

PREVALENCE OF RESPIRATORY SYMPTOMS, LUNG FUNCTION ABNORMALITIES, AND CARDIAC CONDITIONS IN JEEPNEY DRIVERS EXPOSED TO DIFFERENT LEVELS OF BLACK CARBON

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ABSTRACT

Background & Aim: The jeepney, a traditional mode of transportation in the Philippines since the end of World War II, is a major source of black carbon (BC) in Metro Manila's air. Chronic exposure to black carbon may constitute a significant health hazard for jeepney drivers. This study assessed the adverse effects of BC exposure on the prevalence of symptoms, electrocardiogram (ECG), and lung function abnormalities in jeepney drivers in selected areas in Metro Manila.

Methods: Between December 2019 and March 2020, we studied the health status of jeepney drivers plying two routes with different levels of measured BC, using a modified version of the Burden of Obstructive Lung Disease (BOLD) questionnaire, ECG, and spirometry. The effects of BC severity and other respiratory risk factors, such as smoking, environmental exposures, and other occupational exposures, were also determined.

Results: One hundred three (103) jeepney drivers with a mean driving experience of 21.4 ± 11.3 years participated in the study, grouped according to the severity of BC levels in the route. Jeepney drivers on the route with higher BC severity reported five times more symptoms ($p = 0.005$) and showed three times more ECG abnormalities ($p = 0.014$) using univariate analysis. There was no substantial difference in lung function parameters. Logistic regression analysis showed that high BC levels accounted significantly for increased prevalence of symptoms (OR = 5.84 [95% CI: 1.60, 21.39], $p < 0.01$) and ECG abnormalities (OR = 3.2 [95% CI: 1.22, 8.37], $p = 0.018$) in the high BC group. No other respiratory risk factors were found to have significant effects.

Conclusion: The study shows the effect of BC levels on the prevalence of symptoms and ECG abnormalities in the highly exposed jeepney driver population. Further studies are required to determine the effect of BC exposure on lung function in this population.

Key words: ambient black carbon, environmental epidemiology, cardiac conditions

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Year Completed: 2021
Date Received: December 21, 2025
Date Accepted: January 5, 2026

Disclosure of Conflict of Interest:
The authors declare they have no real or perceived conflicts of interest. The use of trade names in this manuscript is for identification only and does not imply endorsement by the authors or their institutions.

Transport- or traffic-related air pollution has been shown to increase mortality from cardiopulmonary causes, increase the risk of respiratory symptoms and diseases not related to asthma or allergies, and cause impaired lung function and cardiovascular morbidity.¹⁻³

Particulate matter measurements (like PM₁₀ and PM_{2.5}) have been correlated with levels of air pollution and adverse health effects in vulnerable populations such as bus drivers,^{4,5} taxi drivers,⁶⁻⁸ and traffic policemen.⁹⁻¹¹

Black carbon (BC) is another component of particulate matter that is formed due to the incomplete combustion of fossil fuels, biofuels, and biomass, and is emitted directly into the atmosphere in the form of fine particles. Mortality and morbidity time are higher for BC than for PM₁₀ or PM_{2.5} for each 1 µg/m³ increase in exposure.¹²⁻¹⁴ BC levels also varied more widely between weekends and weekdays (50 to 100%) compared to PM₁₀ (5 to 15%).¹⁵

Traffic in the Metropolitan Manila area is said to be one of the worst in the world, with the iconic jeepney, a traditional mode of travel in the Philippines since the Second World War, contributing greatly to air pollution. With its pre-Euro4 diesel engine, the jeepney accounts for 94% of the total roadside emitted BC as soot, and up to 99% of the total measured PM_{2.5}.¹⁶

It is therefore not surprising that jeepney drivers are also considered vulnerable to the effects of air pollution. Subida et al. reported a COPD prevalence of 32.5% among jeepney drivers, much higher than among commuters and bus drivers.¹⁷

The present study was conducted to determine the association of traffic-related air pollution measured in black carbon levels and adverse health effects in the vulnerable jeepney driver population.

