ORIGINAL ARTICLE

Effects of Residential Proximity to Industrial Zone on Respiratory Symptoms among Residents in Parit Raja, Batu Pahat

Khairul Nizam Mohd Isa[1], Nur Afza Natasha Md Som[2], Juliana Jalaludin[2], Nor Haslina Hashim[3]

[1] Environmental Health Research Cluster (EHRc), Environmental Healthcare Section, Institute of Medical Science Technology, Universiti Kuala Lumpur, 43000 Kajang, Selangor, Malaysia.
[2] Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, UPM, 43400 Serdang, Selangor, Malaysia.
[3] Environment Unit, Office of the Environment, Occupational Safety and Health, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Johor, Malaysia.

ABSTRACT

Introduction: The industrial park in the district of Parit Raja, Batu Pahat resulted in rapid growth of the town during the last 20 years and has been a reason of concern that this park also has contributed greatly to the problem of air pollution. The aim of this study was to evaluate the association between industrial air pollution and respiratory symptoms in adults living in the Parit Raja. **Methods:** A comparative cross-sectional study was undertaken among residents in the district of Parit Raja, Batu Pahat, Johor, Malaysia. A total of 110 residents aged between 19 and 65 years were randomly selected and information on personal characteristics and respiratory symptoms was obtained through a validated questionnaire. The prevalence of respiratory symptoms was compared between residents recruited from the areas situated about 5km radius of the industrial park (exposed) and >5km radius from the industrial park (comparative). **Results:** A total of 34.5% and 25.5% of adults from the exposed group reported experiencing coughing for the last 3 months and chest tightness for the last 3 years. The logistic regression models showed that symptoms of coughing was associated with the exposed group (aOR=6.34, 95% CI=2.08-19.35), male respondents (aOR=3.18, 95% CI=1.10-9.16) and who stay in Part Raja for more than 14 years (aOR=3.16, 95% CI=1.14-8.79). **Conclusion:** This study demonstrated that long-term air pollution exposures are consistently associated with respiratory symptoms in residents living in the proximity of industrial parks. Therefore, public health initiatives that aim to provide more conducive environment are needed, especially for residents living near industrial parks.
Malaysian Journal of Medicine and Health Sciences (2024) 20(1):168-174. doi:10.47836/mjmhs.20.1.22

Keywords: Industrial air pollution, Respiratory symptoms, Residents

Corresponding Author:
Juliana Jalaludin, PhD
Email: juliana@upm.edu.my
Tel: +603-97692401

INTRODUCTION

Air pollution is now one of the relevant threats to the stability of the ecosystem, driving climate change and endangering human life (1). The World Health Organization (WHO) estimated that approximately 9 million deaths a year worldwide are linked with air pollution (2). It is known that the fossil fuel combustion, agriculture activities, and industrial emissions are the common anthropogenic (man-made) sources of air pollution (3). Key primary of air pollutants released into the atmosphere associated with anthropogenic activities are particulate matter (PM), black carbon (BC), sulfur dioxides (SO_2), nitrogen oxides (NOX), carbon monoxide (CO), volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAH) (4). The impacts of these harmful pollutants are so intense due to rampant industrialization around the world. Furthermore, industrialization is not only affecting the sustainability of economic growth, but also depleting the environmental quality (5). In worse situations, these air pollutants escalate when meteorological factors including rainfall, relative humidity and temperature provide favorable conditions (6).

Many reviews reported that the pollutants released from industrial activities are associated with many acute and chronic diseases (7,8). In particular, health effects of PM_{10} and $PM_{2.5}$ exposure includes pulmonary disease, heart disease, chronic bronchitis, stroke, asthma, cancers and premature mortality (9,10). Similarly, numerous reviews reported that nitrogen dioxide (NO_2) exposure has also been linked to cellular inflammation, bronchial hyperresponsiveness, and an aggravated risk of infection predominantly in the respiratory and cardiovascular systems (11–14). Additionally, human exposure to VOCs is ubiquitous and can occur through inhalation, ingestion and dermal contact. These compounds may reside in the vapor phase, particle phase or both

phases and potentially cause mutagenic, genotoxic, carcinogenic, and neurotoxic effects (15).

