Indonesian Journal of Global Health Research
Volume 8 Number 5, October 2026
e-ISSN 2715-1972; p-ISSN 2714-9749
http://jurnal.globalhealthsciencegroup.com/index.php/IJGHR

THE EFFECT OF TRAVEL DISTANCE ON LEAD EXPOSURE AMONG MOTORCYCLE RIDERS

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ABSTRACT

Lead (Pb) exposure resulting from high traffic density in the Taman Tekno Serpong area, South Tangerang City, may pose significant health risks. The World Health Organization states that there is no safe threshold for Pb exposure. This study aimed to analyze the relationship between daily travel distance and blood lead levels among motorcycle users. This study employed an analytical cross-sectional design, and samples were collected using a purposive sampling technique involving 15 male respondents aged 18–60 years who had worked in the area for at least one year. Blood Pb levels were measured from venous blood samples (K3EDTA) using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Data were analyzed using Spearman correlation and linear regression analyses, while considering potential confounding factors such as age, years of employment, smoking habits, mask usage, and duration of exposure. The results showed that all samples had blood Pb levels ranging from 1,879 to 4,737 µg/L. A significant relationship was found between daily travel distance and blood Pb levels ($r = 0{,}813$; $p < 0{,}05$), indicating a very strong positive correlation. Multicollinearity testing showed VIF values ranging from 1,5 to 2,9 (<10), indicating no strong correlation among the independent variables. The regression model demonstrated a very strong relationship between the independent variables and blood Pb levels ($R = 0{,}929$). Daily travel distance was significantly associated with increased blood Pb levels among motorcycle users in the study area.

Keywords: blood lead; ICP-MS; daily travel distance; exposure; purposive sampling

How to cite (in APA style)
Ratnasari, R. R. P., & Harningsih, T. (2026). The Effect of Travel Distance on Lead Exposure Among Motorcycle Riders. *Indonesian Journal of Global Health Research*, *8*(5), 947–954. https://doi.org/10.37287/ijghr.v8i5.2130.

INTRODUCTION

Air pollution caused by motor vehicle emissions remains one of the most important environmental health problems in urban and industrial areas worldwide. Rapid urbanization, increasing numbers of motorized vehicles, and intensive logistics activities contribute significantly to the accumulation of airborne pollutants, including particulate matter and toxic heavy metals such as lead (Pb). Although the use of unleaded gasoline has reduced environmental lead contamination in many countries, Pb exposure still persists through industrial activities, brake and tire wear, road dust resuspension, and residual emissions from transportation activities. Continuous exposure to lead may result in various adverse health effects, including neurological disorders, hematological abnormalities, kidney dysfunction, and cardiovascular diseases.

Individuals with high daily mobility, particularly motorcycle riders, are considered vulnerable populations because they are directly exposed to roadside air pollution for prolonged durations. In densely trafficked areas, motorcycle riders inhale airborne particles and suspended dust continuously during commuting activities. Previous studies have demonstrated that occupational and environmental exposure to traffic-related pollutants can increase blood lead concentrations among transportation workers and roadside populations. However, most previous studies have primarily focused on occupational duration, industrial exposure, or smoking behavior, while limited research has specifically evaluated the influence of daily travel distance as an indicator of cumulative roadside exposure. Therefore, daily travel distance may represent an important exposure parameter that requires further investigation.

Recent studies have emphasized that traffic-related air pollution remains a major source of human exposure to heavy metals, particularly lead (Pb), in urban environments. Although the global transition toward unleaded gasoline has significantly reduced atmospheric Pb concentrations, residual contamination from brake wear, tire abrasion, industrial emissions, and resuspended road dust continues to contribute to chronic low-level exposure among urban populations. Individuals with high daily mobility, including motorcycle riders, traffic officers, and transportation workers, are considered vulnerable groups because of prolonged inhalation exposure to airborne particulates along congested traffic corridors. Biomonitoring studies have demonstrated that blood Pb concentration remains an important indicator of ongoing environmental exposure and may reflect cumulative inhalation of traffic-derived pollutants (Angrand et al., 2022; Okoye et al., 2023).

The Taman Tekno Serpong industrial and logistics area in South Tangerang represents a strategic location with high transportation intensity and dense traffic activity. The combination of freight transportation, private vehicle use, and rapid urban development potentially increases the concentration of airborne pollutants in this area. Despite the growing concern regarding urban air pollution, studies evaluating blood Pb levels among motorcycle riders in this region remain limited. The novelty of this study lies in its focus on the relationship between daily travel distance and blood Pb levels among motorcycle riders using ICP-MS analysis combined with multivariate statistical evaluation. This study also considers several confounding variables, including age, smoking habits, mask usage, duration of employment, and exposure duration, thereby providing a more comprehensive assessment of factors influencing blood lead levels among high-mobility populations.