This study aimed to compare the prevalence of respiratory symptoms, electrocardiogram, and lung function abnormalities among jeepney drivers operating in selected areas in Metro Manila with high and low levels of measured BC in the air.

METHODS

This was a cross-sectional study of jeepney drivers plying two selected routes in Metro Manila with different levels of measured black carbon (BC). The two routes were selected based on the observed volume of vehicular traffic and actual BC measurements. The high BC route, which passes through several congested roads, had an average BC level of 23.4 ± 14.0 µg/m³, while the low BC route, which circumnavigates a tree-lined university campus, had an average ambient BC level of 6.2 ± 5.2 µg/m³. Details of the BC levels are discussed elsewhere.¹⁸ Criteria pollutants, such as gases (SO₂, NO₂, CO) with possible confounding effects, were not considered because data

on these were not available. Survey data and health-related data of jeepney drivers plying the high BC route were categorically analyzed and labelled as "High Black Carbon" or HBC group, while those plying the low BC route were categorized as "Low Black Carbon" or LBC group.

Participants were licensed professional jeepney drivers who had regularly driven in the specified areas for at least five years and who were willing to provide personal information and undergo study procedures after signing an Informed Consent. Jeepney drivers with unstable co-morbid cardiac and pulmonary conditions, recent hospitalization for a medical illness, and ongoing treatment for active pulmonary tuberculosis were excluded. The study protocol was approved by the Technical Review Board and Ethics Review Board of the Lung Center of the Philippines.

Participants' vital signs, height, weight, and BMI, and medical history such as atopy, asthma, history of tobacco, alcohol, or drug intake, respiratory or any other previously diagnosed medical conditions were recorded. Participants' work characteristics and environment, such as educational background, mode of transport, years in the occupation, transit time (in hours) per day, and exposure to work-related indoor air pollutants, were also recorded. The study used the Filipino translation of the Burden of Obstructive Lung Disease (BOLD) Questionnaire with modifications (added items regarding solid fuel use and mode of transportation) to gather relevant information on environmental and occupational factors that may affect respiratory function. The Filipino translation has been validated and used in two national surveys.^{19,20}

Pulmonary function was measured in forced vital capacity (FVC) and forced expiratory volume in 1 sec (FEV₁). Ratios of FEV₁ to FVC (FEV₁/FVC) were calculated. The measurements were performed according to methods recommended by the American Thoracic Society¹⁰ using the *EasyOne Air* device (Medizintechnik AG, Zurich, Switzerland). The highest of three acceptable measurements was taken as the actual value. The obtained data was compared with predicted values based on age, sex, height and ethnic group (non-smoking male adults) by Crapo et al.²¹ Reduced values of FVC, FEV₁, and FEV₁/FVC were the primary criteria used to diagnose respiratory function impairment based on the following Global Initiative for Chronic Obstructive Lung Diseases (GOLD) criteria [21]: Normal: FEV₁ and FVC above 80% predicted; FEV₁/FVC ratio above 0.7; Obstructive: FEV₁ below 80% predicted; FVC can be normal or reduced, usually to a lesser degree than FEV₁; FEV₁/FVC ratio below 0.7; and Restrictive: FEV₁ normal or mildly reduced; FVC below 80% predicted; FEV₁/FVC ratio normal, above 0.7.

Cardiovascular status was evaluated through a review of cardiac symptoms and medical history, blood pressure measurements, physical examination, and official ECG reading by the in-house cardiologist.