Residents living near industrial areas are exposing to multiple exposures of air pollution including outdoor and indoor environment, occupational exposure and traffic emissions (16). Moreover, the severity of health problems associated with air pollution increase relatively with the distance from industrial areas (17). Recently, a meta-analysis review reported that every 1-km resident living closer to the industrial areas was increased the risk of asthma-related medical visits at hospitals or clinics by 69% (95% CI= 50%-91%) (18).

This study aims to discover the association of exposure to industrial air pollution with the respiratory symptoms experienced by the adult residents living in close proximity to an industrial area in Parit Raja, Johor, Malaysia.

MATERIALS AND METHODS

Study site and participants

This study was performed in Parit Raja, Batu Pahat, Johor, Malaysia (1.8635° N, 103.1089° E). Parit Raja is a small town in the Batu Pahat district, Johor, that has a mixture of industrial zones, residential, university and commercial areas (Fig. 1). Parit Raja Industrial Park consists of diverse manufacturing enterprises, encompassing wood, furniture, electric, electromagnetic, textile, plastic, and paper production, as well as adhesive and resin manufacturing (19). Industrial activity in the Parit Raja area started since the early 1980s, and the subsequent establishment of the industrial park has significantly contributed to the exposure of air pollutants in the region, affecting the air quality and public health. The establishment of heavy industries in the park has led to increased pollutant emissions and environmental concerns. Over the years, Parit Raja has undergone a transformation in economic sector, infrastructure, and socio-economic structure, largely influenced by the growth of the industrial activities (20). Participants from Parit Raja were recruited from the two neighboring areas situated about 5 km radius of the industrial park (exposed) and more than 5 km radius from the industrial park (comparative).

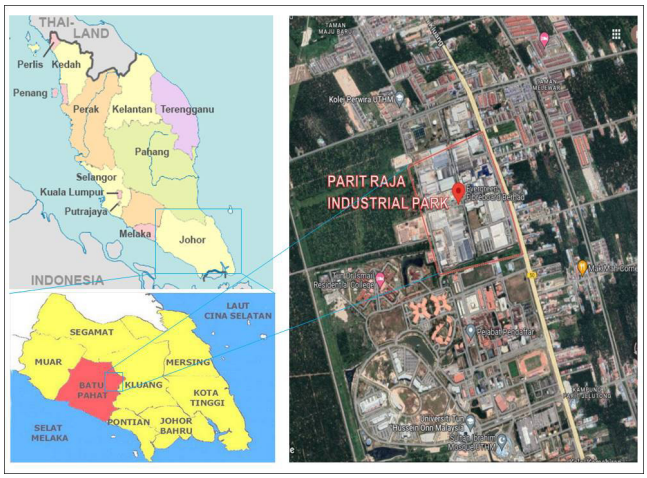

Figure 1: Map of Parit Raja industrial park in the district of Batu Pahat, Johor, Malaysia

The sample size was calculated using Lemeshow et al. formula (21) after considering the 20% non-response rate. The purposive random sampling was carried out and only eligible adults aged between 19 and 65 years, and permanent residency of Parit Raja area were selected for this study. A total of 150 questionnaires were distributed randomly in both sampling sites and 110 were completed, for a response rate of 73.3%. In total, 55 adults from each study area participated in the study.

The questionnaire, consent form and protocol were approved by the Ethic Committee for Research Involving Human Subjects in Universiti Putra Malaysia (JKEUPM-2021-004), and obtained all necessary approvals from local authorities. Written informed consent was obtained from all the participants before their enrolment in the study.

Assessment of respiratory symptoms

The information on demographic characteristics was collected from face-to-face questionnaires. Also, information on respiratory symptoms was gathered by using a questionnaire, which was adapted from American Thoracic Society "ATS-DLD-78". The standardized questionnaire has been translated and proved to be valid in previous studies (22,23). In this study, we focused on four distinct respiratory symptoms that were treated as outcome variables: cough, phlegm, and wheeze for the last 3 months as well as chest tightness for the last 3 years. The questionnaires were distributed to all randomly selected participants in both study areas and verified by the trained enumerators.

Statistical analysis

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corporation, Armonk, NY, USA). Pearson Chi-square analysis was used to test the distribution of personal characteristics that are representative between both sampling groups. Then, we used logistic regression models to determine the associations between respiratory symptoms and group of sampling, duration of stay, and gender. By using the median, duration of stay in Parit Raja was coded as categorical variable (≤ 13 years and > 14 years). The regression models were adjusted for marital status, education level, household income, smoking and type of residence. The regression models were reasonably fits well and met the model assumptions. Associations in the regression analysis were reported as adjusted odds ratios (aORs) with 95% confidence interval (CI). A p-value less than 0.05 was considered to be statistical significant.