South Tangerang has been reported to experience a high burden of air pollution (Sari, 2025). Logistic activities in the Taman Tekno industrial complex contribute to particulate emissions and resuspended road dust that potentially contain lead (Pb) residues. The increasing incidence of Acute Respiratory Infections (ARI) in South Tangerang City is strongly suspected to be associated with poor air quality. Daily motorcycle riders in logistics corridors represent a high-risk group because of cumulative exposure to roadside pollutants. Blood lead concentration is considered a reliable biomarker for assessing lead exposure. Blood Pb levels reflect the dynamic balance between exposure, absorption, distribution, and excretion processes, making them an important indicator for monitoring ongoing exposure (WHO, 2021). The World Health Organization has clearly stated that no level of lead exposure can be considered completely safe, even at low concentrations.

The Taman Tekno Serpong area in South Tangerang City experiences intense vehicle traffic every day, particularly freight transportation activities combined with increasing numbers of private vehicles, thereby elevating the risk of air pollution-related health problems. Rapid urban development in South Tangerang as part of the metropolitan region has also contributed to worsening air pollution conditions (Rachmawati, 2020). Most individuals in this area are exposed to lead through inhalation of contaminated smoke, dust, and gases. Motorcycle riders are particularly vulnerable because they are directly exposed to roadside emissions for prolonged periods (Aliyu & Musa, 2021). A previous study by Victoria et al. (2024) reported that longer working duration was associated with higher lead concentrations in the hair of online motorcycle taxi drivers. However, limited studies have specifically investigated lead exposure among motorcycle riders based on travel distance. Therefore, this study aimed to evaluate the relationship between daily travel distance and blood lead levels among motorcycle riders in the Taman Tekno Serpong area. The findings are expected to provide important information regarding the adverse health effects of lead exposure among individuals with high mobility in traffic-dense environments.

METHOD

This study employed an analytical cross-sectional design using a purposive sampling technique. Subjects were selected using stratified random sampling based on daily travel distance categories: <30 km/day, 30–<50 km/day, and ≥50 km/day. Daily travel distance was verified through smartphone applications or digital maps. To ensure adequate representation of exposure variations within each stratum, respondents were randomly selected from motorcycle riders who met the inclusion criteria, including male gender, appropriate age range, working duration, smoking habits, mask usage, and duration of roadside exposure. The target sample size was 15 respondents. The study was conducted in the Taman Tekno Serpong area, South Tangerang. Blood lead analysis was performed at the Regional Health Laboratory of Tangerang City. Primary data were collected using venous blood samples of 3 cc stored in K3EDTA tubes. Blood Pb levels were analyzed using Thermo Scientific ICP-MS (Inductively Coupled Plasma Mass Spectrometry) type ASX-560. ICP-MS offers several advantages, including simultaneous multi-element analysis, small sample volume requirements, and very low detection limits reaching nanogram levels (Bilqis, Sulistiawati, & Rahman, 2022).

Questionnaires were used to collect respondent characteristics, including age, duration of employment, smoking habits, mask usage, exposure duration, travel routes, and riding schedules. Prior to data collection, the questionnaire instrument was tested for validity and reliability. Content validity was evaluated through expert judgment involving public health and environmental health experts. Construct validity was assessed using Pearson product–moment correlation, where items with correlation coefficients (r-count) greater than the r-table value ($p < 0.05$) were considered valid. Reliability testing was conducted using Cronbach's alpha coefficient, with $\alpha \geq 0.70$ indicating acceptable internal consistency. Statistical analysis was conducted using SPSS version 25. Data normality was assessed using the Shapiro–Wilk test due to its high sensitivity for small sample sizes (Gourinda et al., 2024). The correlation between travel distance and blood Pb levels was analyzed using Pearson correlation for normally distributed data or Spearman correlation for non-normal data, followed by multivariate linear regression analysis. Regression coefficients (β), standard errors (SE), p-values, and adjusted R^2 values were calculated.

RESULT

Tabel 1.
Age frequency Distribution

Age	f	%
22	1	7
23	1	7
27	2	13
29	1	7
30	1	7
32	1	7
33	1	7
35	1	7
38	1	7
40	1	7
41	1	7
43	1	7

Based on table 1, there was 1 respondent each at the ages of 22, 23, 29, 30, 32, 33, 35, 38, 40, 41, 43 years (7%), 2 respondents at the age of 27 years (13%) and 2 respondents at the age of 45 years (13%).

