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AIR POLLUTION AND TRAFFIC MEASUREMENTS WITHIN UNIVERSITY AREAS IN SERDANG, MALAYSIA

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ABSTRACT

Objective: To assess levels of traffic-related air pollution ($PM_{2.5}$, PM_{10} and ozone (O_3)) along designated walking area at three rush hours within university campus. **Method:** Particulates and gaseous concentrations ($PM_{2.5}$, PM_{10} and ozone (O_3)) were measured on two walking routes in a designed circuit (Route 1 and Route 2) in a university campus. Route 1 (R1) is located within academic area and Route 2 (R2) is located nearby residential colleges. All measurements were made in separated days at different traffic peaks (morning, afternoon and evening). Researcher carried handheld instruments including Dust Trak II to measure PM_{10}. Aeroqual S500 and SidePak were used to measure O_3 and $PM_{2.5}$ levels respectively were fitted at the side pockets of researcher's backpack. Vehicles traffic count were conducted simultaneously during the sampling exercises along the designated walking circuit at R1 and R2 respectively. **Result:** Maximum average of $PM_{2.5}$ (51.2 ± 12.1 µg/m^3) and PM_{10} (94.7 ± 27.7 µg/m^3) were recorded during morning commute at R1. In contrast, both levels of $PM_{2.5}$ and PM_{10} were recorded highest during evening commute within R2. Mean O_3 showed highest levels during afternoon and evening for R1 and R2 respectively. Traffic count showed the highest number of vehicles using R1 during morning rush hour (N=234) compared to R2 (N=164). This study found higher traffic volumes were significantly associated with increased of PM_{10} concentrations ($r = 0.65$, $p<0.05$) at R2. Strong correlations were observed between $PM_{2.5}$ and PM_{10} concentrations observed at both sampling routes ($r >0.8$). **Conclusion:** The findings should encourage the university management to reduce the use of vehicles around campus areas and promote walking as alternative to reduce emissions of traffic-related air pollutants. Therefore, of these will highlight the needs to improve pedestrian facility in the campus areas.

Keywords: *Traffic-Related Air Pollution (TRAP), Respiratory Symptoms, Pedestrian*

1. Introduction

Globally it has been reported that three million deaths occur every year from exposure to air pollution (WHO, 2016). It is estimated about 4.2 million deaths occurred in low or middle income countries due to the chronic respiratory disease such as asthma and chronic obstructive pulmonary disease (COPD) resulted from rapid urbanization that affected the air quality (Sylla, Faye, Fall, & Tal-dia, 2017). More people are moving to urban areas and caused more usage of vehicles, therefore the urban population may expose to high levels of traffic related air pollution. Apart from number of vehicles, route chosen, street canyon, presence of trees, vehicles that emitted diesels and high-rise building could prevent the process of diluting the exhaust emission from on-road to roadside. Meteorological factors such as wind speed, temperature and relative humidity also influences the distribution of the pollution (Qiu et al., 2017).

Pollutants such as particulate matter (PM) and ozone (O_3) are some of the components of pollutants that are emitted from the vehicles. PM are particles and droplets that existed in the air and having various size and characteristics. In local study conducted at residential areas in urban Kuala Lumpur found 28% of PM_{10} concentrations were from vehicle emissions source (Khan et al., 2015). These particles could impact the respiratory system as it can enter the lungs and bloodstream (Fung, 2016). Ozone (O_3) is secondary pollutant which formed from chemical reaction of nitrogen dioxide (NO_2), volatile organic compounds (VOCs) with the presence of lights.