Percentages were reported for categorical variables, while means $\pm$ standard deviation were obtained for quantitative variables. Differences in continuous variables (age, height, BMI, and duration on the job) between the two groups were computed using a t-test, and relationships between two categorical variables were tested using a chi-square test. Univariate analysis and logistic regression were performed to test the association between the presence of respiratory and other symptoms, ECG abnormalities, and spirometry abnormalities, and BC levels, as well as the interaction of risk factors like age, tobacco and biomass fuel use, and other environmental or occupational exposures. Odds ratios and the corresponding 95% confidence intervals were obtained. Statistical analysis was performed using Stata 15 software.

RESULTS

One hundred and three participants were recruited, with 49 jeepney drivers belonging to the HBC group and 54 to the LBC group. All of the participants were male. There were comparable distributions of age and comorbid conditions between the two groups. The LBC group had a slightly greater percentage of college-level education (Table 1).

Participants had been driving, on average, for 12 hours a day, five days a week, for more than 20 years, representing a significant exposure to air pollution. There were no significant differences between the two groups in terms of driving profile (hours per day, days per week, and total years of professional driving), smoking profile (years of smoking and total pack-years smoked), exposure to biomass fuel (charcoal and wood), and other environmental and occupational exposures (Table 1).



Most participants were smokers, with 38 (71%) in the LBC group and 33 (66%) in the HBC group reporting a history of smoking. Duration (in years) of smoking and estimated

number of pack-years did not differ significantly between the two groups ($p = 0.781$) (Table 1).

Table 1. Demographic and clinical profile of participants.

Profile	LBC GROUP		HBC GROUP		p-value
	NO.	%	NO.	%	
Age (years)					
18-40	15	27.8	13	26.5	0.239
41-50	16	29.6	17	34.7	
51-60	13	24.1	16	32.7	
61 and above	10	18.5	3	6.1	
Gender					
Male	54	100	49	100	
Educational Attainment					
Elementary	13	24.1	10	20.4	0.277
High School	25	46.3	30	61.2	
College	16	29.6	9	18.4	
Co-Morbidity					
Allergy	8	14.8	8	16.3	0.523
Hypertension	7	13.0	7	14.3	0.535
Diabetes Mellitus	3	5.6	3	6.1	0.613
Asthma	5	9.3	3	6.1	0.414
Tuberculosis	2	3.7	6	12.2	0.106
Pneumonia	1	1.9	0	0.0	0.524
Fuel for Cooking					
Wood	9	16.7	7	14.3	0.477
Charcoal	14	25.9	20	40.8	0.081
LPG	53	98.2	48	98.0	0.728
Electric	9	16.7	11	22.5	0.311
Driving other vehicles	20	37.0	16	33.3	0.428
Burning trash	10	18.5	13	27.1	0.213
Farming	7	13.0	2	12.5	0.455
Roadside home	3	5.6	5	10.4	0.294
	Mean	SD	Mean	SD	p-value
Smoking Profile					
No. of years of smoking	19.1	16.1	17.3	14.6	0.557
Pack-years	14.6	17.7	10.4	12.7	0.175
Jeepney driving					
No. of hours per day	11.3	2.4	11.9	2.2	0.167
No. of days per week	4.8	0.8	4.5	0.9	0.087
Health profile on PE					
Height	1.6	0.1	1.6	0.1	0.112
Weight	69.9	10.3	66.5	10.0	0.094
BMI	25.8	3.4	25.2	3.6	0.359
SBP	122.9	19.2	124.6	13.7	0.602
DBP	83.7	12.2	83.4	9.0	0.875
HR	78.6	12.8	77.6	11.1	0.669
O2 Saturation	97.1	3.2	97.4	1.1	0.570

The HBC group reported more symptoms, with 15 (30.6%) reporting at least one respiratory or constitutional symptom compared with only 4 (7.4%) in the LBC group ($p = 0.002$). Shortness of breath was also more prevalent in the HBC group, with 12% compared with just 2% in the LBC group ($p = 0.042$). None of the participants reported any symptoms of malaise, anorexia, or hemoptysis. There were also more electrocardiographic abnormalities

recorded in the HBC group ($n = 19$, 38.8%) compared to the LBC group ($n = 9$, 16.7%, $p = 0.002$). In particular, 13 jeepney drivers from the HBC group had signs of arrhythmia, significantly higher compared with six drivers from the LBC group ($p = 0.039$). Seven patients in the HBC group had ECG findings of ischemia compared with none in the LBC group (Table 2).