RESULTS

A total of 55 adults from exposed and comparative sampling areas were recruited. Respondents were predominantly Malay (98.2%) and 1.8% were from other ethnicities. A total of 32 (58.2%) and 39 (70.9%) respondents were female for the exposed and comparative group, respectively, and the average age for each group was 33 years. A higher response was observed among adults at age 26-35 years (26.4%) and 36-45 years (33.6%). The self-reported smoking prevalence was 18.2% and 10.9% for exposed and comparative group, respectively. Furthermore, there were a total of 25 (45.5%) participants from exposed group were stay in Parit Raja for more than 14 years. The majority of respondents (72.7%) from the exposed group lived in a terrace house while 72.7% of adults from the comparative group lived in individual unit (Table I). A greater proportion of the exposed group (45.5%) is living within 5.1 to 10 km radius from the industrial park.

Table I: Personal characteristics of respondents for exposed and comparative groups (N=110)

Characteristics	Exposed (N = 55)	Comparative (N = 55)	*p*-value
	n (%)	n (%)	
Gender			
Male	23 (41.8)	16 (29.1)	0.163
Female	32 (58.2)	39 (70.9)	
Age (years)			
19-25	23 (41.8)	14(25.5)	
26-35	11 (20.0)	18 (32.7)	0.156
36-45	16 (29.1)	21 (38.2)	
>46	5 (7.3)	2 (3.6)	
Marital Status			
Single	27 (49.1)	18 (32.7)	0.295
Married	28 (49.1)	37 (63.6)	
Education level			
Secondary	4 (7.3)	10 (18.2)	0.086
Tertiary	51 (92.7)	45 (81.8)	
Employment status			
Yes	14 (25.5)	10 (18.2)	0.356
No	41 (74.5)	45 (81.8)	
Household income			
Low	29 (52.7)	33 (60.0)	
Medium	24 (43.6)	19 (34.5)	0.636
High	2 (3.6)	3 (5.5)	
Smoking			
Yes	10 (18.2)	6 (10.9)	0.279
No	45 (81.8)	49 (89.1)	
Type of residences			
Terrace	40 (72.7)	14 (25.5)	
Apartment/flat	3 (5.5)	1 (1.8)	28.595
Individual unit	12 (21.8)	40 (72.7)	
Duration of stay in Parit Raja			
≤ 13 years	30 (54.5)	25 (45.5)	0.340
> 14 years	25 (45.5)	30 (45.5)	
Distance from main road			
< 100 meters	22 (40)	15 (27.3)	
100–500 meters	23(41.8)	22 (40.0)	0.019*
501–1000 meters	9 (16.4)	7 (12.7)	
> 1000 meters	1 (1.8)	11 (20.0)	
Distance from industrial area			
< 500 meters	9 (16.4)	Na	
500–1000 meters	21 (38.2)	Na	
1.1–5 kilometres	25 (45.5)	Na	< 0.001**
5.1–10 kilometres	Na	24 (43.6)	
> 10 kilometres	Na	31 (56.4)	

* $p < 0.05$; ** $p < 0.001$
Na = Not available

Prevalence of respiratory symptoms

Generally, the most common symptom reported by the exposed group was coughing in the past 3 months with the prevalence value of 34.5% followed by chest tightness in the past 3 years (25.5%). Among the comparative group, about 9.1%, 7.3%, 5.5% and 7.3% of respondents reported cough, phlegm and wheezing in the past 3 months and chest tightness in the past 3 years, respectively. Furthermore, higher odds of coughing in the past 3 months and chest tightness in the past 3 years were observed among exposed group compared to comparative group with the odd of 5.28 (95% CI = 1.80-15.45) and 4.35 (95% CI = 1.33-14.24), respectively (Table II).