Tao et al. (2014) found PM_{10} were statistically significant with hospital admission for respiratory disease. Their study reported that an increase of pollutants by 10 µg/m^3 could cause about 0.2 – 1.1% higher respiratory admission to hospital. Arbex et al. (2012) had observed that one day lag could result in 11.6% increased of patients being hospitalized when they exposed to 10 µg/m^3 increased of PM. Long-term exposure to the pollutants could result in hospital admission for respiratory disease (Samoli et al., 2016; Tao, Mi, Zhou, Wang, & Xie, 2014). Exposure to traffic-related air pollution is suggests contribute to higher risk of having respiratory tract disease compared to other types of pollution (Q. Liu et al., 2017). Short-term exposure to traffic pollution could cause people to experience symptoms such as difficulties of breathing, chest pain and inflammation of the respiratory airways.

Currently, there are limited number of studies reported the exposure of traffic-related air pollution (TRAP) among active travelers compared to vehicles users. Active travel is defined as activities that involved physical activity moving from one place to another such as walking and cycling. This activity is widely known to give a lot of benefit not only to the person but also to the environment in which will reduce number of vehicles on the road and increase the air quality. Few countries in the Europe and United States are promoting their citizens to do active travel, nonetheless it is important to study their exposure to the air pollution especially pollutants emitted from traffic vehicles (Mueller et al., 2015).

Apart from exposure to high levels of TRAP, socio-demographics of the respondents also could affect their response to the pollution. Although exposed to same levels of pollution, male and female would response differently as female were found to be more susceptible to the exposure of TRAP (Yin et al., 2017) and developed Chronic Obstructive Pulmonary Disease (COPD) (Tao et al., 2014). Younger people also have higher tendency to develop respiratory-related problems compared to adults.

Commuting near roadside may allow people to have high exposure to pollution. According to Hankey (2014), commuting by active traveling caused people to have highest exposure to air pollution as compared to vehicles users. W.-T. Liu et al. (2015) reported that pedestrians were exposed about 4.7 times higher of PM_{10} and 2.2 times higher of $PM_{2.5}$ concentration when compared to bus passengers, car drivers and subway users. Nyhan, McNabola, & Misstear (2013) found higher concentrations of particulates being exposed to active commuters such as pedestrian and cyclists. Therefore, it is important to provide a baseline data of TRAP exposures among pedestrian in order to characterize the exposure to these pollutants.

University areas have unique features of landscape and roadsides. The load of vehicles should be comparatively low within the campus areas. However, a study conducted in one of university located in the central Kuala Lumpur found the use of motor vehicles in the campus may resulted in air quality and noise pollution (Kong et al. 2009). Recent study conducted in university areas had found high levels of benzene concentrations in three campuses located in Bucharest (Popescu and Popescu, 2017). However, little is known about the levels of traffic related air pollutants nearby the roadsides across university campuses. This is important to promote sustainable green campus in connection with transportation mode taken by the staff and student.

In short, our aim is to determine levels of traffic-related air pollution ($PM_{2.5}$, PM_{10} and ozone (O_3)) along different walking areas in university campus areas. This study simulated measured levels of TRAP being exposed to active commuter in three rush hour periods; morning, afternoon and evening. We also included traffic count measurements at main roadside along designated walking areas.

2. Materials and Method

2.1. Study design and location

Sampling campaign was observed between January and March 2018, involving mobile measurements conducted by a researcher carried a set of air monitoring instruments and walk on the pavement nearby roadsides. The use of portable and handheld sensors to conduct mobile monitoring study is commonly exploited for personal monitoring studies at the vicinity of roadsides. Similar studies were done in different places carrying the monitors along designated sampling route (Cattaneo et al., 2010; Steinle et al., 2015; Wu, Reis, Lin, Beverland, & Heal, 2015).

Measurements took place in University campus areas located in Serdang in state of Selangor and approximately 28 km southeast from central Kuala Lumpur, Malaysia. The university is chosen due to its location nearby main roadsides whereby the traffic flow can be heavily congested during peak hours, therefore might resulted in high levels of traffic emissions. The study areas included two walking routes located nearby academic zone at Route (R1) and student residential areas at Route 2 (R2). Both routes are located in one-way roadsides which connected the main entrance to academic zone and exit at R2, similarly to R1 that connected the main entrance to residential college and exit gate from residential college to the main roadside at Jalan Universiti 1. An overview of walking route can be found in Figure 1.

