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# Appraisal of Public Health Responses Exposure to Air and Noise Pollution from Diverse Modes of Transportation in an Urban Context

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**Abstract**

This research looked at commuter exposure to respirable suspended particles ($PM_{10}$ and $PM_{2.5}$), particle counts, gaseous pollutants as TVOC, HCHO, and carbon monoxide (CO), and onsite noise levels in Chattogram city. In 8 important urban routes of Chattogram city, sampling was undertaken in 8 prominent commuting modes (bus, minibus, 3-wheeler, rickshaw, CNG, car, motorbike, rail, and boat). A total of 116 people of various ages and sexes provided health responses (in terms of body temperature, oxygen saturation level, blood pressure, and heart rate). The spearman rank correlation method was used to do correlation analysis in Origin Pro 2021b (95% confidence interval). The study found that Bus, rickshaw, CNG, and 3-wheeler are the most polluted modes of transportation, while boat and train are less polluted options. The ventilation condition of the mode of transportation has an impact on the in-vehicle level. The noise level was likewise over the acceptable range. Different modes of transportation show a substantial positive correlation with oxygen saturation and blood pressure. The exposure level is unaffected by driving time. Unwanted noise levels are a result of poor urban design, machinery, and transportation. The principal reasons of high in-car emissions in some public transit journeys are assumed to be weak vehicle emission controls, poor vehicle maintenance, and slow moving traffic with multiple pauses.

***Keywords:*** *Particulate matter; transportation modes; health response; correlation.*

## 1 Introduction

Transport is a major and escalating contributor to global air pollution, with vehicle-related greenhouse gas emissions surging especially in low-income & middle-income countries. Except for a few exceptions, all modes of transportation emit air pollution as a result of the combustion of liquid fossil fuels (Colvile et al., 2001). Again, high level of air pollution is directly linked with high rate of mortality and shortened life expectancy (Zhai & Wolff, 2021). People who live within 300 meters of a busy road are more likely to be exposed to higher levels of pollutants such as particulate matter, carbon monoxide, and nitrogen oxide (Zhu et al., 2002). Cepeda et al. (2021) drew the conclusion in a study comparing air pollution exposure and inhalation, that motorists and mass transit commuters are more exposed than cyclists and pedestrians. However, some studies suggest that the concentration of $N0_2$ is higher in buses than in cars due to in vehicle sources (Kingham et al., 2013). Similarly other studies reveal that the level of ultra-fine particles (UFA's) is more in bus than in cars (Peretz et al., 2008). The CO exposure level inside the car was 2–3 times higher than that recorded in other modes of transportation, such as bus, subway, and walking (Chan et al., 2002). In case of particulate matter, the exposure of cyclists were significantly lower than the levels found inside buses (Int et al., 2010). In China, when compared to roadway transportation systems, especially buses, the Beijing subway system had greater averaged PMC and PNC (Yan et al., 2015) . PNC is regarded as one of the most significant sources of particles in the urban environment. A substantial body of literature suggests that noise from traffic has a negative impact on one's health and well-being. (Boogaard et al., 2009) Considered the co-relation between noise and air for 11 Dutch cities and it seem that noise pollution and ambient air pollution is fluctuating at a certain place. The correlation between Noise level with Particle Number Concentration (PNC) and $PM_{2.5}$ is found moderate (0.34) and low (0.009), respectively (Boogaard et al., 2009). A total of 85 bicycle journeys were examined, in a study of Montreal where 70.5 dB(A) was the average exposure level after roughly collecting 25 hours of data (Apparicio et al., 2016a). Noise level is also linked with the vehicle speed such. A study in Saudi Arabia represent that the sound level is 59.4dB when vehicle is at normal speed whereas at idle speed the sound level becomes 50.4dB (AlQdah, 2013). In Tehran, 8.79% of 78 land uses (residential, recreational, and medical) were subjected to a permissible sound pressure level range, while the rest are subjected to unacceptable noise levels (Monazzam & Karimi, 2014). Due to potential high levels of exposure to air pollution, road noise, and high traffic congestion, different modes of transportation may be related with health and safety issues (Apparicio et al., 2016b). Almost 70% air pollution is produced to the environment by transport factor (Shrivastava et al., 2013). Daily commutes can have a disproportionately high impact on overall daily exposure to pollution concentrations in urban air and factors like enormous number of automobiles, decreased road capacity, and insufficient investment in public transportation, rises the amount of pollutants in air (Desouza et al., 2021). Potentially relevant exposure includes ultrafine particles, fine particles ($PM_{2.5}$), toxic gases and noise. Numerous studies have examined pollution levels in various transportation modes, but there is a lack of research illustrating the specific impact of the in-vehicle environment on human health, especially in the context of a developing country. Therefore, the primary aim of this study is set to determine the most eco-friendly transportation modes in Chattogram city and investigate their impact on human health in various transportation options.

