ORIGINAL ARTICLE

Temporal Analysis of Environmental Noise and Air Pollution Nearby a Government Hospital in Suburban Klang Valley, Malaysia

Amirul Aiman Helmi, Eliani Ezani, Sharifah Norkhadijah Syed Ismail, Irniza Rasdi

Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia 43400 Serdang, Selangor, Malaysia

ABSTRACT

Introduction: Exposure to ambient noise and air pollution from road traffic has been associated with an increased risk of adverse health effects, such as heart disease and mental health. Although recent studies have identified temporal variations of noise and air pollution in urban areas, there has been limited data on the levels within sensitive areas such as a hospital. Thus, this study presents the scenario of noise and air quality level in the temporal dimension assessed near a hospital located in the suburban area of Klang Valley, Malaysia. **Methods:** A-weighting noise level (dBA) 3M™ Edge™ 5 Personal Noise Dosimeter and $PM_{2.5}$ concentration Dusttrak II Handheld Aerosol Monitor Model 8523 (μg/m^3) were measured simultaneously with a 1-min interval. All measurements were taken from 0700 hrs until 1900 hrs on weekdays and weekends. **Results:** High noise level (min= 61.1 dBA, max= 62.0 dBA) and $PM_{2.5}$ concentrations (min= 20 μg/m^3, max= 29 μg/m^3) were observed during morning peak hours on weekdays and weekends. Noise levels measured are exceeded the Department of Environment (DOE) guideline limit (55 dBA) and $PM_{2.5}$ concentrations complied with the annual standard (35 μg/m^3). We observed moderate correlations between noise and particulate pollution $PM_{2.5}$ during weekdays and weekends (r= 0.66, p<0.01). **Conclusion:** Noise level and $PM_{2.5}$ concentration varied widely over time and could have a negative impact on human health. Our case study recommends that measurement of both noise and air pollution deserved further investigation to allow detailed exposure characterisation of this relationship.

Keywords: Noise pollution, Traffic-related Air Pollution, Exposure Assessment, Outdoor worker, Hospital

Corresponding Author:
Eliani Ezani, PhD
Email: elianiezani@upm.edu.my
Tel: +603-86092937

INTRODUCTION

The number of vehicles on the road has increased significantly, and it is now recognised as one of the dominant sources of noise and air pollution (1). Carbon Monoxide (CO), Sulphur Dioxide (SO_2), and Particulate Matter (PM) are dominantly emitted from the outdoor road vehicles from fuel combustion (2). Meanwhile, the compression and expansion process due to engine vibrations is considered the primary source of traffic noise (3). Ambulance, fire engine, and police car sirens often cause high outdoor noise pollution, despite the fact that the loud sirens are supposed to help these vehicles arrive safely and quickly (4). It is reported that the A-weighted noise level of the car is approximately 70 dBA and can increase to 115 dBA for ambulance siren (5-6). Generally, floor impacts, transmission by air between homes, household appliances, and air conditioning equipment are considered as indoor noise. Meanwhile new furnishings and floorings, cleaning equipment, cigarette smoke, and HVAC systems, such as chillers, cooling towers, exhaust fans, and filters, are known as sources of indoor air pollution (4). In addition, the main sources of indoor noise in hospital are observed from equipment, alarms and staff activity. Other noise sources that perceived as most annoying for patients are from cleaning machines, coughing and talking, meanwhile alarms and telephones are found annoying for hospital staff (7). The major indoor pollutant sources in hospital buildings are occupants and their activities, building equipment (machines and appliances), and maintenance (8).

Hospital is regarded as unique and complex setting unlike other commercial or public buildings. The indoor occupants of hospitals including patients, medical staff and visitors are at a higher risk of health symptoms such as eye irritation, headaches, coughs, colds, dizziness, asthma, and respiratory and cardiovascular diseases from to nosocomial and occupational exposures. Nosocomial infections, especially fungal infections like aspergillosis, cause significant morbidity and mortality in immunocompromised patients (9). Fungal spores are one of the major types of bioaerosols that can be transmitted through indoor and outdoor air, visitors, patients, and air conditioners (10). Air pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), and particulate matter (PM) can affect hospital workers, patients, and caregivers who spend longer time indoors (11). It is reported that long-term exposures should be considered for hospital workers experiencing symptoms associated with sick building syndrome (working >5 days per week) (12). Public health consequences of outdoor air pollution exposure such as $PM_{2.5}$ can vary from shortness of breath to cardiorespiratory diseases (13).