For each site, researcher carried all sampling equipment and walked in clockwise circuit for three different sampling rush hours; morning (0730-0830), noon (1300-1400) and evening (1700-1800). Researcher started walking from traffic count point and ended the walk at the same point. The circuit walking route for R1 has approximately 1.8 km and for R2 is about 1.4 km. For R1, walking route comprised of Jalan Alpha, Jalan Universiti 1, Persiaran Tulang Daing, Lorong Asam Jawa and Persiaran Asam Jawa. Sampling was conducted along R2 which included Persiaran Tulang Daing, Jalan Sapucaya, Persiaran Asam Jawa and Lorong Asam Jawa 1. All measurements were conducted on separate days for each walking route R1 and R2.

Figure 1 : Map showing sampling route on circuit walking Route 1 (R1 - red dots) and Route 2 (R2 - yellow dots) along university campus areas in Serdang, Malaysia.

2.2. Instrumentation and methods

2.2.1. TRAP Measurement

Mass concentration of $PM_{2.5}$, PM_{10} and O_3 were measured using DustTrak (Model 8532, TSI Incorporated, USA), SidePak (Model AM520, TSI Incorporated, USA) and Aeroqual (Model S500, Aeroqual Ltd, New Zealand). Background measurement were taken 30 minutes before actual measurements were observed. All instruments were placed in a backpack and carried by the researcher along the designated sampling routes (Figure 1). The bagpack was adapted to carry SidePak and Aeroqual and fitted at both side pockets. The Dustrak was carried by the researcher. The data were logged at 1-min interval for each measurement period. All instruments were calibrated before each sampling exercise. All monitoring was conducted during sunny days.

2.2.2. Traffic count

Traffic count was manually performed simultaneously by another researcher at Jalan Sapucaya for R1 and Jalan Alpha for R2 using traffic count sheet adopted from Zheng and Mike (2012). This is to assess relationship between traffic volumes and traffic related air pollutant measurements of PM_{10}, $PM_{2.5}$ and ozone. The type of vehicles was divided in three categories such as light, medium and heavy type of vehicles (Zheng & Mike, 2012). Light vehicles consist of motorcycle, medium for cars and taxis while heavy category comprised of buses and good vehicles.

3. Results

3.1. Measurement of Traffic Related Air Pollutants

Measurement of $PM_{2.5}$, PM_{10} and O_3 for each sampling route (R1 and R2) with traffic count at different rush hour were shown in Table 1 (a) and (b). These included sampling trips for R1 and 17 sampling trips for R2. Highest traffic count was observed at R1 with maximum traffic volumes was during morning traffic count (N=235). This observation followed with highest particulates concentrations measured along the sampling route R1 including $PM_{2.5}$ (51.2 µg/m^3) and PM_{10} (94.7 µg/m^3).

O_3 levels were found highest during afternoon measurements at R1 sampling route. This suggests many vehicles used R1 as the main road to enter and exit student's residential areas during morning rush hour. In contrast, most of particle concentrations ($PM_{2.5}$ and PM_{10}) were found highest during evening commute on sampling route R2. Similar observation was made for O_3 levels which recorded 203.6 µg/m^3. There were moderate levels of $PM_{2.5}$, PM_{10} and O_3 observed during afternoon sampling for both sampling routes.