## 2 Methods and Materials

Chattogram City (22.3569° N and 91.7832° E) is Bangladesh's second largest city and financial capital, with an area of approximately 155.4 $km^2$ and a population of 73 million people (ChCC, 2021). The number of vehicles on the road is increasing in tandem with the rapid urbanization of the Chattogram City Corporation Area. There are 2802 roads in the city area, with 1056 asphalt roads, 1055 concrete roads, 359 brick soling roads, and 332 Kacha roads (ChCC, 2021). The increased number of motor vehicles on these roads has resulted in substantial air and noise pollution in Chattogram City. In this paper concentrations of the major traffic related pollutants were monitored namely: particulate matter concentrations (those smaller than 10 μm, $PM_{10}$; those smaller than 2.5 μm, $PM_{2.5}$;, four gaseous pollutants (CO, $CO_2$, TVOC, HCHO), and two climatic parameter (Temperature & Humidity) were collected from eight (8) major travel modes from their origin to destination (O-D) path (see Table 1) within December, 2022 to February, 2023.

Table 1. Data collection details of the travel modes with their Origin-Destination (O-D).

| Travel Modes | Origin-Destination (O-D) | Time Duration |
|---|---|---|
| **Bus** | GEC –New market | 12.51 pm-1.47 pm |
| **Minibus** | GEC-Bohardarhat | 10.27 am-11.02 am |
| **Car** | Lalkhan Bazar-chawkbazar | 02.53 pm-03.35 pm |
| **CNG** | 2 No gate-agrabad | 02.01 pm-02.30 pm |
| **Three wheeler** | Khulhi-GEC | 10.18 am-11.37 am |
| **Motor Bike** | Muradpur -Khulshi | 12.09 pm-12.48 pm |
| **Rickshaw** | Khulshi R/A | 02.42 pm-03.25 pm |
| **Train** | New market-Sholashohor Rail | 11.49 am-12.25 pm |
| **Boat** | Karnaphuli River | 10.21 am-11.03 am |

Box plot and other statistical analysis were carried out using SPSS v23 in order to assess pollution levels. The concentration of the pollutants compared with standards (BECR, 1997; CASE-DoE, 2018; Goh et al., 2016; WHO, 1997). Thus, the most environmentally hazardous modes of transportation are also identified. Finally, Correlation plot and was used to determine the correlation between the variables in Origin Pro 2021b.