Excessive noise will affect the psychological and physiological well-being of patients and healthcare workers. Acute health effects have been associated with ambient noise and air pollution from road traffic. An extreme or high noise exposure might lead to permanent hearing loss, aggressive behaviour, sleep disruption, stress, fatigue and hypertension (14-15). Those who work in noisy environments may experience a temporary threshold shift, resulting in temporary hearing loss. Noise pollution has a negative impact on patients including disturbance of sleep quality, cognitive processing and speech. It is reported that the hospital's average noise level was consistently 59-60 dB(A), exceeding the recommended guideline. This had resulted in a constant noise exposure for patients (16).

Hospital also built close to the main roadways with no buffer zones or proper sound proofing. The situation has been exacerbated by increased outdoor traffic, heavy inflow of staff, patients and visitors, and the wailing of the siren from the ambulance (17-19). Seasonal factors, dust storms and on-road vehicle emissions have been linked to elevated outdoor particles and ingress through the indoor buildings (9). It is also reported that people who live near busy roads inhale large amounts of complex pollutant mixtures, and each person reacts differently to them (20). A study in the Southern region of Peninsular Malaysia has reported the traffic noise pollution within sensitive areas, including schools and hospitals, surpassed the noise limit set by Department of Environment Malaysia (21). The current guideline of Malaysia Environmental Noise Controls and Limits (2^{nd} schedule) is set for 60 dBA from 7 a.m to 10 p.m and 55 dBA from 10 p.m to 7 a.m for noise sensitive areas including school hospital and worship areas. Despite numerous reports of exposure to dreadful ambient noise and air pollution as a result of high traffic capacity in sensitive areas (10,22), there are few study reported on the temporal variations of pollution peaks in the hospital area in different rush hours. Our study examines the temporal variability of ambient noise and air quality near a hospital located in Greater Kuala Lumpur.

METHODS AND MATERIALS

Noise and $PM_{2.5}$ measurements were conducted at level 2 of a campus balcony that located approximately 300 m from a government hospital's main entrance in the suburban area of Klang Valley (2°58'30"N and 101° 43'10"E) (Figure 1). This government-funded multi-specialty hospital is located in the district of Sepang, Selangor and approximately 28 km southeast from Kuala Lumpur City Centre. There is an on-going construction project of newly eight-storey building located beside the hospital at around 430 meters from our sampling point. The construction site is operated from 8 a.m to 6 p.m, Monday to Saturday. We observed a plywood barrier protection which can act as a silencer at the construction site. We also observed that a water tanker is brought in to spray water on the affected areas to prevent dust becoming airborne during afternoon rush-hour.

Fig. 1 : Sampling site for the sampling set deployment (yellow pin). The yellow pin is the sampling point and red dots (---) denoted the hospital premise (Source: Google Earth)

A traffic light is also located at the intersection of Jalan Cempaka and Jalan Hospital Serdang, approximately 80 meters away from the sampling point. Our study site might be affected by accelerating, queueing or cruising traffic from the traffic activity. The presence of the tree and roadside vegetation near the intersection may reduce pollution impacts near the roadsides. However, given the study's spatial resolution, any inferences regarding the site's topographic effect on our measurements are speculative due to the intersection's complexity. Both noise and $PM_{2.5}$ measurements were carried out in September of 2020 during working days (n= 5) and non-working days (n= 3) from 7.00 a.m until 7.00 p.m with a 1-minute interval. Measurement periods were selected to capture the potential variation in exposure due to the different traffic profiles during peak and quiet hours.

Noise level measurement

The noise measurement levels were taken by 3M™ Edge™ 5 Personal Noise Dosimeter (3M, Minnesota, USA). The dosimeter is calibrated each time before and after measurements following the Manufacturer's Manual. The "A" weighted scale was applied in the sampling observation. The noise dosimeter's microphone was set up on a tripod and was positioned at the height of 1.5 m from the floor surface at the balcony. The unmanned measurements were taken for 12 hours without any noise barrier including walls built in front of at this measuring point. The measurement followed the sampling protocol provided by ISO 1996-2 (23).

The noise data were then tabulated in the Microsoft Office Excel Spreadsheet® 2016 to establish the descriptive statistics such as the average noise level, maximum (L_{max}), and minimum (L_{min}) level of noise. The equivalent sound levels, L_{Aeq} was calculated by using the following Eq. (1);

$$L_{Aeq}=10 \log \sum_{i=1}^{i=n} 10^{\left(\frac{Li}{10}\right)} * t_i$$

Where,
n = total number of samples taken;
Li = noise level in dBA of the ith sample and;
t_i = the fraction of the total sample taken.

