and HCHO in CRH train is the lowest and relatively stable. So taking the CRH train during the SFTR may be the best choice. During the Corona Virus Disease 2019 (COVID-19) outbreak, spraying 70% alcohol for disinfection in public spaces significantly increased the personal exposure level to VOCs.

1. Introduction
The 2020 Spring Festival Travel Rush (SFTR) started on January 10, 2020, and ended on February 18, 2020. The number of passengers reached about 3 billion person-times during the SFTR. The public transportation is in full load mode every day, and commuters are exposed to serious public transportation pollution. However, the Corona Virus Disease 2019 (COVID-19) broke out in Wuhan, Hubei, China on January 23, 2020. The virus may spread in public transportation, increasing the risk of passengers.

One of the essential air pollutants is volatile organic compounds (VOCs), such as benzene, toluene, ethylbenzene, xylene, and styrene. The sources of in-cabin VOC may come from interior structural material, engine emissions, and atmospheric pollutants[1, 2]. The different fuel and the age of the vehicle are also the main factors impacting the in-cabin VOC concentrations[3, 4]. Lv et al. study indicates that among the 820 possible combinations of 41 VOCs identified, about half are significantly correlated, indicating that they come from some common source.[5]. Besides, the in-cabin VOCs are higher than the ambient, and mucosal irritation to neurological system damage, lung cancer, and leukemia are related to the exposure to VOCs[6-9].

Therefore, the VOCs and carbon dioxide (CO2), formaldehyde (HCHO) in five transport modes are investigated in this article. This study aims to analyze the air pollutant exposure of commuters in five modes of transportation before and after the SFTR with the impact of the COVID-19 outbreak.

2. Materials and methods
In this study, the researchers monitored the concentration of gaseous pollutants under different transportation modes during the SFTR. The route is from Nanjing to Xuzhou, as shown in Figure 1. The five modes of transportation are CRH train, subway, bus, car, and walk.
The experimenter detected the data of gas pollutants by carrying a portable air quality detector (BoHu model BH1-B3, China). This instrument uses a Figaro TGS2602-B00 sensor (Japan) using an oxide semiconductor to detect VOC. The Sense Air S8-PWM sensor (Sweden) was used to detect CO₂, which was used nondispersive infrared to monitor the change in concentration. Weather parameters such as temperature, relative humidity, were also measured by BoHu model BH1-B3. All collected data are stored in the memory card of the instrument. Table 1 shows the specific information on various vehicles, including transportation modes ventilation type, segments, duration, and distance. This article separately monitored the gas pollutants in different public transportation modes for four days. Table 1 records the routes of a commuter from Nanjing to Xuzhou to home and the public transportation modes used.

Table 1 The information summary about travel routes

| Transportation modes | Ventilation type | Segments | Data       | Duration (min) | Distance (km) |
|----------------------|------------------|----------|------------|----------------|---------------|
| CRH train 1          | AC               | NO.1 Nanjing-Xuzhou | 19th Jan | 150           | 283.5         |
|                      |                  | NO.2 Xuzhou-Nanjing  | 6th May  | 222           | 283.5         |
| Walk                 | Open-air         | NO.3 Xuzhou CRH-Xuzhou Subway | 19th Jan | 24            | 0.4           |
|                      |                  | NO.4 Jiulonghu-Xincheng Hospital | 6th May  | 9             | 0.2           |
| Subway               | AC               | NO.5 Xuzhou-Xuzhou Dong | 19th Jan | 27            | 9.0           |
|                      |                  | NO.6 Xuzhou Dong-Pengcheng Square | 21st Jan | 30           | 9.0           |
|                      |                  | NO.7 Pengcheng Square-Xuzhou Dong | 21st Jan | 33           | 9.0           |
|                      |                  | NO.8 Nanjing Nan-Jiulonghu | 6th May  | 20           | 8.9           |
| CRH train 2          | AC               | NO.9 Xuzhou Dong-Guanyin Airport | 19th Jan | 16           | 35.3         |
|                      |                  | NO.10 Guanyin Airport-Xuzhou Dong | 21st Jan | 15           | 35.3         |
|                      |                  | NO.11 Xuzhou Dong-Guanyin Airport | 21st Jan | 16           | 35.3         |
|                      |                  | NO.12 Guanyin Airport-Xuzhou Dong | 6th May  | 17           | 35.3         |
| Bus                  | AC               | NO.13 Guanyin Airport-Terminal 2 | 19th Jan | 9             | 2.0           |
|                      |                  | NO.14 Guanyin Airport-Terminal 2 | 21st Jan | 9             | 2.0           |
| Car                  | Non-AC+1/2 WO    | NO.15 Guanyin Airport-Home | 19th Jan | 15           | 9.2           |
|                      | Non-AC+1/2 WO    | NO.16 Home-Guanyin Airport | 21st Jan | 20           | 9.2           |
3. Results and discussion