## 3 Results and Discussion

### 3.1 Variation of Pollution Parameters in Different Transportation Modes

Variation of particulate matters in various transportation modes collected along the urban road are shown in figure 1 (a-c). It can be stated from the figure that both the particulate matters ($PM_{2.5}$ and $PM_{10}$) shows the same trend. Boxplot of different transport mode exposure result shows that the rickshaws were the most exposed transport with the highest mean concentration of $PM_{2.5}$ of 230 μg/$m^3$ and $PM_{10}$ of 250 μg/$m^3$ respectively. The lowest exposure was the car among all the transport modes along road with a mean $PM_{2.5}$ of 165 μg/$m^3$ and mean $PM_{10}$ of 220 μg/$m^3$. Bus, Mini Bus and CNG like other travel mode rickshaw seem to have highest exposure due to open window. The concentration of particulate matter in the waterway travel mode (Boat) is shown to be less variable, with a high level of $PM_{2.5}$. Numbers of particles is higher in boat compared with other transportation mode. Numbers of particles found in this study is almost negligible for mini-bus, car and CNG. Other transport mode like bus, train, rickshaw & 3-wheeler have a concentration ranging from 20000 to 30000 Count/L. Motorbike have a mean concentration of about 30000 Count/L during their travel time. The spatial variation of gaseous pollutant for different transportation mode are shown in the figure 1(d-f). The different means of transportation mode for the three gaseous pollutants does not show the same trend. 3-wheeler has the highest exposure in case of TVOC but has the lowest exposure for HCHO. The minimum value of HCHO for the different mode of transport is approximately 10 mgm$^{-3}$. Car have the highest exposure to HCHO of about 42mgm$^{-3}$. Other transportation mode like bus, mini-bus, CNG, motor-bike, train have very little variations for HCHO during their travel time. The highest $CO_2$ concentration is observed in the rickshaw, with an average of about 2200 ppm. The Motor Bike and Train follow with relatively elevated $CO_2$ levels. In contrast, most other transportation modes show $CO_2$ concentrations ranging between 1200 ppm to 1600 ppm on average. The data collected for the eight modes of transportation indicated that noise levels exceeded the World Health Organization's recommended limits of 55dB during the day and 40dB at night. The Train recorded the highest noise exposure, while the Rickshaw had the lowest noise levels (see figure 1g). The noise levels for cars and CNG vehicles were relatively similar, whereas the rest of the transportation modes ranged between 75dB and 80dB.