L_{max}, L_{min}, L_{50}, L_{10}, and L_{90} were also calculated. L maximum is the highest value measured by the sound level meter over a given period (L_{max}). L minimum is the lowest value measured by the sound level meter over a given period (L_{min}). L_{50} is the noise level exceeded for 50% of the measurement duration and often used to indicate the median value of noise. L_{10} is the sound level at 10 % of the measurement period and act as an indicator for the upper limit of a range of sounds (etc., from road traffic). The value of L_{90} is the noise level at 90% of the measurement period and regarded as the background noise level. L_{50}, L_{10} and L_{90} were calculated by the following steps in Microsoft Office Excel Spreadsheet® 2016.

Air pollution monitoring

$PM_{2.5}$ measurements were measured using a Dusttrak II Handheld Aerosol Monitor Model 8523 (TSI, Minnesota, USA). This Class I laser-based instrument recorded the aerosol mass concentrations of particulate airborne. The built-in integrated pump allows for size-selective measurement by installing different inlet conditioners. The 2.5-micrometre inlet was used to acquire $PM_{2.5}$ data. Before each reading is taken, the monitor was set for zero calibration following the manufacturer's instructions. The monitor was positioned at 1.5 m on a table from the floor surface at the balcony and away from corridor walkaways inside the campus building.

Data analysis

The data collected were first analysed using Stata 16.0 and Statistical Package for Social Science (SPSS®) version 25 software for the normality and homogeneity test. To ascertain the data's characteristics, it is necessary to classify them as parametric or non-parametric. Normality was tested by assessing the Shapiro-Wilk and Levene's test value. The noise level distribution (p<0.05) is non-Gaussian, the median is used instead of the mean as a representative. For the next step in data analysis, the statistical significance Kruskal-Wallis Test was used. For the 95 % confidence level, statistical analysis is considered. Through RStudio®, correlation analysis was carried out. The Spearman Rank Correlation Coefficient calculates the relationship between the two parameters or variables (r_s). The evaluated parameters will be in the +1 and -1 ranges representing the strength of the parameter relationship, where +1 indicates a perfect positive relationship, -1 indicates a perfect negative relationship, and 0 indicates no relationship exists. The equation of r for the sample is defined as Eq. 2;

$$r_s = \frac{\frac{1}{n}\sum_{i=1}^{n} (R(x_i)-\overline{R(x)}) \, . \, (R(y_i) - \overline{R(y)})}{\sqrt{\frac{1}{n}\left(\sum_{i=1}^{n} (R(x_i)-\overline{R(x)})^2\right).\left(\frac{1}{n}\sum_{i=1}^{n}(R(y_i) - \overline{R(y)})^2\right)}}$$

Where,
n = total number of samples taken;
R(x) and R(y) = the ranks of the x and y variables
$(\overline{R(x)})$ and $(\overline{R(y)})$ = the mean ranks

RESULTS

Variations in the Noise Level and $PM_{2.5}$ Concentration

Fig. 2 shows the comparison of noise levels near the hospital, during the weekdays (working days), and weekends (non-working days). It is noticeable that the average levels measured during the weekdays were higher than those measured on the weekends. However, both noise measurements on weekdays (62.0 dBA) and weekends (61.1 dBA) slightly exceeded the limit (60 dBA) of The Planning Guidelines for Environmental Noise Limits and Control by the Department of Environment for 7 a.m to 10 p.m permitted levels (24). Meanwhile, Fig. 3 shows the comparison of $PM_{2.5}$ concentrations during weekdays (working days) and weekends (non-working days). In parallel with noise level, $PM_{2.5}$ the concentration measured during weekdays (29 μg/m^3) are higher than those measured on weekends (20 μg/m3), but both still comply with the limit (35 μg/m^3) stated by The New Malaysia Ambient Air Quality Standard (25).