Table 1 (a) Levels of $PM_{2.5}$, PM_{10} and O_3 with Motor Vehicles Traffic Count (TC) at Route 1 During Peak Hour (am, noon and pm)

RUSH HOUR	n	TC	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	O_3 (µg/m^3)
AM	7	235	**51.2 ± 12.1**	**94.7 ± 27.7**	30.9 ± 7.9
NOON	6	166	31.1 ± 8.0	53.5 ± 16.6	**200.3 ± 124.2**
PM	5	182	26.1 ± 13.9	48.6 ± 21.1	134.2 ± 51.2

Table 1 (b) Levels of $PM_{2.5}$, PM_{10} and O_3 with Motor Vehicles Traffic Count (TC) at Route 2 During Peak Hour (am, noon and pm)

RUSH HOUR	n	TC	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	O_3 (µg/m^3)
AM	6	166	49.5 ± 11.8	88.5 ± 20.6	34.5 ± 4.4
NOON	6	143	36.5 ± 9.1	71.5 ± 16.4	157.6 ± 52.4
PM	5	164	**58.7 ± 9.7**	**103.5 ± 13.8**	**203.6 ± 63.4**

3.2 Vehicles Traffic Count and TRAP Concentrations

To further explore relationships between traffic count and TRAP concentrations at two sampling routes, correlation analysis was shown in Table 2. We observed significant high correlation of traffic count and PM_{10} levels (r = 0.65) at sampling route R1. This indicate levels of PM_{10} were dominated from vehicle emissions nearby student's residential areas. Moderate correlations were observed for both $PM_{2.5}$ and PM_{10} with traffic counts at sampling route R2. We found negative associations measured for O_3 and traffic count at R1. This suggests vehicle emissions did not influence the levels of O_3 within R1.

Table 2 Relationship between Vehicles Count and Pollutants Concentration at Route 1 (R1) and Route 2 (R2)

Pollutant Levels	Traffic counts	
	R1	**R2**
$PM_{2.5}$	0.62*	0.49*
PM_{10}	0.65*	0.48*
O_3	-0.33	0.07

*p-value significant at 0.05 level using Pearson correlation

3.3. Relationships between airborne particulates and O_3

Particulates concentrations (PM_{10} and $PM_{2.5}$) were correlated with O_3 measured at both sampling routes. As shown in Table 3, the correlation coefficient between $PM_{2.5}$ concentrations and PM_{10} was r=0.94 and r=0.85 for sampling route 1 and 2 respectively. This suggests particle mass concentrations of $PM_{2.5}$ may originated from coarse particle PM_{10}. There is weak association between particles mass concentrations and O_3 measurements observed at two sampling routes.

Table 3 Correlation coefficients between $PM_{2.5}$, PM_{10} and O_3 measured at sampling route 1 and 2

Route 1	PM_{10}	O_3
$PM_{2.5}$	0.94	-0.32
PM_{10}	1	-0.33
Route 2	PM_{10}	O_3
$PM_{2.5}$	0.85	0.27
PM_{10}	1	0.32

3.4 Example of TRAP Profiles at 1-min Resolution

Figure 2 shown below are example from dataset collected from measurements of $PM_{2.5}$, PM_{10} and O_3 during walking at Route 1 in February 2018. These profiles illustrating the individual temporal exposure during commuting at designated sampling routes. The increase of O_3 concentrations was observed from few peaks of 1-min trends during walking at Route 1 in different rush hours of morning (am), afternoon (noon) and evening (pm).

The O_3 measurement peaks was fluctuate during the course of monitoring. This may suggest the Aeroqual used by the researcher appear to show drift in detection of O_3 gaseous. The short-term increase of PM_{10} levels were observed during morning walk can be explained as the results of higher volume of vehicles especially few buses entered the student's residential areas along R1 to fetch students and move through Jalan Universiti to the academic zones. Measurements of PM_{10} and $PM_{2.5}$ coincided during all rush hours commutes. For instance, the trends of PM_{10} and $PM_{2.5}$ levels showed similar increased during afternoon walk between 13:42 and 13.44 pm.