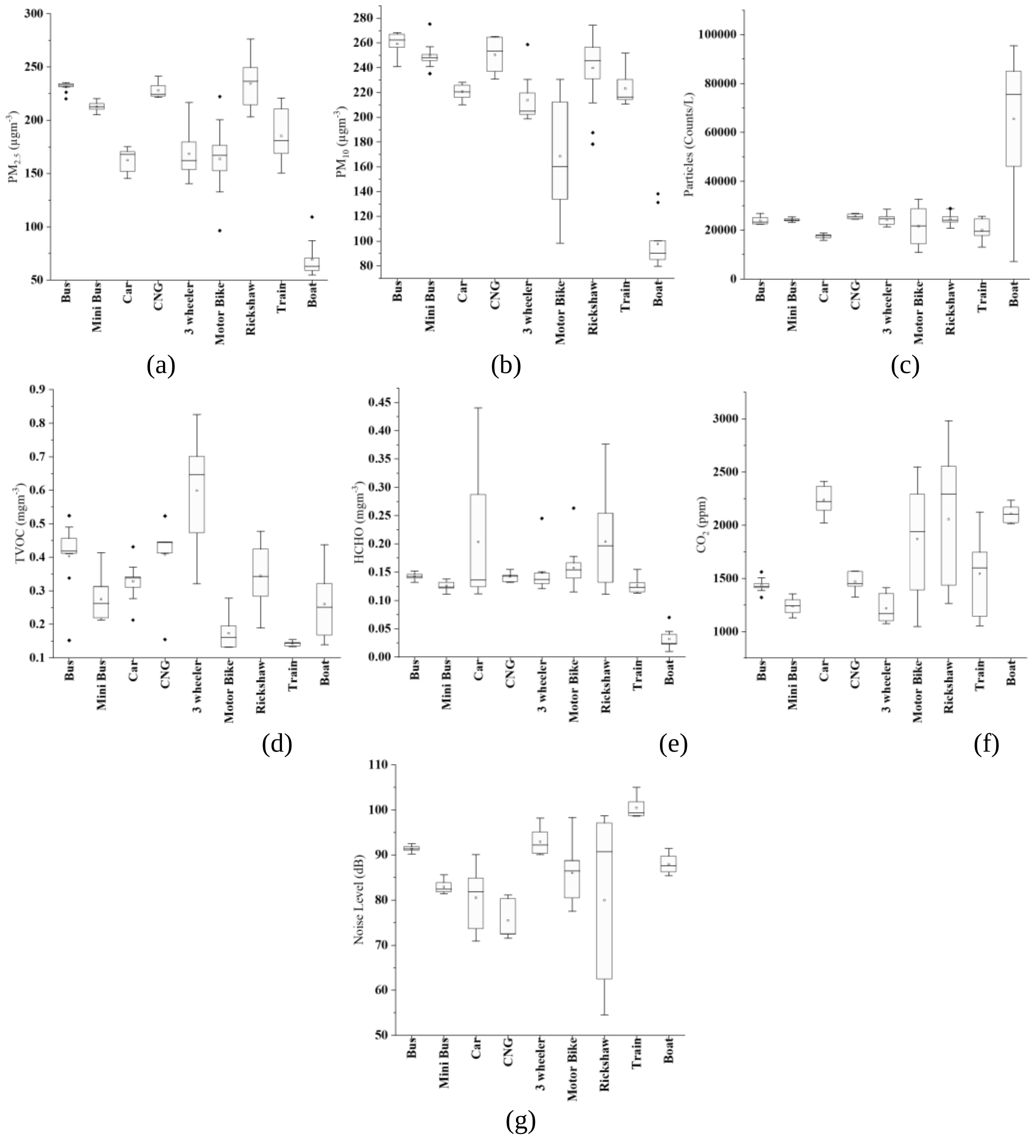


Figure 1. Variations of pollution parameters in different modes of transportation in Chattogram city (a) $PM_{2.5}$, (b) $PM_{10}$, (c) Particle Counts, (d) TVOC, (e) HCHO, (f) $CO_2$, (g) Noise level

**3.2 Variation of Weather Parameters in Different Transportation Modes**

In Figure 2, box plots illustrate the fluctuations in relative humidity (RH), temperature, total rainfall, and wind speed across the eight transportation modes. The temperature varies between 23°C and 27°C (see figure 1a), with CNG having the lowest temperature, while 3-wheeler, Motor Bike, Rickshaw, and Car maintain an average temperature of around 27°C. However, wind speed and light intensity do not follow the same patterns as temperature. There are slight exceptions in these cases. Motor Bike shows significant variation in wind speed during its travel time, averaging at 17m/min. Conversely, Bus, Mini-Bus, CNG, Rickshaw, and Boat demonstrate negligible variation in wind speed.

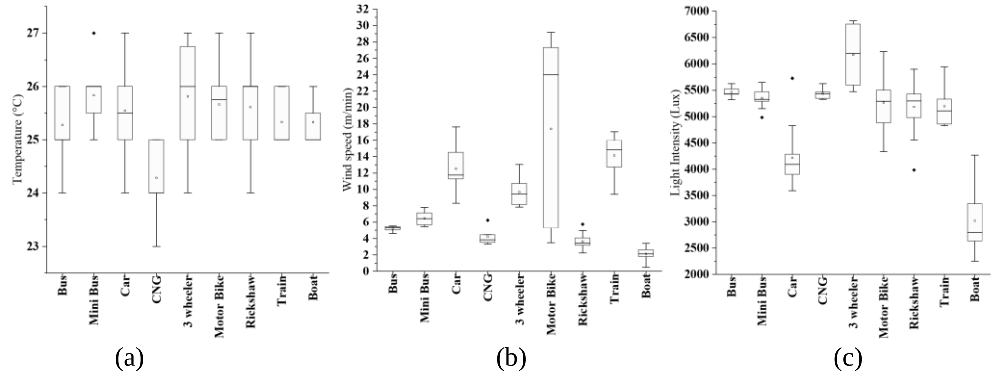


Figure 2. Variations of weather parameters in different modes of transportation in Chattogram city (a) Temperature; (b) Wind speed and (c) Light intensity

Cars and Trains also exhibit slight variation during their travel time. There are no noticeable fluctuations regarding light intensity for Bus, Mini-Bus, and Car. Among the transportation modes, 3-wheeler displays the highest variation with a mean light intensity of 6250Lux. Train, Rickshaw, and Motor Bike have minimum variation in light intensity, ranging from 4500 Lux to 6250 Lux. The waterway transportation mode, Boat, exhibits the lowest light intensity.

### 3.3 Variation of Pollution Human Health Responses in Different Transportation Modes

Figure 3 depicts the variation in human body temperature across different transportation modes, ranging from 29°C to 37°C (see figure 3a). Notably, the Motor Bike shows the highest body temperature among all the modes. Motor Bike stands out with the highest oxygen level of 95% $SpO_2$ (see figure 3b).