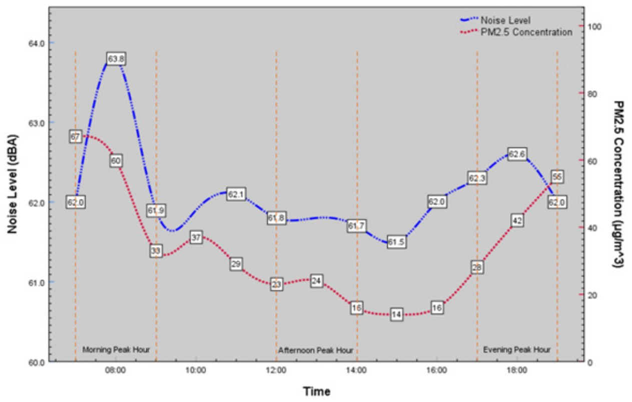

Fig. 2 : Comparison of (a) noise (dBA) and (b) air (µg/m³) levels during weekdays and weekends

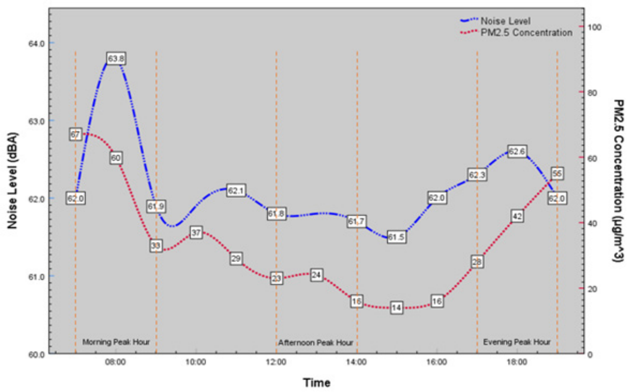

Fig. 3 : Trend of noise level and $PM_{2.5}$ (dBA) concentration (µg/m³) during weekdays

Hourly Trend of Noise Level and $PM_{2.5}$ Concentrations

The hourly trend of noise in the study area varies during different peak hours (Fig. 3). During weekdays, the high noise level was found during the morning peak hour, followed by evening and subsequently, afternoon peak hour, where the noise levels are 62.5 dBA, 62.4 dBA, and 61.7 dBA, respectively. During the morning peak hour, the L_{max} is observed at 72.5 dBA. Similarly, a high concentration of $PM_{2.5}$ was observed during the morning peak hour, followed by evening and subsequently afternoon peak hour, where the concentrations are 65 µg/m³, 35 µg/m³, and 23 µg/m³, respectively. The noise levels exceeded the permissible limit over the whole period, while $PM_{2.5}$ concentrations only comply with the limit during the peak hour of the afternoon.

We also observed a similar trend of levels of noise and $PM_{2.5}$ during the weekend, however, the levels were 1.45% lower for noise and 32.1% for $PM_{2.5}$ compared to the weekdays observation (Fig.4). This event may contribute to the reduction of traffic flow within the campus and hospital during non-working days. During the morning peak hour, a high noise level was found, followed by evening and subsequently afternoon peak hour, where the noise level is 61.7 dBA, 61.0 dBA, and 60.8 dBA, respectively. The morning peak hour showed the L_{max} is at 68.1 dBA. Similarly, a high concentration

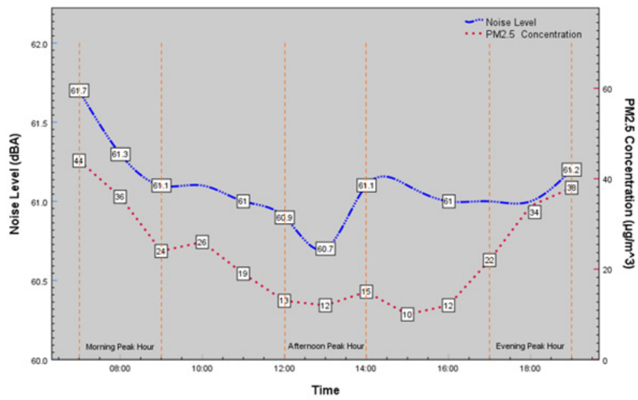

Fig. 4 : Trend of noise level and $PM_{2.5}$ concentrations during weekends

of $PM_{2.5}$ was found during the morning peak hour, followed by evening and subsequently afternoon peak hour, where the concentration is 38.0 µg/m³, 28.0 µg/m³, and 12.0 µg/m³, respectively. It is noted that the morning peak hour on weekdays and weekends had the highest levels of noise and $PM_{2.5}$ concentrations, this followed by the evening and afternoon peak hours.

Correlation Between Noise Level and $PM_{2.5}$ Concentrations

The Spearman correlation coefficient was calculated using SPSS® version 25 and Rstudio® to determine the relationship between two parameters in this non-parametric dataset. Table 1 summarised the correlation between noise level and $PM_{2.5}$ concentrations in the study area. A loading factor greater than 0.59 is considered strong, a range of 0.40-0.59 is considered moderate, and 0.39 or less is considered weak (26). Despite differences in noise reduction and $PM_{2.5}$ concentrations, the results revealed a moderate correlation between noise level and $PM_{2.5}$ concentration during weekdays and weekends (r_s= 0.66, p<0.01).