Table 2.
Frequency Distribution of Length of Service

Length of Service	Total	%
	f	
≤ 5 years	5	33
≥ 5 tahun	10	67

Table 3.
Frequency Distribution of Daily Mileage

Mileage	Total f	%
< 30 km / day	5	33,33
30 - < 50 km/ day	5	33,33
≥ 50 km / day	5	33,33

Based on table 3, there are 5 respondents (33.33%) who travel a distance of <30 km/day, 5 respondents (33.33%) who travel a distance of 30 - <50 km/day, and 5 respondents (33.33%) who travel a distance of ≥ 50 km/day. Based on table 4. 4 respondents (27%) used medical masks and 11 respondents (73%) used non-medical masks.

Table 5.
Distribution of Respondent Characteristics

Characteristics	f	%
Employment status		
Indoor	11	73
Outdoor	4	27
Smooking		
Yes	13	87
No	2	13
Compliance in using PPE		
Obedient	15	100
Disobedient	0	0
Driving time		
Peak	15	100
Non peak	0	0
Road routes		
Big	15	100
Local	0	0
History of receiving blood transfusions		
Ever	0	0
Never	15	100
History of regular drug consumption		
Yes	0	0
No	15	100

Table 6.
Blood Lead Test Results

No	Sample Code	Distance/day	Concentration Pb(µg/L)	Result
1	A1	< 30 km	1,979	Detected
2	A2	< 30 km	2,021	Detected
3	A3	< 30 km	18,83	Detected
4	A4	< 30 km	1,906	Detected
5	A5	< 30 km	1,792	Detected
6	B1	30 - < 50 km	2,793	Detected
7	B2	30 - < 50 km	2,437	Detected
8	B3	30 - < 50 km	3,144	Detected
9	B4	30 - < 50 km	1,999	Detected
10	B5	30 - < 50 km	1,879	Detected
11	C1	≥ 50 km	2,851	Detected
12	C2	≥ 50 km	4,119	Detected
13	C3	≥ 50 km	4,737	Detected
14	C4	≥ 50 km	3,474	Detected
15	C5	≥ 50 km	3,035	Detected

The data was tested for normality (Shapiro-Wilk) because it has high sensitivity to small-scale data.

Table 7.
Normalitay Shapiro-Wilk Test

	Normality Test	
	Shapiro-Wilk	
	Statistic	Sig
Distance	0.805	0.004
Blood Pb	0.874	0.038

Based on table 7, since the number of research samples was less than 50, a normality test was conducted using the Shapiro–Wilk method. The test results showed a significance value of 0.038 for distance traveled ($p < 0.05$) and 0.004 for blood lead ($p < 0.05$). Therefore, it can be concluded that the data on distance traveled and blood lead levels do not follow a normal distribution. If the data distribution is not normal, the Spearman correlation test (non-parametric test) is used (Suyanto *et al.*, 2018).

Table 8.
Correlation Spearman Test

Distance	Correlation Coefficient	1.000	.813**
	Sig. (2-tailed)	.	.000
	N	15	15
Blood Pb	Correlation Coefficient	.813**	1.000
	Sig. (2-tailed)	.000	.
	N	15	15

Based on the results of the bivariate analysis using the Spearman correlation test in Table 4.8, the correlation coefficient (r) was 0.813 and the significance value (p) was 0.000 ($p < 0.05$). These results indicate a significant correlation between distance traveled and blood lead (Pb) levels, with a very strong correlation and a positive direction.

Table 9.
Linear Regression Test for Correlation Coefficient

Coefficients				
	B	Std Error	Standart Beta	VIF
(Constant)	2.424	.998		
Age	.013	.025	.114	2.987
Work duration	-.015	.037	-.063	1.564
Smoking	-.917	.451	-.357	2.027
Mask	-.689	.376	-.349	2.386
Duration	.795	.184	.921	2.995

Based on Table 4.9, the VIF (Variance Inflation Factor) values for all independent variables are in the range of 1.5–2.9 (<10), so it can be concluded that there is no strong relationship between the variables. Thus, the regression model free from multicollinearity can be used optimally. The variables analyzed are age, length of service, smoking, masks, and duration of exposure.