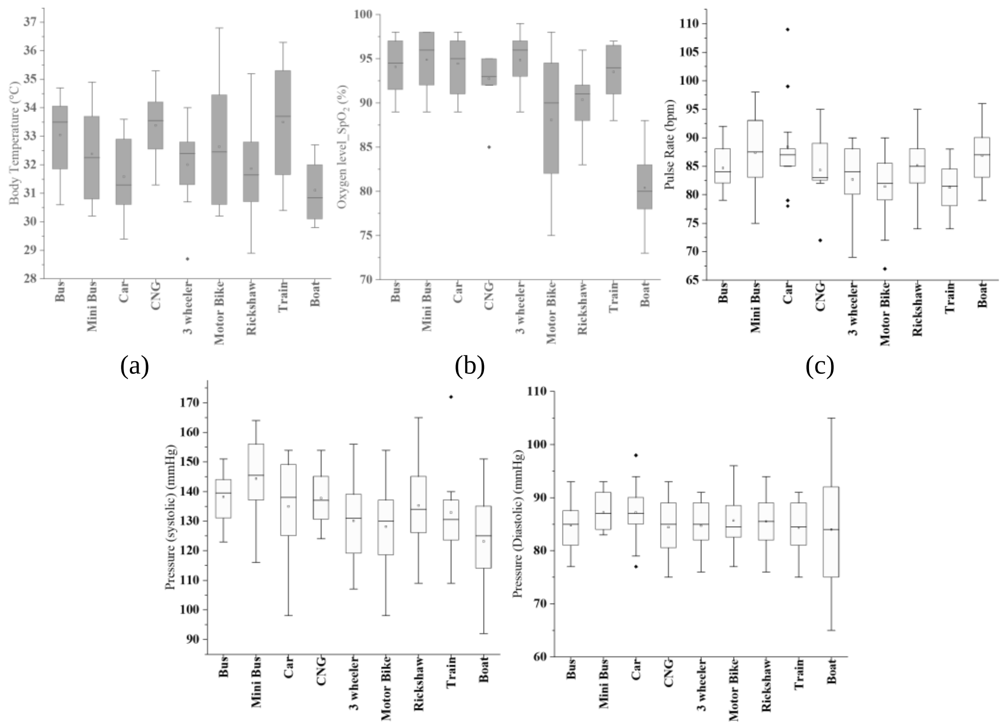


Figure 3. Variations of Human responses in different modes of transportation in Chattogram city (a) body temperature, (b)Oxygen level, (c) Pulse rate, (d) pressure (systolic), (e) Pressure (diastolic)

Interestingly, Boat shows a similar pattern in both body temperature and oxygen level, but the oxygen level is notably lower, ranging from 72.5% to 82.5% $SpO_2$. Regarding pulse rate, individuals riding in the Mini Bus display the highest pulse rate compared to other modes, while the variation in pulse rate for Car riders is minimal. For 3-wheeler, Motorbike, Rickshaw, Train, and Boat, the pulse rate falls between 70Bpm to 95Bpm (see figure 3c). The study reveals an inverse relationship between systolic and diastolic blood pressure patterns. People traveling in boats seem to have higher diastolic pressure, ranging between 65mmHg to 100mmHg, while other transportation modes show associations with diastolic pressure ranging from 75mmHg to 95mmHg. Notably, Mini Bus and Rickshaw are strongly associated with higher systolic blood pressure, while Train exhibits the lowest systolic blood pressure exposure.

### 3.4 Correlation and Principle Component analysis

The correlation plot in Figure 4 illustrates the relationship between vehicle types, various air pollutants, and meteorological parameters. It shows that the types of vehicles are notably correlated with oxygen levels and systolic pressure which indicates that the choice of transportation mode seems to have an impact on the oxygen level and the systolic blood pressure of people using those vehicles. Similar relationship is also seen with air pollutants and meteorological parameters. Again, concentration of $PM_{2.5}$ is significantly associated with systolic pressure and oxygen level and noteworthy negative correlation is observed between other pollutants. $PM_{10}$ is highly correlated with body temperature and the correlation with oxygen level, systolic pressure and noise level are in the positive range. Gaseous pollutants are also negatively correlated with ambient air particulate matter and weather parameters. A strong correlation is observed between body temperature and weather parameter temperature. Particle Nos show the same correlation as $PM_{10}$. However, No correlation is observed between diastolic and gaseous or air pollutant.