3.1 During Chinese SFTR

The U.S. Occupational Safety and Health Administration (OSHA) indicates that the CO$_2$ levels in outdoor air typically range from 300 to 400 ppm (0.03% to 0.04%) but can be as high as 600-900 ppm in metropolitan areas. OSHA Permissible Exposure Limit (PEL) and ACGIH Threshold Limit Value (TLV) for 8-hour exposure is 5000 ppm (0.5%). There are no national or international standards or guidelines for air pollutant concentrations in vehicles. However, China Environmental Protection Agency (CEPA) has released a set of guidelines for air quality assessment of passenger cars (GB/T 27630-2011)[10]. In this study, Figure 2 indicates that the average VOC concentration of five transportation modes ranges from 0.7 to 2.4 mg/m$^3$. The commuter has the lowest personal exposure to VOC (0.7 mg/m$^3$) in CRH train 2 but has the highest personal exposure to VOC (2.4 mg/m$^3$) with the lowest SD (0.1 mg/m$^3$) when walking. The CRH train is powered by electricity instead of fuel, and the VOC sources are limited. However, when commuting by walking, traffic-related VOCs are various, such as hydrocarbons, aromatic hydrocarbons, oxygen-containing hydrocarbons, terpenes, and halogenated compounds, which may come from the combustion or volatilization of gasoline[11]. Besides, the average VOC concentrations in bus and car are the same but the SD of VOC concentration in the bus is smaller (0.8 mg/m$^3$). Overall, taking the CRH train can significantly reduce the exposure level to VOC among other tested public transportation modes, which can be recommended as the first choice for commuting during the Chinese SFTR.

![Figure 2: The VOC and CO$_2$ under different modes of transportation during the SFTR](image-url)

The average CO$_2$ concentrations under six modes are 1365.6 ppm, 509.6 ppm, 833.1 ppm, 1208.1 ppm, 1163.7 ppm, 705.3 ppm. As shown in Figure 2 and Figure 3, walking has the lowest average CO$_2$ exposure, and it is 509.6 ppm with the smallest SD among all modes of transportation.
Figure 3 the boxplot of the concentrations of gas pollutants in different transportations during the SFTR (a: VOC concentration; b: CO2 concentration).

During walking, the instrument was carried with the researcher, which was fixed on the shoulder bag with tape. Higher CO2 concentration in the passenger exit corridor is contributed by the narrow passengers waiting to check out. During the Chinese spring travel rush, the CRH train tickets are very difficult to buy and fully loaded. Therefore, the exposure levels to CO2 is in CRH train are highest (CRH train 1: 1365.6ppm, CRH train 2: 1208.1ppm), which produced by passenger breath.

3.2 After Chinese SFTR

The average concentration of VOC, formaldehyde (HCHO), and CO2 in different transportation modes during and after the SFTR are shown in Table 2. The average VOC concentration of five different transport modes range from 0.7 to 2.4mg/m3 during the SFTR, and 0.8-2.8mg/m3 after the SFTR. There are the highest exposure levels to VOC when walking, and it is 2.4mg/m3 (during) and 2.8mg/m3 (after), respectively. Traffic-related VOC, such as hydrocarbons, aromatic hydrocarbons, oxygen-containing hydrocarbons, terpenes, and halogenated compounds, emitted from the gasoline or diesel vehicles. The followings are cars, subway, and CRH train. Also, CRH train 2 has the lowest VOC concentration during the SFTR, and it is 0.7mg/m3. The high speed of CRH trains may promote ventilation to decrease VOC concentration.

Table 2 also shows the comparison of VOC concentrations during and after the SFTR. Affected by the COVID-19, there was less traffic after the SFTR, but the VOC value was higher than during the Spring Festival transportation. The US. Centers for Disease Control and Prevention (CDC) announced that the public spaces should be disinfected regularly using 70% alcohol, which can affect the monitoring value of VOC and increased the volume of VOC in the air. Also, the concentrations of benzene, toluene, xylene, ethylbenzene, formaldehyde, acetaldehyde, acetone, and acrolein inside new cars were significantly greater than those inside old vehicles[12]. Therefore, the VOC concentration in the new car used after the SFTR is higher than the old one as Table 2 shows.