Table I : Correlation coefficient of noise level and concentrations during weekday and weekend

	Parameters	Noise Level	$PM_{2.5}$ Concentrations
Weekday	Noise Level	1	0.655*
	$PM_{2.5}$ Concentrations	0.655*	1
Weekend	Noise Level	1	0.661*
	$PM_{2.5}$ Concentrations	0.661*	1

*Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

Our study assessed the variation of noise level and $PM_{2.5}$ concentrations near a public hospital located in a suburban area of Klang Valley. We found that both noise level and $PM_{2.5}$ concentrations from day time (7 a.m to 7 p.m) of 12 hours measurements were higher during weekdays compared to weekends. The high level of noise detected is most likely due to the high volume of road vehicles passing the main road in front of the areas (mostly motorcycles and cars) during the week rather than on weekends, when a statistically significant difference ($p<0.05$) exists between weekdays and weekends. Weekends are a time when both the campus and the hospital slow down. Naturally, this reduces traffic flow.

Both noise and $PM_{2.5}$ levels were found high during the morning peak hour, followed by evening and subsequently afternoon peak hour. Typically, the number of road vehicles were reported higher in the morning and the evening peak hours, but lower for the rest of the noon (27). Cars, motorcycles, and public transportation from the hospital and nearby campus contributed to higher noise and $PM_{2.5}$ concentrations. Furthermore, numerous drivers park and stop their vehicles on nearby road sidewalks and shoulders, causing significant traffic congestion in the hospital area. Traffic congestion raises noise levels and is a significant indicator of pollution dispersion and air pollution caused by excessive traffic, particularly in urban areas (28).

The traffic noise is generated by the vehicle's gearbox caused by vibration transmitted through the gear, and shaft (29). The presence of a traffic light (approximately 80 metres from the sampling point) may contributed to the elevated levels of traffic noise and $PM_{2.5}$. When vehicles reach the traffic light, they will brake and then accelerate when the light turns green. This braking and acceleration procedure contributes to the vehicle's noise level (17). Increased accelerations, decelerations, stops, and starts will also increase exhaust emissions and brake and tyre wear, resulting in particulate emissions.

The significant decrease in $PM_{2.5}$ concentration was suggested due to the proximity of a parking lot to the sampling point. Wind speeds are generally higher in large open spaces (30) due to the lack of obstacles that obstruct air movement and contribute to the washing out and dispersion of PM emissions. Despite a significant reduction in road vehicle density, this results in a relatively small reduction in noise levels, as increases in average wind speed significantly increase the sound levels emanating from an uncontrolled source at a high elevation (31). The higher $PM_{2.5}$ concentrations during the morning peak hour are related to relative humidity, which has a significant positive relationship with it (32). PM concentrations are highest in the morning peak hour because to the more stable boundary layer, lower height of the thermal inversion at the surface, and low friction velocity (33). A nearby construction project may also be a contributing factor, as construction activities generate a lot of dust (34). This will increase dust emissions, a major source of atmospheric particulates (35).

Our results also indicate a similar correlation between noise level and air pollutants with other studies (36-38). A previous study observed that noise could potentially confound correlations between air quality in traffic and health outcomes where the 1-week average noise measurements, L_{eq} and L_{dn}, were moderately associated with levels of $PM_{2.5}$ (r= 0.45-0.51) (39). Furthermore, noise data were strongly correlated with $PM_{2.5}$ ($p \leq 0.05$), indicating their control effects at the 95% confidence interval, likely because such pollutants are more localised from the source of emission. Similarly, noise and ultrafine particulate matter levels exhibited moderate correlations were observed in three middle-sized cities in Europe (37). Both noise and air pollutions are often correlated with one another as they originated from the same source (i.e traffic) (36). A relationship between noise and vibration is explained when the sound field vibrates the air particles, causing them to vibrate and travel at varying amplitudes (38). Also, in the Mutual Scattering Effect, the particle surface scatters part of the incident noise vibration wave, resulting in a scattered wavefield of slightly damped longitudinal and transverse waves (40).