Table 2. Comparison of symptoms and ECG findings of Low and High Black Carbon groups.

	LBC GROUP		HBC GROUP		FISHER'S EXACT TEST
	NO.	%	NO.	%	p-value
Any symptom	4	7.4	15	30.6	0.002
Cough	2	3.7	5	10.2	0.180
Fever	0	0.0	1	2.0	0.476
Sputum	2	3.7	3	6.1	0.454
Weight loss	0	0.0	1	2.0	0.476
SOB	1	1.9	6	12.2	0.042
Night sweats	1	1.9	2	4.1	0.463
Chest/back pains	1	1.9	4	8.2	0.152
Any findings on ECG	9	16.67	19	38.78	0.011
Axis Deviation	2	3.70	2	4.08	0.654
Arrhythmia	6	11.11	13	26.53	0.039
Atrial enlargement	1	1.85	4	8.16	0.152
Ischemia	0	0.00	7	14.29	0.004

*LBC: Low Black Carbon group; HBC: High Black Carbon group

Univariate analysis showed that the presence of any symptom was significantly related to the level of BC exposure in their respective routes. Jeepney drivers from

the HBC group were 5.5 times more likely to report any symptoms than the drivers from the LBC group ($p = 0.005$, 95% CI: 1.57, 19.7) (Table 3).

Table 3. Univariate analysis of the association of the presence of symptoms with BC severity and other risk factors among jeepney drivers.

Factor	N	With Symptoms (n %)	Odds Ratio	95% Confidence Interval of OR	p-value
Black carbon severity					
LBC group	54	4 (7.4)			
HBC group	49	15 (30.6)	5.51	1.68, 18.05	0.005
Use of charcoal for cooking					
No	69	9 (13.0)			
Yes	34	10 (29.4)	2.78	1.00, 7.68	0.049
Use of firewood for cooking					
No	87	15 (17.2)			
Yes	16	4 (25.0)	1.60	0.45, 5.65	0.465
Exposure to environmental pollutants					
No	42	5 (11.9)			
Yes	61	14 (23.0)	2.20	0.73, 6.68	0.162
No. of years of driving			0.98	0.94, 1.03	0.484
Pack-years of smoking			1.01	0.98, 1.04	0.641
Age			1.01	0.96, 1.05	0.741

On the other hand, driving-years, pack-years, use of biomass, and environmental exposure were not significant risk factors for the development of symptoms. Further

logistic regression analysis showed that the BC severity was significantly associated with the presence of any symptom (Table 4).

Table 4. Logistic regression analysis of the presence of symptoms with BC level and other risk factors among jeepney drivers

Variable	Odds Ratio	Std. Err.	95% Interval	Conf.	p-value
Black carbon level	5.8401	3.8558	1.6011	21.301	0.008
Exposure to environmental pollutants	1.9544	1.2507	0.5575	6.9509	0.295
Use of firewood for cooking	1.1361	0.3354	0.2688	4.801	0.862
Use of charcoal for cooking	2.0415	1.1989	0.6457	6.4544	0.224
Age, years	1.0506	0.0446	0.9667	1.1418	0.244
Smoking, pack-years	1.0094	0.0197	0.9715	1.0488	0.631
Driving, years	0.9371	0.0393	0.8629	1.0715	0.122
Constant	0.0109	0.0186	0.0003	0.3065	<0.001

Log likelihood = -41.1166
p = 0.0229

Univariate analysis showed that the level of BC exposure was related to the prevalence of ECG abnormalities

among the jeepney drivers (Table 5).