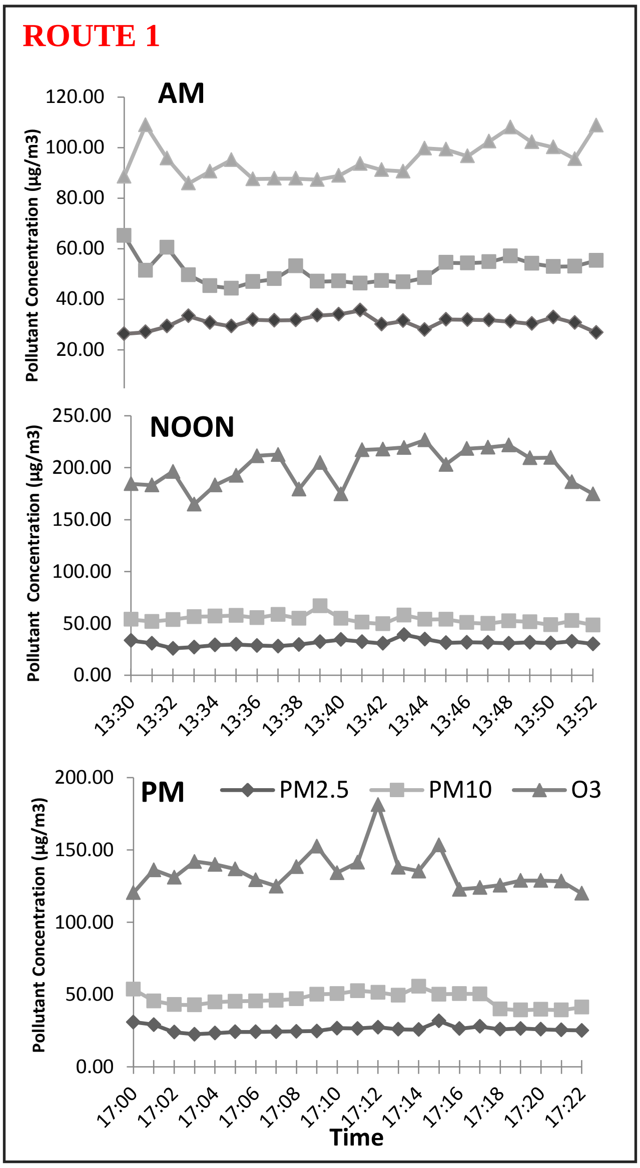

Figure 2 Profiles of $PM_{2.5}$ (◆), PM_{10} (■) and O_3 (▲) from 1-min temporal resolutions at Route 1 in the morning (AM), afternoon (noon) and evening (PM)

4. Discussion

This study recorded real-time traffic related air pollutants ($PM_{2.5}$, PM_{10} and O_3) for two different sampling routes in university areas at three rush hour periods (morning, afternoon and evening). All measured particulates levels showed that both sampling routes were influenced by the traffic volumes resided within the peak hours particularly PM_{10}. Our study found PM_{10} has significant correlation with traffic count (r=0.65) at busy roadside within sampling route 1. This in line with findings from traffic count study conducted in Jordan. Their study found PM_{10} concentrations were highly correlated with traffic count at highly polluted area (r=0.71) (Alnawaiseh, Hashim, & Md Isa, 2015).

Another study conducted by Buonanno, Fuoco, and Stabile (2011) showed PM_{10} dominates the exposure concentrations within their sampling routes during walking on the streets located in the Central Italy. Their study also stated that emission of pollutants such as $PM_{2.5}$ and PM_{10} would increase when the vehicles move in higher speed which made the particles to easily resuspended from road surface. However, in our study the speed limit within the campus area is 35 km/h, therefore the high number of traffic volumes is suggested to contribute to high levels of PM_{10} observed during sampling exercises (maximum R1 = 94.7 $\mu g/m^3$, maximum R2 = 103.5 $\mu g/m^3$). Nonetheless, no significant correlation was found between traffic count and O_3 at both study location. O_3 levels measured were found low in the morning and increased in the afternoon. This in line with study by Leong, Muttamara, & Laortanakul (2002) which found low values of O_3 in the morning. The concentration increased as the UV light intensity increased which it could each highest peak during afternoon rush hour and eventually reduce in late evening. Other factors that affect the dispersion of this pollutants such as presence of NO_x and VOCs and meteorological parameters including wind speed and temperature.