Nevertheless, meteorological factors influence pollutant dispersion. For example, the wind speed intensity and turbulence influence each other (41) by increasing dispersion (42). A previous study on the downwind factor showed a 25% increase in UFP concentrations (43). Our study had some limitations, such as limited number of sampling days. Our study also did not examine the effect of weather on noise or $PM_{2.5}$ concentrations for example wind speed, relative humidity and temperature. However, to minimise meteorological conditions on any of these parameters, no measurements were made on rainy or windy days in our study. Future research could also include seasonal variations by monitoring temporal changes of meteorological factors with noise and air pollution. Monsoonal winds are important when studying the seasonal effect on air pollutants, especially in Malaysia. Malaysia has two monsoon seasons: southwest (June–September) and northeast (November–March) (44).

Another limitation presented in our study is the traffic flow data. We did not perform the traffic count for the sum of motorcycles, light-duty gasoline vehicles, light-duty diesel trucks, and heavy-duty diesel trucks that passed by the nearest roadside to our sampling site. It is recommended that a qualitative and quantitative assessment of typical traffic behavior and data at each location can be performed during peak flow times, using on-site observations and the typical traffic flow representation. During peak flow periods, traffic should be classified as either accelerating, cruising, or queuing (a combination of idling and accelerating). This is similar to the work done by Beckwith et al. 2019 (45). We also did not assign the environmental noise measurements to the different sources that generated nearby to our sampling location. Future research should include environmental noise monitoring employing source classification, such as audio recording and time-activity diary.

CONCLUSION

Our simple set of monitoring indicates that the averaged noise level during weekdays and weekends exceeded the Department of Environment's Planning Guidelines for Environmental Noise and Control (2019) for daytime (55 dBA) for sensitive areas such as institutional and hospital areas (24), posing a risk to human health. On the contrary, $PM_{2.5}$ concentrations during weekdays and weekends comply with the limit (35 μg/m^3) stated by The New Malaysia Ambient Air Quality Standard 2020 (NMAAQS). The noise level and $PM_{2.5}$ concentration trend indicated that the morning peak hour had the highest levels, followed by evening and afternoon peaks. These are the times that correspond to rush hour. Unlike morning and evening peak hours, we observed a decrease in pollution during afternoon peak due to lower road density (dominantly motorcycles and cars).

Our findings suggest that people who work or spend most of their time outside (i.e. outdoor workers) are more susceptible to noise and air pollution than people who live away from major traffic zones. Both pollutions are likely to be harmful to the health of nearby residents, pedestrians, cyclists, and outdoor workers. However, the indoor environments of the hospital can be affected from the outdoor sources including construction and traffic noise and air pollutants. It is suggested that using an external active silencer can help reduce construction noise because the exhaust noise is reduced inside the external ducts before it enters the air. Also, constructing traffic noise-air emission barriers may help reduce noise levels by blocking, absorbing, and deflecting sound waves while lowering pollutant concentrations by deflecting upward airflow. In the sensitive zone such as hospital or school, it is critical to carefully plan the infrastructure and to enforce stricter vehicle movement, traffic management, and air quality monitoring regulation. Our results showed that there exists a moderate correlation between both noise levels and $PM_{2.5}$ concentrations (r= 0.66). It is critical to understand the variability and differences in correlations between noise and air pollution levels over area and time in order to evaluate potential confounding or interactions that could alter exposure-response calculations used to inform policy interventions (46). Future study should be able to conduct an extensive analysis of temporal and spatial variations for both noise and air pollution in order to characterise a personal exposure assessment.

ACKNOWLEDGEMENTS

The authors would like to thank Miss Khatijah Ahmad Ramli from Occupational Health and Safety Laboratory, Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia for her technical and equipment assistance.