Association between respiratory symptoms, sampling groups, duration of stay and gender

We further analyzed the association of respiratory symptoms with sampling groups, duration of stay and gender. Based on the results of logistic regression, the exposed group had a significantly higher chance of experienced coughing for the last 3 months compared with the comparative group (aOR = 6.34, 95% CI = 2.08-19.35). Further, the same model also showed that male respondents and who stay in Part Raja for more than 14 years had a higher chance of experience coughing for the last 3 months with the adjusted odd ratio of 3.18 (95% CI = 1.10-9.16) and 3.16 (95% CI = 1.14-8.79), respectively (Table III).

Moreover, the symptom of chest tightness for the last 3 years were significantly associated with the exposed group (aOR = 4.20, 95% CI = 1.26-13.97). Interestingly, symptoms of phlegm and wheezing for the last 3 months were positively associated with the exposed group and those who stay in Part Raja for more than 14 years. Also, male respondents were at higher odds of having these two symptoms, but they were not statistically significant at a 0.05 level. The analysis also identified that distance from the main road and age groups were not significantly associated with the respiratory symptoms experienced by the adults ($p > 0.05$).

Table II: Prevalence of respiratory symptoms for exposed and comparative group

Variables	Exposed (N = 55) n (%)	Comparative (N = 55) n (%)	*p*-value	OR	95% CI
Cough					
Yes	19 (34.5)	5 (9.1)	< 0.001**	5.28	1.80-15.45
No	36 (65.5)	50 (90.9)			
Phlegm					
Yes	6 (10.9)	4 (7.3)	0.507	1.56	0.42-5.87
No	49 (89.1)	51 (97.2)			
Wheezing					
Yes	5 (9.1)	3 (5.5)	0.716	1.73	0.39-7.64
No	50 (90.9)	52 (94.5)			
Chest Tightness					
Yes	14 (25.5)	4 (7.3)	0.010*	4.35	1.33-14.24
No	41 (74.5)	51 (92.7)			

* $p < 0.05$; ** $p < 0.001$; OR = Odd ratio, CI = Confidence interval

Table III: Association of respiratory symptoms in relation to sampling groups, duration of stay and gender

Variable	aOR (95% CI)	*p*-value
Cough		
Group-Exposed	6.34 (2.08-19.35)	0.002*
Duration of stay- >14 years	3.16 (1.14-8.79)	0.027*
Gender-Male	3.18 (1.10-9.16)	0.032*
Phlegm		
Group-Exposed	1.45 (0.38-5.54)	0.584
Duration of stay- >14 years	2.45 (0.59-10.07)	0.214
Gender-Male	1.61 (0.42-6.13)	0.485
Wheezing		
Group-Exposed	1.52 (0.36-6.90)	0.587
Duration of stay- >14 years	2.66 (0.50-14.23)	0.253
Gender-Male	2.71 (0.60-12.37)	0.197
Chest tightness		
Group-Exposed	4.20 (1.26-13.97)	0.019*
Duration of stay- >14 years	1.66 (0.57-4.85)	0.357
Gender-Male	1.93 (0.66-5.67)	0.233

* $p < 0.05$
aOR = Adjusted odd ratio ; CI = Confidence interval ; The regression models were adjusted for marital status, education level, household income, smoking and type of residence.

DISCUSSION

This current study was carried out to assess the impacts of industrial air pollution exposure on four distinct respiratory symptoms among adults in Parit Raja industrial area. Our data obtained in two neighboring industrial areas shows that adults residing about 5 km radius of the industrial park (exposed group) more frequently reported symptoms of coughing for the last 3 months and chest tightness for the last 3 years compared to the comparative group. This is consistent with the earlier studies conducted among adults in Eastern-Estonia and Korea (24,25). Additionally, in the Islamabad Industrial Estate, adults who residing <650 meter away from the industrial zone were found to be severely affected with cough, phlegm, dyspnoea, wheezing and chronic bronchitis (17). Air pollutants have been linked with respiratory tract irritation and infections (4,26). Coughing is one of the body's defense mechanisms for removing pollutants from the respiratory tract (27). Therefore, a high proportion of coughs among residents living closer to the Parit Raja industrial park indicates that they are more exposed to industrial air pollutants than those in the comparative group.