Table 5. Univariate analysis of the association of abnormal ECG findings with BC severity and other risk factors among jeepney drivers.

Factor	N	With ECG Findings (n %)	Odds Ratio	95% Confidence Interval of OR	p-value
Black carbon severity					
LBC group	54	9 (16.7)			
HBC group	49	19 (38.8)	3.17	1.26, 7.93	0.014
Use of charcoal for cooking					
No	69	17 (24.6)			
Yes	34	11 (32.4)	1.46	0.59, 3.61	0.409
Use of firewood for cooking					
No	87	23 (26.4)			
Yes	16	5 (31.3)	1.26	0.40, 4.03	0.691
Exposure to environmental pollutants					
No	42	9 (21.4)			
Yes	61	19 (31.2)	1.66	0.66, 4.14	0.278
No. of years of driving			0.99	0.95, 1.03	0.537
Pack-years of smoking			1.00	0.98, 1.03	0.794
Age			1.00	0.96, 1.04	0.922

Jeepney drivers from the HBC group were three times more likely to show abnormalities on ECG than drivers from the LBC group ($p = 0.014$). Logistic regression

confirmed that High BC levels accounted for the increase in ECG abnormalities (Table 6)

Table 6. Logistic regression analysis of the presence of ECG findings with BC level and other risk factors among jeepney drivers.

Variable	Odds Ratio	Std. Err.	95% Interval	Conf.	p-value
Black carbon level	3.2013	1.5714	1.2231	8.3786	0.018
Exposure to environmental pollutants	1.5269	0.7761	0.5638	4.1349	0.405
Use of firewood for cooking	1.0559	0.6842	0.2965	0.2965	0.933
Use of charcoal for cooking	1.1145	0.565	0.4126	3.0103	0.831
Age, years	1.0295	0.0364	0.9605	1.1034	0.410
Smoking, pack-years	1.0045	0.0165	0.9727	1.0375	0.781
Driving, years	0.9646	0.0326	0.9026	1.0309	0.288
Constant	0.0710	0.0937	0.0053	0.9449	0.045

Log likelihood = -55.852
 $p = 0.2656$

There were no significant differences in the lung function

parameters (both pre- and post-bronchodilator) between the groups (Table 7).

Table 7. Comparison of lung function values of Low and High BC groups.

SPIROMETRY	LBC GROUP		HBC GROUP		T-TEST
	Mean	SD	Mean	SD	p-value
PRE-BD					
Pre-FEV Predicted	3.04	0.39	2.98	0.38	0.503
Pre-FEV Actual	2.64	0.52	2.61	0.54	0.732
Pre-FEV % Predicted	0.88	0.18	0.87	0.13	0.851
Pre-FVC Predicted	3.68	0.44	3.60	0.42	0.346
Pre-FVC Actual	3.31	0.50	3.26	0.53	0.628
Pre-FVC % Predicted	0.91	0.14	0.91	0.10	1.000
Pre-FEV/FVC Predicted	0.82	0.02	0.83	0.02	0.180
Pre-FEV/FVC Actual	0.78	0.09	0.80	0.08	0.463
Pre-FEV/FVC % Predicted	0.95	0.10	0.96	0.09	0.631
POST-BD					
Post-FEV Predicted	3.04	0.40	3.00	0.37	0.627
Post-FEV Actual	2.69	0.51	2.70	0.51	0.974
Post-FEV % Predicted	0.89	0.16	0.90	0.12	0.838
Post-FVC Predicted	3.68	0.44	3.61	0.42	0.431
Post-FVC Actual	3.33	0.51	3.27	0.51	0.551
Post-FVC % Predicted	0.91	0.15	0.91	0.10	0.767
Post-FEV/FVC Predicted	0.82	0.02	0.83	0.02	0.133
Post-FEV/FVC Actual	0.81	0.09	0.82	0.07	0.363
Post-FEV/FVC % Predicted	0.98	0.10	0.99	0.08	0.542