Averaged concentrations of $PM_{2.5}$, PM_{10} and O_3 measured at both sampling routes were found higher than standard set by WHO and Malaysia Ambient Air Quality Standard (MAAQS). Our study will be useful guidance for the university management to set policy of controlling traffic flows within the campus areas. This will reflect to the exposure of TRAP to pedestrian especially to students who are actively commute from their residential areas to the academic zones during peak hours. W.-T. Liu et al. (2015) reported that pedestrian was highly exposed to TRAP compared to other vehicles users. It is estimated that active walkers were 21 times greater exposed to $PM_{2.5}$ inhalation doses compared to the driver if using the same route (Chaney et al., 2017). The use of conventional diesel buses within the university campus should also be revised. This is because diesel bus emitted highest source of PM_{10} and soot (Zuurbier et al., 2010). This might be of interest if findings from this study may be considered by the university management to propose the use of electric shuttle buses.

We acknowledge several limitations in our study. Other meteorological factors such as wind speeds and ambient temperature were not included. Cheng and Li (2010) suggested that high wind speed may influence the increased of $PM_{2.5}$ and PM_{10} in which formed under resuspension of airborne particulates under dispersion state. The individual's total exposure should be taken into account in the future study. This will demonstrate a complete heterogeneity of spatial and activities for active commuters such as pedestrian and cyclist daily exposure to traffic-related air pollution. The use of geospatial system using geo-coded will provide comprehensive snapshot of individual or general population total exposure. Additional TRAP metric such as black carbon (BC) and nitrogen dioxide (NO_2) should be included in the future study. BC and NO_2 has been found to be consistent indicator for diesel exhaust emissions (Ezani et al., 2018), therefore of these will better characterize the exposure to TRAP.

5. Conclusion

This study highlights the important influence of traffic volumes on variations in traffic-related air pollutants concentrations such as $PM_{2.5}$, PM_{10} and O_3. In conclusion, pedestrian was exposed to high levels of traffic pollution during commuting around campus area. Airborne particulates air pollutants were found dominant in both academic zones and residential college within university campus areas. University management should also take into consideration to limit the number of vehicles coming into or out from campus areas and promote active commutes to the university staff and students. However, the pedestrian facility within the campus should also be improved by the university management.

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References

Alnawaiseh, N. A., Hashim, J. H., Isa, Z. M., & Salahat, S. J. (2014). Respiratory Symptoms from Particulate Air Pollution Related to Vehicle Traffic in Amman, Jordan. European Journal of Scientific Research, 120(4), 550-563.

Arbex, M. A., Santos, U. D. P., Martins, L. C., Saldiva, P. H. N., Pereira, L. A. A., & Braga, A. L. F. (2012). Air pollution and the respiratory system. Jornal Brasileiro de Pneumologia, 38(5), 643-655.

Buonanno, G., Fuoco, F. C., & Stabile, L. (2011). Influential parameters on particle exposure of pedestrians in urban microenvironments. *Atmospheric Environment, 45*(7), 1434-1443. doi:https://doi.org/10.1016/j.atmosenv.2010.12.015

Brugha, R., & Grigg, J. (2014). Urban Air Pollution and Respiratory Infections. *Paediatric Respiratory Reviews*, *15*(2), 194–199. https://doi.org/10.1016/j.prrv.2014.03.001

Chaney, R. A., Sloan, C. D., Cooper, V. C., Robinson, D. R., Hendrickson, N. R., McCord, T. A., & Johnston, J. D. (2017). Personal exposure to fine particulate air pollution while commuting: An examination of six transport modes on an urban arterial roadway. *PLoS ONE, 12*(11), e0188053. doi:10.1371/journal.pone.0188053