Moreover, we found that the prevalence of both symptoms, coughing for the last 3 months and chest tightness for the last 3 years were more prominent among adults living near the industrial park for more than 14 years. This finding was similar to the results observed in the previous study conducted by Tanyanont et al. (28) in Map Ta Phut Industrial Estate (MTPIE), Rayong Province, Thailand. They found that upper respiratory symptoms and wheezing were significantly more frequently reported among adults living within 5 km radius from the industrial zone and adults who lived in Map Ta Phut locality longer than 5 years. The association between long-term exposure and respiratory diseases has been observed in several studies (29,30). Moreover, many reviews summarized that long-term exposure to poor air quality was associated with dysfunction of immune system and neuroinflammation effects such as an abnormal increase of immunoglobulin A (IgA), immunoglobulin M (IgM), complement component 3 (C3), and upregulation costimulatory molecules such as CD80 and CD86 (4,31). Such disorder responses induced by air pollutants may underlie the diverse pathologies of respiratory and cardiovascular diseases (32).

In the multivariate analysis, we also observed that the symptom of cough was associated with male adults. Overall, many studies and reviews summarized that female adults reported more respiratory symptoms than male, but this was not true for every cohort (33–35). Occupational exposure and smoking that male adults normally engage in are also the contributing factor to this higher outcome (36). Nevertheless, we were unable to evaluate these contributing factors due to the small number of respondents. Moreover, we also found that symptoms of phlegm and wheezing for the last 3 months were positively associated with male adults from the exposed group and those who stay in Parit Raja for more than 14 years, however those associations did not meet the statistical significance level thresholds. There are many evidences supporting long-term pollution exposure associated with exercitation of respiratory diseases and symptoms especially asthma, chronic obstructive pulmonary disease (COPD), phlegm, cough, wheezing problem, breathing problem and pre-existing cardiovascular disease (ischemia, arrhythmias and cardiac failure) (37,38). Furthermore, people living

in developing countries, low- and middle-income countries of the South-East Asia, Central Africa and Western Pacific regions experiencing more burden of outdoor air pollution (39). Additionally, a recent report revealed that the concentration of PM_{10} measured from three monitoring stations in Parit Raja areas were below the 24 hours mean recommended by the World Health Organization (WHO) guideline (50 μg/m^3) (40), the National Ambient Air Quality Standard by U.S. EPA (150 μg/m^3) (41) and the new Malaysian Ambient Air Quality Standard 2018 Interim Target-2 (120 μg/m^3) (42,43). A number of reviews have highlighted that chronic exposure to the air pollutants, particularly PM_{10} and $PM_{2.5}$ below the current WHO guideline is still associated with an increased risk of cardiovascular disease, respiratory disease and lung cancer (44,45).

Given the potential health risks associated with chronic exposure to air pollutants, even when the PM_{10} levels are within acceptable limits, it is crucial for local authorities and stakeholders in Parit Raja to take proactive measures to further improve air quality. This may include implementing stringent emission control policies for industries, promoting the use of cleaner technologies, and enhancing green spaces and urban planning to mitigate the impact of air pollution (46,47). Additionally, public awareness campaigns about the importance of reducing personal exposure to pollutants and adopting cleaner practices could be beneficial in safeguarding public health (48). Continuous monitoring and evaluation of air quality should also be a priority to ensure that the implemented measures remain effective and responsive to changing environmental conditions.

A few limitations need to be recognised. First, the nature of cross-sectional research design makes it impossible to directly determine the causality effects between respiratory outcomes and independent variables. Therefore, further investigation using longitudinal studies is warranted in the future to validate the patterns of associations observed in this study. Second, the stratified analysis of occupational exposure was not identified and cannot be differentiated clearly. Lack of such information may have influenced the findings since prolonged occupational exposure may have detrimental impacts on respiratory functions. Third, pollution levels were not estimated which may not adequately represent industrial exposure. Another limitation to this study is the lack of specific information regarding daily activity since individuals do not spend all their time at home. The future studies could include the continuous meteorological data collected from the nearest monitoring stations to elucidate the interrelationships between exposure to industrial air pollutants and health effects. Finally, it is recommended that future study should address the scientific exposure assessment to minimize the possibility of misclassification of the exposure.

CONCLUSION

Findings from this study add to the body of knowledge that adults living in close proximity to the industrial zones for a period of more than 14 years had a risk of respiratory symptoms manifestation including coughing and chest tightness. Amongst the residents, male adults were found to be more severely affected than females. Knowledge of respiratory health impacts due to industrial air exposure would offer a beneficial justification for both policy makers and authorities to implement community-based intervention strategies to minimize and prevent population exposure.