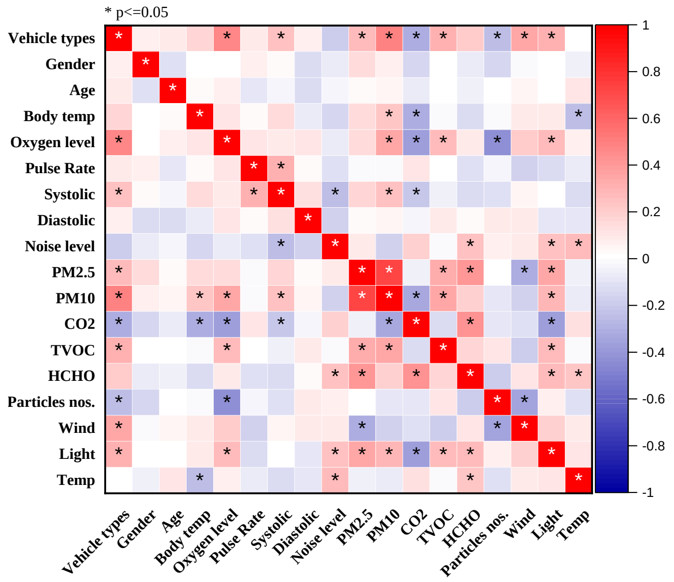


Figure 4. Correlation plot among human health responses, pollution parameters and weather parameters.

### 4 Conclusion

This analysis has offered a detailed investigation of pollution status of different transportation modes and the impacts of air pollutants on human health response in vehicle environment in Chattogram City. Roadside sources, industries and other construction activities have contributed to high PM concentrations and other air pollutants in roadside environment. Bus, rickshaw, CNG, and 3-wheeler are identified as the most polluted transportation modes, while boat and train are considered less polluted transportation options. Interestingly, despite being less polluted, boat and train still have significantly high concentrations of $CO_2$. The correlation between vehicle types and oxygen levels, systolic pressure, air pollutants, and meteorological parameters suggests that transportation choices influence the oxygen level and systolic blood pressure of individuals, with $PM_{2.5}$ concentration showing a significant association and other pollutants displaying noteworthy negative correlations. The decrease in vehicle-to-vehicle distance and the increase in emission source strength are two examples of such repercussions. As a result, control measures such as better traffic management, vehicle maintenance, and the acceleration of vehicle emission control regulations to worldwide standards should all be promoted at the same time.

### References

AlQdah, K. S. (2013). Experimental investigation of noise pollution level emerged from the most common use car in Saudi Arabia. Energy Procedia, 36, 939–947. https://doi.org/10.1016/j.egypro.2013.07.107

Apparicio, P., Carrier, M., Gelb, J., Séguin, A., & Kingham, S. (2016a). Cyclists ’ exposure to air pollution and road traffi noise in central city neighbourhoods of Montreal. Journal of Transport Geography (JTRG), Vol. 57, No. 2016, pp. 63–69. https://doi.org/10.1016/j.jtrangeo.2016.09.014

BECR. (1997). The Environment Conservation Rules, 1997. Bangladesh Department of Environment, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, pp. 179–227.

Boogaard, H., Borgman, F., Kamminga, J., & Hoek, G. (2009). Exposure to ultrafine and fine particles and noise during cycling and driving in 11 Dutch cities. Atmospheric Environment, Vol. 43, No. 27, pp. 4234–4242. https://doi.org/10.1016/j.atmosenv.2009.05.035

CASE-DoE. (2018). Ambient Air Quality in Bangladesh. In Clean Air and Sustainable Environment (CASE) Project, Department of Environment, Government of Bangladesh. http://case.doe.gov.bd/

Cepeda, M., Schoufour, J., Freak-poli, R., Koolhaas, C. M., Dhana, K., Bramer, W. M., & Franco, O. H. (n.d.). Levels of ambient air pollution according to mode of transport : a systematic review. The Lancet Public Health, Vol. 2, No. 1, pp. e23–e34. https://doi.org/10.1016/S2468-2667(16)30021-4

Chan, L. Y., Lau, W. L., Zou, S. C., Cao, Z. X., & Lai, S. C. (2002). Exposure level of carbon monoxide and respirable suspended particulate in public transportation modes while commuting in urban area of Guangzhou , China. Vol. 36, pp. 5831–5840.