A total of twenty-eight or 27.2% of the whole study cohort had abnormal spirometry findings. Table 8 shows the univariate analysis of factors that may be related to findings of pulmonary function test (PFT) abnormalities. There were more PFT abnormalities seen in the LBC

group (37.0%) compared with the HBC group (16.3%); thus, BC severity was paradoxically associated with a lower risk for PFT abnormalities (OR = 0.33; $p = 0.03$). The number of years of driving, the number of pack-years of smoking, and age showed a trend toward increased risk of PFT abnormalities.

Table 8. Univariate analysis of the association of PFT abnormality with BC severity and other factors among jeepney drivers.

Factor	N	With PFT Findings (n %)	Odds Ratio	95% Confidence Interval of OR	p-value
Black carbon severity					
LBC group	54	20 (37.0)			
HBC group	49	8 (16.3)	0.33	0.13, 0.85	0.021
Use of charcoal for cooking					
No	69	22 (31.9)			
Yes	34	6 (17.7)	0.46	0.17, 1.27	0.132
Use of firewood for cooking					
No	87	26 (29.9)			
Yes	16	2 (12.5)	0.34	0.07, 1.58	0.167
Exposure to environmental pollutants					
No	42	15 (35.7)			
Yes	61	13 (21.3)	0.49	0.20, 1.17	0.109
No. of years of driving			1.04	1.00, 1.08	0.061
Pack-years of smoking			1.03	1.00, 1.06	0.047
Age			1.03	0.99, 1.08	0.097

DISCUSSION

The present study measured the health effects of BC exposure on jeepney drivers in two categorized routes in Metro Manila, with an average of more than 20 years of driving their vehicles.

The results of the study show that exposure to higher levels of BC led to more reported respiratory or cardiac symptoms. Jeepney drivers in the HBC group were five times more likely to report any symptoms compared to those in the LBC group. It is widely recognized that acute or chronic exposure to air pollution is responsible for an increase in respiratory symptoms and diseases in communities or specific occupational groups.²²⁻²⁶ There was also a higher prevalence of any electrocardiographic abnormality, ischemia, or arrhythmias seen in the high BC group (OR > 3). These abnormal ECG findings may indicate the presence of chronic cardiac conditions, but may also indicate the acute effects of recent exposure to air pollutants.

Exposure to particulate matter air pollution, whether acute or chronic, is associated with increased risk of death from cardiovascular diseases, including ischemic heart disease, heart failure, and ischemic/thrombotic stroke.²⁷ Levels of PM2.5 have consistently correlated

with negative cardiovascular outcomes regardless of location.²⁸ Experimental studies have shown that exposure to increasing levels of ultrafine particulate matter in a controlled setting causes immediate electrocardiogram changes. Breitner et al.,²⁹ using four different study designs involving different study populations, exposure scenarios, and exposure levels, found evidence that recent exposures (within hours) to ultrafine particles and PM2.5 can induce acute pathophysiological responses that are apparent in ECG measurements. Another prospective panel study conducted in 56 males with ischemic heart disease showed the following ECG changes following 24 hours of exposure: a significant increase in QT duration in response to exposure to organic carbon; a significant decrease in T-wave amplitude with exposure to ultrafine, accumulation mode, and PM2.5 particles; and a corresponding significant increase in T-wave complexity in association with PM2.5 particles. Variability of T-wave complexity also significantly increased with exposure to components of the particulate matter (for the panel study mentioned, organic and elemental carbon) in the same time interval.³⁰

We did not find significant differences in the FEV₁, FVC, and FEV₁/FVC ratio before and after inhalation of bronchodilators between the two groups. Univariate analysis showed that high BC exposure was not a

significant factor in the development of PFT abnormalities, with a higher percentage of PFT abnormalities seen with the LBC group. There was a trend toward a higher number of PFT abnormalities due to increasing age, pack-years of smoking, and number of driving years, but these were not statistically significant.