Cheng, Y.-H., & Li, Y.-S. (2010). Influences of Traffic Emissions and Meteorological Conditions on Ambient PM10 and PM2.5 Levels at a Highway Toll Station. *Aerosol and air quality research, 10*(5), 456-462. doi:10.4209/aaqr.2010.04.0025

Cattaneo, A., Taronna, M., Garramone, G., Peruzzo, C., Schlitt, C., Consonni, D., & Cavallo, D. M. (2010). Comparison between Personal and Individual Exposure to Urban Air Pollutants. *Aerosol Science and Technology, 44*(5), 370-379. doi:10.1080/02786821003662934

Ezani, E., Masey, N., Gillespie, J., Beattie, T. K., Shipton, Z. K., & Beverland, I. J. (2018). Measurement of diesel combustion-related air pollution downwind of an experimental unconventional natural gas operations site. *Atmospheric Environment*. doi:https://doi.org/10.1016/j.atmosenv.2018.06.032

Fung, D. (2016). Particulate Matter (PM). Retrieved March 25, 2018, from https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM

Hankey, S. (2014). *Exposure to on-road particulate air pollution during active travel*. UNIVERSITY OF MINNESOTA.

Hansen-Flaschen, J., & Bates, D. V. (2017). respiratory disease _ Definition, Causes, & Major Types _ Britannica. Retrieved March 24, 2018, from https://www.britannica.com/science/respiratory-disease

Hasan, A. R., & Nair, P. L. (2014). Urbanisation and growth of metropolitan centres in Malaysia. *Malaysian Journal of Economic Studies*, *51*(1), 87–101.

Khan, F., Latif, M. T., Juneng, L., Amil, N., Mohd Nadzir, M. S., & Syedul Hoque, H. M. (2015). Physicochemical factors and sources of particulate matter at residential urban environment in Kuala Lumpur. *J Air Waste Manag Assoc, 65*(8), 958-969. doi:10.1080/10962247.2015.1042094

Kong, S., Aziz, A. A., Rao, S., & Inangda, N. (2009). Environmental Effects of Driving Automobiles in the University of Malaya Campus: A Pilot Study,Journal of Design and Built Environment, 5,1-17

Leong, S. T., Muttamara, S., & Laortanakul, P. (2002). Air Pollution and Traffic Measurements in Bangkok Streets. *Asian J. Energy Environ.*, *3*(3–4), 185–213.

Liu, Q., Xu, C., Ji, G., Liu, H., Shao, W., Zhang, C., … Zhao, P. (2017). Effect of exposure to ambient PM 2 . 5 pollution on the risk of respiratory tract diseases : a meta-analysis of cohort studies, *31*(June 2016), 130–142. https://doi.org/10.7555/JBR.31.20160071

Liu, W.-T., Ma, C.-M., Liu, I.-J., Han, B.-C., Chuang, H.-C., & Chuang, K.-J. (2015). Effects of commuting mode on air pollution exposure and cardiovascular health among young adults in Taipei, Taiwan. *International Journal of Hygiene and Environmental Health*, *218*(3), 319–323. https://doi.org/10.1016/j.ijheh.2015.01.003

Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., de Nazelle, A., Dons, E., Gerike, R., . . . Nieuwenhuijsen, M. (2015). Health impact assessment of active transportation: A systematic review. *Preventive Medicine, 76*, 103-114. doi:https://doi.org/10.1016/j.ypmed.2015.04.010

Nyhan, M., McNabola, A., & Misstear, B. (2013). Comparison of particulate matter dose and acute heart rate variability response in cyclists, pedestrians, bus and train passengers. *Science of the Total Environment*, *468–469*, 821–831. https://doi.org/10.1016/j.scitotenv.2013.08.096

Popescu, R. and Popescu, L. (2017). Assessment of Air Pollution, by the Urban Traffic, in University Campus of Bucharest. Journal of Environmental Protection, 8, 884-897. doi: 10.4236/jep.2017.88055.