ChCC. (2021). Media Brief of ChCC. Chattogram City Corporation. https://www.ccc.org.bd/media_brief

Colvile, R. N., Hutchinson, E. J., Mindell, J. S., & Warren, R. F. (2001). The transport sector as a source of air pollution. Atmospheric Environment, Vol. 35, No. 9, pp. 1537-1565. https://doi.org/10.1016/S1352-2310(00)00551-3

Desouza, P., Lu, R., Kinney, P., & Zheng, S. (2021). Exposures to multiple air pollutants while commuting: Evidence from Zhengzhou, China. Atmospheric Environment, Vol. 247, No. 118168, pp. 1-9. https://doi.org/10.1016/j.atmosenv.2020.118168

Goh, C. C., Kamarudin, L. M., Shukri, S., Abdullah, N. S., & Zakaria, A. (2016). Monitoring of carbon dioxide (CO2) accumulation in vehicle cabin. 3rd International Conference on Electronic Design, ICED 2016, June 2016, pp. 427–432. https://doi.org/10.1109/ICED.2016.7804682

Int, L., Geus, B. De, Vandenbulcke, G., Willems, H., Degraeuwe, B., Bleux, N., Mishra, V., Thomas, I., & Meeusen, R. (2010). Exposure to particulate matter in traffic : A comparison of cyclists and car passengers. Vol. 44, No. 19, pp. 2263-2270. https://doi.org/10.1016/j.atmosenv.2010.04.028

Kingham, S., Longley, I., Salmond, J., & Pattinson, W. (2013). Variations in exposure to traf fi c pollution while travelling by different modes in a low density , less congested city. Environmental Pollution, Vol. 181, pp. 211–218. https://doi.org/10.1016/j.envpol.2013.06.030

Monazzam, M. R., & Karimi, E. (2014). Outdoor Noise Pollution Mapping Case Study of Tehran. Fluctuation and Noise Letters, Vol. 13, No. 4, pp. 1–16. https://doi.org/10.1142/S0219477514500278

Peretz, A., Kaufman, J. D., Trenga, C. A., Allen, J., Carlsten, C., Aulet, M. R., Adar, S. D., & Sullivan, J. H. (2008). Effects of diesel exhaust inhalation on heart rate variability in human volunteers. Environmental Research, Vol. 107, No.2, pp. 178–184. https://doi.org/10.1016/j.envres.2008.01.012

Shrivastava, R., Neeta, S., & Geeta, G. (2013). Air pollution due to road transportation in India: A review on assessment and reduction strategies. Journal of Environmental Research And Development, 8(1), 69–77.

WHO. (1997). World Health Organization, Assessment of exposure to indoor air pollutants. https://www.euro.who.int/

Yan, C., Zheng, M., Yang, Q., Zhang, Q., Qiu, X., Zhang, Y., Fu, H., Li, X., Zhu, T., & Zhu, Y. (2015). Commuter exposure to particulate matter and particle-bound PAHs in three transportation modes in Beijing, China. Environmental Pollution, Vol. 204, pp. 199–206. https://doi.org/10.1016/ j.envpol.2015.05.001

Zhai, M., & Wolff, H. (2021). Air pollution and urban road transport: evidence from the world's largest low-emission zone in London. Environmental Economics and Policy Studies, Vol. 23, No. 4, pp. 721–748. https://doi.org/10.1007/s10018-021-00307-9

Zhu, Y., Hinds, W. C., Kim, S., & Sioutas, C. (2002). Concentration and size distribution of ultrafine particles near a major highway. Journal of the Air and Waste Management Association, Vol. 52, No. 9, pp. 1032-1042. https://doi.org/10.1080/10473289.2002.10470842