ACKNOWLEDGEMENT

We are grateful to all Parit Raja communities who had voluntarily participated in this study.

REFERENCES

1. Ravindra K, Rattan P, Mor S, Nath A. Generalized additive models: Building evidence of air pollution, climate change and human health. Environ Int. 2019;132:1–10. doi: 10.1016/j.envint.2019.104987
2. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu NN, et al. The Lancet Commission on pollution and health. Lancet. 2018;391(10119):462–512. doi: 016/S0140-6736(17)32345-0
3. Sopian NA, Jalaludin J, Tamrin SBM. Risk of Respiratory Health Impairment among Susceptible Population Living near Petrochemical Industry- A Review Article. Iran J Public Health. 2016;45(1):9–16.
4. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and Health Impacts of Air Pollution: A Review. Front Public Heal. 2020;8(14):1–13. doi: 10.3389/fpubh.2020.00014
5. Nasrollahi Z, Hashemi M, Saeed H, Taghvaee VM. Environmental pollution, economic growth, population, industrialization, and technology in weak and strong sustainability: using STIRPAT model. Environ Dev Sustain. 2020;22:1105–22. doi: 10.1007/s10668-018-0237-5
6. Yu H-R, Lin C-HR, Tsai J-H, Hsieh Y-T, Tsai T-A, Tsai C-K, et al. A Multifactorial Evaluation of the Effects of Air Pollution and Meteorological Factors on Asthma Exacerbation. Int J Environ Res Public Health. 2020;17(11):1–13. doi: 10.3390/ijerph17114010
7. Mannucci PM, Franchini M. Health Effects of Ambient Air Pollution in Developing Countries. Int J Environ Res Public Health. 2017;14(1048):1–8. doi: 10.3390/ijerph14091048
8. Hisamuddin NH, Jalaludin J, Bakar SA, Latif