Qiu, Z., Xu, X., Song, J., Luo, Y., Zhao, R., Zhou, B. X. W., … Hao, Y. (2017). Pedestrian exposure to traffic PM on different types of urban roads: A case study of Xi'an, China. *Sustainable Cities and Society*, *32*(January), 475–485. https://doi.org/10.1016/j.scs.2017.04.007

Requia, W. J., Adams, M. D., & Koutrakis, P. (2017). Association of PM2. 5 with diabetes, asthma, and high blood pressure incidence in Canada: A spatiotemporal analysis of the impacts of the energy generation and fuel sales. Science of the Total Environment, 584, 1077-1083.

Samoli, E., Atkinson, R. W., Analitis, A., Fuller, G. W., Green, D. C., Mudway, I., … Kelly, F. J. (2016). Associations of short-term exposure to traf fi c-related air pollution with cardiovascular and respiratory hospital admissions in London , UK, 1–8. https://doi.org/10.1136/oemed-2015-103136

Sylla, F. K., Faye, A., Fall, M., & Tal-dia, A. (2017). Air Pollution Related to Traffic and Chronic Respiratory Diseases (Asthma and COPD) in Africa, 1378–1389. https://doi.org/10.4236/health.2017.910101

Steinle, S., Reis, S., Sabel, C. E., Semple, S., Twigg, M. M., Braban, C. F., . . . Wu, H. (2015). Personal exposure monitoring of PM2.5 in indoor and outdoor microenvironments. *Science of The Total Environment, 508*, 383-394. doi:http://dx.doi.org/10.1016/j.scitotenv.2014.12.003

Tao, Y., Mi, S., Zhou, S., Wang, S., & Xie, X. (2014). Air pollution and hospital admissions for respiratory diseases in Lanzhou , China. *Environmental Pollution*, *185*, 196–201. https://doi.org/10.1016/j.envpol.2013.10.035

WHO | Ambient air pollution. (2016). Retrieved October 26, 2017, from http://www.who.int/gho/phe/outdoor_air_pollution/en/

World Health Organization. (2016). WHO | Chronic respiratory diseases (CRDs). Retrieved December 11, 2017, from http://www.who.int/respiratory/en/

Wu, H., Reis, S., Lin, C., Beverland, I. J., & Heal, M. R. (2015). Identifying drivers for the intra-urban spatial variability of airborne particulate matter components and their interrelationships. *Atmospheric Environment, 112*, 306-316. doi:http://dx.doi.org/10.1016/j.atmosenv.2015.04.059

Zheng, P., & Mike, M. (2012). An Investigation on the Manual Traffic Count Accuracy. *Procedia - Social and Behavioral Sciences, 43*, 226-231. doi:https://doi.org/10.1016/j.sbspro.2012.04.095

Zuurbier, M., Hoek, G., Oldenwening, M., Lenters, V., Meliefste, K., van den Hazel, P., & Brunekreef, B. (2010). Commuters' Exposure to Particulate Matter Air Pollution Is Affected by Mode of Transport, Fuel Type, and Route. *Environmental Health Perspectives, 118*(6), 783-789. doi:10.1289/ehp.0901622

Yin, W., Hou, J., Xu, T., Cheng, J., Wang, X., Jiao, S., … Yuan, J. (2017). Association of individual-level concentrations and human respiratory tract deposited doses of fine particulate matter with alternation in blood pressure. *Environmental Pollution*, *230*, 621–631. https://doi.org/10.1016/j.envpol.2017.07.006

Yoshizaki, K., Mára, J., Fernando, L., Lino-dos-santos-franco, A., Perroni, D., Calciolari, R., … Macchione, M. (2017). Science of the Total Environment The effects of particulate matter on in fl ammation of respiratory system : Differences between male and female. *Science of the Total Environment*, *586*, 284–295. https://doi.org/10.1016/j.scitotenv.2017.01.221