REFERENCES

1. Zhang K, Batterman S. Air pollution and health risks due to vehicle traffic. The Science of the total environment. 2013;450-451:307-16.10.1016/j.scitotenv.2013.01.074.
2. Xue Y, Cao X, Ai Y, Xu K, Zhang Y. Primary Air Pollutants Emissions Variation Characteristics and Future Control Strategies for Transportation Sector in Beijing, China. Sustainability. 2020;12(10):4111.
3. Grubesa S, Suhanek M. Traffic Noise. In: Noise Pollution. IntechOpen; 2020. 10.5772/intechopen.92892.
4. Cervinka D, Salih O, Ahmad Z, Rajbhandari S. Reducing Noise Pollution of Emergency Vehicle Sirens with an Early Warning System. In2018 11th International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP) 2018 Jul 18 (pp. 1-4). IEEE.
5. Sliggers J. A noise label for motor vehicles: towards quieter traffic. InUNECE GRB 61st meeting, Informal document GRB-61-03 2015 Jan.
6. Privopoulos EP, Howard CQ, Maddern AJ. Acoustic characteristics for effective ambulance sirens. Acoustics Australia. 2011;39(2):43-53.
7. MacKenzie DJ, Galbrun L. Noise levels and noise sources in acute care hospital wards. Building Services Engineering Research and Technology. 2007;28(2):117-31.10.1177/0143624406074468
8. Dikmen ЗB, Gьltekin AB. Sustainable Indoor Air Quality (IAQ) in Hospital Buildings. In: Gцkзekus H, Tьrker U, LaMoreaux JW, editors. Survival and Sustainability: Environmental concerns in the 21st Century. Berlin, Heidelberg: Springer Berlin Heidelberg; 2011. p. 557-65.
9. Chamseddine A, Alameddine I, Hatzopoulou M, El-Fadel M. Seasonal variation of air quality in hospitals with indoor–outdoor correlations. Building and Environment. 2019;148:689-700. https://doi.org/10.1016/j.buildenv.2018.11.034
10. El-Sharkawy MF, Noweir MEH. Indoor air quality levels in a University Hospital in the Eastern Province of Saudi Arabia. J Family Community Med. 2014;21(1):39-47. Doi: 10.4103/2230-8229.128778
11. Zhang X, Ahmadi G, Qian J, Ferro A. Particle Detachment, Resuspension and Transport Due to Human Walking in Indoor Environments. Journal of Adhesion Science and Technology. 2008;22(5-6):591-621.10.1163/156856108X305624.

12. Babaoglu UT, Milletli Sezgin F, Yag F. Sick building symptoms among hospital workers associated with indoor air quality and personal factors. Indoor and Built Environment. 2019;29(5):645-55.10.1177/1420326X19855117.
13. Magzamen S, Mayer AP, Barr S, Bohren L, Dunbar B, Manning D, et al. A multidisciplinary research framework on green schools: Infrastructure, social environment, occupant health, and performance. Journal of School Health. 2017;87(5):376-87.
14. Wartinger F, Malyuk H, Portnuff CD. Human exposures and their associated hearing loss profiles: Music industry professionals. The Journal of the Acoustical Society of America. 2019;146(5):3906-10.
15. Pantawane RN, Maske KV, Kawade NS. Effects of Noise Pollution on Human Health. International Advanced Research Journal in Science, Engineering and Technology. 2017;4(3):33-5.
16. Jue K, Nathan-Roberts D. How Noise Affects Patients in Hospitals. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2019;63(1):1510-4.doi: 10.1177/1071181319631325
17. Abdullah S, Akhtari MI, Ismail M, Ahmed AN, Mansor WNW, Zulkifli MFR. Spatio-temporal analysis of environmental noise in institutional area. International Journal of Recent Technology and Engineering. 2019;8(2):4037-42.
18. Khaiwal R, Singh T, Tripathy JP, Mor S, Munjal S, Patro B, et al. Assessment of noise pollution in and around a sensitive zone in North India and its non-auditory impacts. Science of The Total Environment. 2016;566:981-87.
19. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels in Johns Hopkins hospital. The Journal of the Acoustical Society of America. 2005;118(6):3629-45.
20. Adams MD, Kanaroglou PS. Mapping real-time air pollution health risk for environmental management: Combining mobile and stationary air pollution monitoring with neural network models. Journal of Environmental Management. 2016;168:133-41.http://dx.doi.org/10.1016/j.jenvman.2015.12.012
21. Segaran VC. Assessment of Traffic Noise Pollutions Outside School, Residential, Hospital and Commercial Areas along Jalan Kluang, Batu Pahat, Johor. International Journal of Integrated Engineering. 2019 Dec 30;11(9):123-31
22. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels in Johns Hopkins hospital. The Journal of the Acoustical Society of America. 2005;118(6):3629-45
23. ISO 1996-2. Description and Measurement of Environmental Noise. Part 2: Acquisition of Data Pertinent to Land Use.
24. Department of Environment Malaysia (DOE). The Planning Guidelines for Environmental Noise Limits and Control. Ministry of Environment and Water, Putrajaya; 2019.
25. Department of Environment Malaysia (DOE). New Malaysia Ambient Air Quality Standard. Ministry of Environment and Water, Putrajaya; 2020.
26. Yan Z, Wang S, Ma D, Liu B, Lin H, Li S. Meteorological Factors Affecting Pan Evaporation in the Haihe River Basin, China. Water. 2019;11(2):317.
27. Wemegah TD, Zhu S, Atombo C. Modeling the effect of days and road type on peak period travels using structural equation modeling and big data from radio frequency identification for private cars and taxis. European Transport Research Review. 2018;10(2):1-4.
28. Jacyna M, Wasiak M, Lewczuk K, Karo□ G. Noise and environmental pollution from transport: decisive problems in developing ecologically efficient transport systems. Journal of Vibroengineering. 2017;19(7):5639-55.
29. Akerblom M. Gearbox Noise. Sweden: Department of Machine Design;2008.
30. Xu Q, Xu Z. What can urban design learn from changing winds?. The Journal of Public Space. 2020;5(2):7-22.
31. Trikootam SC, Hornikx M. The wind effect on sound propagation over urban areas: Experimental approach with an uncontrolled sound source. Building and Environment. 2019;149:561-70.
32. Srimuruganandam B, Nagendra SMS. Analysis and interpretation of particulate matter-PM10, PM2.5 and PM1 emissions from the heterogeneous traffic near an urban roadway. Atmospheric Pollution Research. 2010;1(3):184-94.
33. Yan G, Yu Z, Wu Y, Liu J, Wang Y, Zhai J, et al. Understanding PM2.5 concentration and removal efficiency variation in urban forest Park-Observation at human breathing height. PeerJ. 2020;8:e8988.
34. Yan H, Ding G, Li H, Wang Y, Zhang L, Shen Q, et al. Field evaluation of the dust impacts from construction sites on surrounding areas: a city case study in China. Sustainability. 2019;11(7):1906.
35. Song N, Xu H, Bi XH, Wu JH, Zhang YF, Feng, HH, et al. Source apportionment of PM2.5 and PM10 in Haikou. Research Journal of Environmental Sciences. 2015;(28):1501-9.
36. Kheirbek I, Ito K, Neitzel R, Kim J, Johnson S, Ross Z, et al. Spatial variation in environmental noise and air pollution in New York City. Journal of Urban Health. 2014;91(3):415-31.
37. Morelli X, Foraster M, Aguilera I, Basagana X, Corradi E, Deltell A, et al. Short-term associations between traffic-related noise, particle number and traffic flow in three European cities. Atmospheric Environment. 2015;103:25-33.
38. Zhou D, Luo Z, Fang M, Jiang J, Chen H, Sha D, Lu M. Numerical study of the movement of fine particle in sound wave field. Energy Procedia.