MT. The Influence of Environmental Polycyclic Aromatic Hydrocarbons (PAHs) Exposure on DNA Damage among School Children in Urban Traffic Area, Malaysia. Int J Environ Res Public Health. 2022;19(4):1–18. doi: 10.3390/ijerph19042193
9. Orellano P, Reynoso J, Quaranta N, Bardach A, Ciapponi A. Short-term exposure to particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: Systematic review and meta -analysis. Environ Int. 2020;142:1–15. doi: 10.1016/j.envint.2020.105876
10. Tseng W, Lu J, Chao H, Tsai M, Chang Y, Wang L, et al. Associations between Children's Exposure to PM2.5 and their Serum Inflammatory Responses in Taiwan. Aerosol Air Qual Res. 2022;22(12):1–15. doi: 10.4209/aaqr.220288
11. Zhao S, Liu S, Sun Y, Liu Y, Beazley R, Hou X. Assessing NO2-related health effects by non-linear and linear methods on a national level. Sci Total Environ. 2020;744:140909. doi: 10.1016/j.scitotenv.2020.140909
12. He MZ, Kinney PL, Li T, Chen C, Sun Q, Ban J, et al. Short- and intermediate-term exposure to NO2 and mortality: A multi-county analysis in China. Environ Pollut. 2020;261(2):1–7. doi: 10.1016/j.envpol.2020.114165
13. Jarkoni MNK, Mansor WNW, Abdullah S, Othman CWMNCW, Bakar AA, Ali SA, et al. Effects of exhaust emissions from diesel engine applications on environment and health: A review. J Sustain Sci Manag. 2022;17(1):281–301. doi: 10.46754/jssm.2022.01.019
14. Mohd Isa KN, Hashim Z, Jalaludin J, Norbдck D, Jabbar MA, Hashim JH. The Impact of Exposure to Indoor Pollutants on Allergy and Lung Inflammation among School Children in Selangor, Malaysia: An Evaluation Using Factor Analysis. Aerosol Air Qual Res. 2020;20:2371–83. doi: 10.4209/aaqr.2020.03.0128
15. Li AJ, Pal VK, Kannan K. A review of environmental occurrence, toxicity, biotransformation and biomonitoring of volatile organic compounds. Environ Chem Ecotoxicol. 2021;3:91–116. doi: 10.1016/j.enceco.2021.01.001
16. Pascal M, Pascal L, Bidondo M, Cochet A, Sarter H, Stempfelet M, et al. A Review of the Epidemiological Methods Used to Investigate the Health Impacts of Air Pollution around Major Industrial Areas. J Environ Public Health. 2013;2013(737926):1–17. doi: 10.1155/2013/737926
17. Bano R, Khayyam U. Industrial air pollution and self-reported respiratory and irritant health effects on adjacent residents: a case study of Islamabad Industrial Estate (IEI). Air Qual Atmos Heal. 2021;14(10):1709–22. doi: 10.1007/s11869-021-01051-5
18. Buteau S, Geng X, Labelle R, Smargiassi A. Review of the effect of air pollution exposure from industrial point sources on asthma-related effects in childhood. Environ Epidemiol. 2019;3(e077):1–15. doi: 10.1097/EE9.0000000000000077
19. Shamsuddin AFM, Jalaludin J, Hashim NH. Exposure to industrial air pollution and its association with respiratory symptoms among children in Parit Raja, Batu Pahat. IOP Conf Ser Earth Environ Sci. 2022;1013:1–11. doi: 10.1088/1755-1315/1013/1/012008
20. Shafii H, Miskam N. Transformasi Pekan Parit Raja untuk Kesejahteraan Hidup Masyarakat (Transformations at Pekan Parit Raja impact towards socio economic landcape and community to quality of life). Batu Pahat, Johor: Penerbit UTHM; 2017. 67 p.
21. Lemeshow S, Hosmer DW, Klar J. Sample size requirements for studies estimating odds ratios or relative risks. Stat Med. 1988;7(7):759–64. doi: 10.1002/sim.4780070705
22. Ayub ZA, Jalaludin J, Isa KNM, Noraini NMR. Evaluation of In-Vehicle Pollutants Exposure and Respiratory Symptoms among Bus Drivers in Kota Bahru, Malaysia. IOP Conf Ser Earth Environ Sci. 2022;1013:1–8. doi: 10.1088/1755-1315/1013/1/012010
23. Suhaimi NF, Jalaludin J, Bakar SA. The Influence of Traffic-Related Air Pollution (TRAP) in Primary Schools and Residential Proximity to Traffic Sources on Histone H3 Level in Selected Malaysian Children. Int J Environ Res Public Health. 2021;18(15):1–19. doi: 10.3390/ijerph18157995
24. Eom S, Choi J, Bae S, Lim J, Kim G, Yu S, et al. Health effects of environmental pollution in population living near industrial complex areas in Korea. Environ Health Toxicol. 2018;33(1):1–8. doi: 10.5620/eht.e2018004
25. Orru H, Idavain J, Pindus M, Orru K, Kesanurm K, Lang A, et al. Residents' Self-Reported Health Effects and Annoyance in Relation to Air Pollution Exposure in an Industrial Area in Eastern-Estonia. Int J Environ Res Public Heal. 2018;15(252):1–22. doi: 10.3390/ijerph15020252
26. Jo E, Song W. Environmental triggers for chronic cough. Asia Pac Allergy. 2019;9(2):1–10. doi: 10.5415/apallergy.2019.9.e16
27. Zhang J, Perret JL, Chang AB, Idrose NS, Bui DS, Lowe AJ, et al. Risk factors for chronic cough in adults: A systematic review and meta-analysis. Respirology. 2022;27:36–47. doi: 10.1111/resp.14169
28. Tanyanont W, Vichit-Vadakan N. Exposure to volatile organic compounds and health risks among residents in an area affected by a petrochemical complex in Rayong, Thailand. Southeast Asian J Trop Med Public Health. 2012;43(1):201–11.
29. Bauleo L, Bucci S, Antonucci C, Sozzi R, Davoli M, Forastiere F, et al. Long-term exposure to air pollutants from multiple sources and mortality in an industrial area: a cohort study. Occup