The reading of each variable is as follows:

1) Duration of exposure
   $\beta = 0.795$, $p = 0.002$ ($p < 0.05$), standardized beta = 0.921 had a significant and dominant effect on Pb levels. Each increase in exposure duration increased Pb levels in the blood.
2) Age
   $\beta = 0.013$, $p = 0.607$ ($p>0.05$) showed no significant correlation.
3) Length of Service
   $\beta = -0.015$, $p = 0.694$ ($p>0.05$) showed no significant correlation.
4) Smoking
   $\beta = -0.917$, $p = 0.073$ ($p < 0.05$) showed a trend toward an effect but was not significant.
5) Masks
   $\beta = -0.689$, $p = 0.100$ ($p>0.05$) showed no significant correlation, but tended toward protection to reduce Pb.

Table 10.
Multivariate Linear Regression Test

Model Summary			
R	R Square	Adjusted R Square	Std. Error
.929[a]	.863	.787	.417297

The correlation coefficient (R = 0.929) shows a very strong correlation between all independent variables and Pb levels.

DISCUSSION

The strong positive correlation observed between travel distance and blood Pb levels in this study supports that cumulative exposure to roadside pollutants increases proportionally with mobility intensity. Individuals traveling longer distances spend more time in traffic-dense environments where airborne particulate matter and resuspended road dust are continuously inhaled. Similar findings have been reported in transportation-related biomonitoring studies, where occupational exposure duration significantly influenced blood Pb accumulation among drivers and roadside workers (Prihatiningsih et al., 2023; Christyaningsih et al., 2023).

The present findings are also consistent with previous systematic reviews indicating that traffic emissions remain an important contributor to environmental Pb exposure despite the elimination of leaded gasoline in many countries. Angrand et al. (2022) reported that blood Pb levels continue to correlate with transportation-related pollution due to residual environmental contamination and industrial activities. Chronic exposure to Pb may induce oxidative stress, endothelial dysfunction, hypertension, and neurological disturbances even at relatively low concentrations.

The use of ICP-MS in this study provided highly sensitive detection of blood Pb concentrations, allowing accurate biomonitoring of low-level exposure among motorcycle riders. ICP-MS has been widely recommended for trace metal analysis because of its superior sensitivity and precision compared with conventional analytical methods. The analytical capability of ICP-MS is particularly advantageous for occupational and environmental exposure studies involving low concentrations of heavy metals in biological matrices (Bilqis et al., 2022; Okoye et al., 2023).

Normality testing was conducted to determine whether the data followed a normal distribution. Since the sample size was relatively small ($n = 15$), the Shapiro–Wilk test was applied. The results showed that the variables were not normally distributed; therefore, non-parametric statistical analysis was considered more appropriate. Spearman correlation analysis revealed a very strong positive relationship between daily travel distance and blood Pb levels ($r = 0.813$; $p < 0.05$). This finding suggests that individuals who travel longer distances are exposed to air pollution for longer periods, particularly vehicle emissions.

Longer riding distances increase the duration of exposure to roadside pollutants originating from motor vehicle emissions (Ludyaningrum & Airlangga, 2017). Among the compounds emitted by motor vehicles, carbon monoxide and lead are considered major pollutants with systemic health effects. Continuous exposure to these pollutants increases the likelihood of lead particles entering the body through inhalation and subsequently accumulating in the bloodstream. Blood Pb levels are influenced not only by travel distance but also by other factors, including smoking habits, mask usage, and environmental conditions. In this study, Spearman correlation analysis was appropriate because the data were not normally distributed according to the Shapiro–Wilk test.

Multicollinearity analysis demonstrated that all VIF values were below 10, indicating that the regression model did not suffer from serious multicollinearity problems. Therefore, the combination of independent variables, including age, duration of employment, smoking habits, mask usage, and exposure duration, could be reliably analyzed. The regression analysis showed a very strong relationship between the independent variables and blood Pb levels ($R = 0.929$). The adjusted coefficient of determination (Adjusted $R^2 = 0.787$) indicated that 78.7% of the variation in blood lead levels could be explained by the variables included in the model, while the remaining variation was influenced by other factors not examined in this study. Overall, the findings confirm that travel distance is significantly associated with blood lead levels among motorcycle riders. Therefore, preventive measures to reduce heavy metal exposure are highly recommended, especially for individuals with high daily mobility in densely trafficked environments.

CONCLUSION

There was a significant and very strong correlation between daily travel distance and blood Pb levels. Blood Pb levels were influenced not only by travel distance but also by other factors such as smoking habits, mask usage, and environmental conditions.

ACKNOWLEDGEMENTS

The authors also thanks to programme study DIV Medical Laboratory Technology at Sekolah Tinggi Ilmu Kesehatan Nasional for their support during the research process and manuscript preparation.

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