2015;75:2415-20.
39. Kim KH, Ho DX, Brown RJ, Oh JM, Park CG, Ryu IC. Some insights into the relationship between urban air pollution and noise levels. Science of The Total Environment. 2012;424:271-79.
40. Song L, Koopmann GH, Hoffmann TL. An improved theoretical model of acoustic agglomeration. Journal of Vibration and Acoustics. 1994;116(2):208-14
41. Ezani E, Hisham NAA, Ismail SNS, Wahab MIA. Air Pollution and Traffic Measurements Within University Areas in Serdang, Malaysia. Asia Pacific Environ-mental and Occupational Health Journal. 2018;4(3):58-65.
42. Chowdhury KA, Debsarkar A, Chakrabarty S. Assessment of combined Noise-Air quality and combined exposure to Noise-Air pollution at the curbside open-air microenvironment of Kolkata city, India. Pollution. 2016;2(1):35-47.
43. Sartini C, Sajani SZ, Ricciardelli I, Delgado-Saborit JM, Scotto F, Trentini A, et al. Ultrafine particle concentrations in the surroundings of an urban area: comparing downwind to upwind conditions using Generalised Additive Models (GAMs). Environmental Science: Processes & Impacts. 2013;15(11):2087-95.
44. Mohtar AAA, Latif MT, Baharudin NH, Ahamad F, Chung JX, Othman M, et al. Variation of major air pollutants in different seasonal conditions in an urban environment in Malaysia. Geoscience Letters. 2018;5(1):21.10.1186/s40562-018-0122-y
45. Beckwith M, Bates E, Gillah A, Carslaw N. NO2 hotspots: Are we measuring in the right places? Atmospheric Environment: X. 2019;2:100025. https://doi.org/10.1016/j.aeaoa.2019.100025.
46. Fecht D, Hansell AL, Morley D, Dajnak D, Vienneau D, Beevers S, et al. Spatial and temporal associations of road traffic noise and air pollution in London: Implications for epidemiological studies. Environment International. 2016;88:235-42. https://doi.org/10.1016/j.envint.2015.12.001.