Environ Med. 2019;76:48–57. doi: 10.1136/oemed-2018-105059
30. Siddique HMA, Kiani AK. Industrial pollution and human health: evidence from middle-income countries. Environ Sci Pollut Res. 2020;27(11):12439–48. doi: 10.1007/s11356-020-07657-z
31. Kurt OK, Zhang J, Pinkerton KE. Pulmonary Health Effects of Air Pollution. Curr Opin Pulm Med. 2016;22(2):138–43. doi: 10.1097/MCP.0000000000000248
32. Glencross DA, Ho T-R, Camica N, Hawrylowicz CM, Pfeffer PE. Air pollution and its effects on the immune system. Free Radic Biol Med. 2020;151:56–8. doi: 10.1016/j.freeradbiomed.2020.01.179
33. Clougherty JE. A Growing Role for Gender Analysis in Air Pollution Epidemiology. Environ Health Perspect. 2010;118(2):167–76. doi: 10.1289/ehp.0900994
34. Zhou M, He G, Liu Y, Yin P, Li Y, Kan H, et al. The associations between ambient air pollution and adult respiratory mortality in 32 major Chinese cities, 2006–2010. Environ Res. 2015;137:278–86. doi: 10.1016/j.envres.2014.12.016
35. Surawattanasakul V, Sirikul W, Sapbamrer R, Wangsan K, Panumasvivat J, Assavanopakun P, et al. Respiratory Symptoms and Skin Sick Building Syndrome among Office Workers at University Hospital, Chiang Mai, Thailand: Associations with Indoor Air Quality, AIRMED Project. Int J Environ Res Public Health. 2022;19(17):1–14. doi: 10.3390/ijerph191710850
36. Fix J, Annesi-maesano I, Baldi I, Boulanger M, Cheng S, Cortes S, et al. Gender differences in respiratory health outcomes among farming cohorts around the globe: findings from the AGRICOH consortium. J Agromedicine. 2021;26(2):97–108. doi: 10.1080/1059924X.2020.1713274
37. Sopian NA, Jalaludin J, Bakar SA, Hamedon TR, Latif MT. Exposure to Particulate PAHs on Potential Genotoxicity and Cancer Risk among School Children Living Near the Petrochemical Industry. Int J Environ Res Public Health. 2021;18(5):2575. doi: 10.3390/ijerph18052575
38. Rajak R, Chattopadhyay A. Short and long-term exposure to ambient air pollution and impact on health in India: A systematic review. Int J Environ Health Res. 2020;30(6):593–617. doi: 10.1080/09603123.2019.1612042
39. Tiotiu AI, Novakova P, Nedeva D, Chong-Neto HJ, Novakova S, Steiropoulos P, et al. Impact of Air Pollution on Asthma Outcomes. Int J Environ Res Public Health. 2020;17(6212):1–29. doi: 10.3390/ijerph17176212
40. WHO. WHO Air Quality Guidelines Global Update 2005. World Heal Organ Denmark. 2005;
41. Environmental Protection Agency. NAAQS Table. 2021. https://www.epa.gov/criteria-air-pollutants/naaqs-table
42. Department of Environment Malaysia. New Malaysia Ambient Air Quality Standard. 2021. https://www.doe.gov.my/portalv1/en/info-umum/english-air-quality-trend/108
43. Raffee AF, Hamid HA, Mohamed RMSR, Jaffar MI. Time series analysis of PM10 concentration in Parit Raja residential area. Int J Eng Technol. 2018;7(3.23 Special Issue 23):15–21. doi: 10.14419/ijet.v7i3.23.17252
44. Stafoggia M, Oftedal B, Chen J, Rodopoulou S, Renzi M, Atkinson RW, et al. Long-term exposure to low ambient air pollution concentrations and mortality among 28 million people: results from seven large European cohorts within the ELAPSE project. Lancet Planet Heal. 2022;6(1):e9-18. doi: 10.1016/S2542-5196(21)00277-1
45. Chen J, Hoek G. Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. Environ Int. 2020;143:105974. doi: 10.1016/j.envint.2020.105974
46. Sofia D, Gioiella F, Lotrecchiano N, Giuliano A. Mitigation strategies for reducing air pollution. Environ Sci Pollut Res. 2020;27:19226–35. doi: 10.1007/s11356-020-08647-x
47. Idrees Z, Zheng L. Low Cost Air Pollution Monitoring Systems: A Review of the Protocols and the Enabling Technologies. J Ind Inf Integr . 2019;17:100123. doi: 10.1016/j.jii.2019.100123
48. Usmani RSA, Saeed A, Abdullahi AM, Pillai TR, Jhanjhi NZ, Hashem IAT. Air pollution and its health impacts in Malaysia: a review. Air Qual Atmos Heal. 2020;13:1093–118. 10.1007/s11869-020-00867-x