Both CEPA and WHO offer the guideline of HCHO, and the limit value is not greater than 0.1mg/m3 (30-minute average concentration). In this study, the average HCHO concentration is 0.41 mg/m3 ranging from 0 to 0.64 mg/m3 in a new car, which is about 4 times the guideline. Because the material of the car seat and its cover is leather, artificial leather, or textile, which can contribute to high HCHO in a new car[13]. Besides, HCHO, as one of the most serious air pollutants, can induce lung function as well as including nasopharyngeal cancer and myeloid leukemia in humans [14].

The CRH train is one of the best choices when commuting on a mid-haul trip, and the seats are fully loaded during and after the SFTR. Whether during or after the SFTR, the CO2 generated from passenger breath is the highest in CRH trains compared with other modes. According to WHO’s regulations, people are supposed to maintain at least 1-meter (3 feet) distance each other during the impact of COVID-19.
Besides, enterprise resumption and student return to school are carried out in batches, so compared with the Spring Festival traffic, the number of passengers has been greatly reduced. Therefore, it is the lowest CO\textsubscript{2} concentration exposure when walking after the SFTR as shown in Table 2.

**Table 2 Comparison of the average concentration of VOC and CO\textsubscript{2} during and after the Chinese SFTR**

| Transport modes | VOC (mg·m\textsuperscript{-3}) | CO\textsubscript{2} (ppm) | HCHO |
|-----------------|-------------------------------|--------------------------|------|
|                 | during | after | during | after | during | after |
| CRH train 1     | 1.0±0.8 (0.5, 4.3) | 0.8±0.7 (0.4, 2.3) | 1365.6±199.5 (528.0, 1850.0) | 0.8±0.7 (0.4, 2.3) | 751.4±92.7 (503.0, 840.0) | 0.01±0.02 (0.00, 0.11) |
| Walking         | 2.4±0.1 (2.3, 2.7) | 2.8±0.8 (2.3, 2.9) | 509.6±175.1 (368.0, 937.0) | 2.8±0.8 (2.3, 2.9) | 452.9±13.7 (439.0, 478.0) | 0.04±0.04 (0.00, 0.09) |
| Subway          | 1.0±0.7 (0.3, 2.2) | 2.4±0.2 (2.2, 2.3) | 833.1±411.5 (357.0, 2601.0) | 2.4±0.2 (2.2, 2.3) | 510.3±64.6 (434.0, 599.0) | 0.02±0.03 (0.00, 0.13) |
| CRH train 2     | 0.7±0.4 (0.1, 2.2) | 2.7±0.1 (2.6, 3.0) | 1208.1±462.5 (357.0, 2601.0) | 2.7±0.1 (2.6, 3.0) | 827.4±317.4 (434.0, 1414.0) | 0.02±0.02 (0.00, 0.08) |
| Bus             | 1.6±0.8 (0.4, 2.7) | - | 1163.7±331.0 (373.0, 1697.0) | - | - | 0.05±0.04 (0.00, 0.12) |
| Car             | 1.6±1.3 (0.0, 4.3) | 2.8±0.1 (2.3, 2.9) | 705.3±218.6 (305.0, 1151.0) | 2.8±0.1 (2.3, 2.9) | 670.6±117.2 (503.0, 876.0) | 0.03±0.03 (0.00, 0.10) |

**4. Discussion and Conclusions**

This research studies the personal air pollutants exposure of commuter under five different modes of transportation during the SFTR, namely CRH train1, CRH train2, subway, bus, car, walk. The results indicate that the personal exposure levels to VOCs and HCHO in CRH trains are the lowest and relatively stable. Affected by the interior decoration materials, the HCHO inside the new passenger car is 4 times that of the WHO-guideline. During the COVID-19 outbreak, spraying 70% alcohol for disinfection in public spaces significantly increased the personal exposure to VOCs.

However, it should be noted that our study has several limitations. First, the type of VOCs is not refined in this study. Second, wind speed and wind direction are not considered, which may have an impact on the concentration of pollutants. Besides, the proportion of workers and students among passengers is not calculated, and studying their departure and destination has a certain significance for the spread of COVID-19.

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