The effect of air pollution on the lung function of adults remains controversial. Few studies have assessed this association, but individual cohort studies from Europe,³¹⁻³³ the USA,³⁴ and Asia,³⁵ and a recent multi-cohort study of five European cohorts within the European Study of Cohorts for Air Pollution Effects (ESCAPE) project,³⁶ suggest adverse effects on adult lung function, despite having mixed results. The ventilatory effects are shown to be obstructive in some studies,^{23,34,37} and restrictive in other studies.^{29,31,32,35}

Several factors explain the lack of conclusive evidence of the adverse ventilatory effects of BC. The study by de Jong et al.³² suggests that the association of PM10 and PM2.5 with impaired lung function levels in adults is stronger in subjects who are female, have higher BMI, and have underlying respiratory diseases such as asthma or COPD. Notably, our cohort consisted of all males, with borderline BMI, and low prevalences of asthma and COPD. A study in Parisian taxi drivers also did not find a relationship between BC levels and lung function,³⁸ but this was probably due to the very low BC levels of 2.2 to 3.9 ug/m³ measured inside the taxis compared to the 6.2 to 23.4 ug/m³ of BC measured in ambient air in our study. We also had a small sample size, making it the major limitation of this study. Our recruitment of study participants and data collection were cut short due to community lockdowns to prevent the spread of COVID-19. Future studies on the health impacts of the gaseous pollutants may also be considered once the data are made available. Certainly, more studies are needed to further define the associations of BC levels and other air quality criteria pollutants with lung function.

CONCLUSIONS

In conclusion, our study provides evidence of the categorized levels of chronic BC exposure that affect the local prevalence of symptoms and ECG abnormalities in the vulnerable jeepney driver population. There was no association between abnormalities in lung function parameters and high BC exposure in this cohort. However, further studies are required to determine the interactions between exposure to BC (and other risks) and lung function.

Author Contributions: Conceptualization: Tamara Schikowski, Luisito F. Idolor, Vincent M. Balanag, Mylene G. Cayetano; recruitment of study cohort: Mylene G. Cayetano, Sheryllyn M. Linda; Data curation: Luisito F. Idolor, Mylene G. Cayetano, Sheryllyn M. Linda; formal analysis: Vincent M. Balanag; funding acquisition: Tamara

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FUNDING

This research was funded by the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) No. URBAN_SEA2-034.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Ethics Review Board of the Lung Center of the Philippines (protocol code LCP-CT-021-2019 on 28 November 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. All adult participants (Over 18 years old) provided written informed consent to participate in this study.

Data Availability Statement: Data supporting statements for high and low BC values will be provided once the doi is made available. Cayetano M.G., Linda S.M., Lamorena-Lim R., and Bagtasa G. (2021). "Low and high emission zones at the pedestrian breathing level identified using multi-parameter air pollution measurements", Manuscript in preparation.

ACKNOWLEDGMENTS

Thank you to Clean Air Asia, Inc., for facilitating the BMBF funding. We also thank Prof. Peter G. J. Burney and his group at the BOLD Centre, UK, for permitting us to use the BOLD (Burden of Obstructive Lung Disease) questionnaire. Sincere gratitude to the jeepney operators and drivers' association and transport cooperative that participated in the study cohort, to our biostatistician Mariannette T. Inobaya, PhD, for her invaluable help in assessing our data, to the Nurses and Radiology Technicians of Lung Center of the Philippines, and the researchers and staff of the Environmental Pollution Studies Laboratory of UPD-IESM (Enrique Mikhail Cosep, Raian Lapresca, Melody Batongbakal).

CONFLICTS OF INTEREST

The authors declare they have no real or perceived conflicts of interest. The use of trade names in this manuscript is for identification only and does not imply endorsement by the authors or their institutions.

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