



The Relationship between Particulate Matter and Length of Exposure to Respiratory Complaints and Lung Function Disorder among Brick Craftsmen in Aceh Besar

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Submitted: September 17th, 2024

Accepted: November 18th, 2024

Published: November 28th, 2024

Respir Sci. 2024; 5(1): 28-39

<https://doi.org/10.36497/respirsci.v5i1.161>



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Abstract

Background: Brick craftsmen are heavily exposed to particulate matter (PM) from brick burning, possibly contributing to respiratory complaints. The research aims to evaluate the association between PM levels, duration of exposure, respiratory complaints, and lung function disorders among brick craftsmen in Aceh Besar.

Method: The research method is observational analytic with a cross-sectional design. It was conducted in September 2023 on 68 respondents to assess lung function using spirometry and PM levels using the Air Quality Monitor.

Results: The data analysis revealed restrictive types of lung function disorders (47.1%), 75% of participants had worked for more than three years with working hours ≥ 8 hours/day (100%), the most frequent respiratory complaint was coughing (23.5%) and shortness of breath (13.2%), and the dominant type of work was brick molding (67.6%) rather than burning (32.4%). The PM_{2.5} index in the brick manufacturing area is classified as very dangerous (100%), while the PM₁₀ index is identified as very unsafe (55.6%) and very dangerous (44.4%). The correlation analysis revealed a significant connection between PM_{2.5} as well as PM₁₀ and lung function impairments (values of $P=0.002$ and 0.012 , respectively). There was a significant correlation between work periods and lung function impairments ($P=0.037$). Multivariate analysis showed that a working term of 1-3 years was strongly linked with lung function disorder (FEV_1) among brick craftsmen in Aceh Besar ($P=0.026$).

Conclusion: This study showed that PM exposure was significantly associated with impaired lung function but not with respiratory complaints. Furthermore, a long working period is significantly associated with respiratory symptoms, especially for workers with 1-3 years, and is associated with impaired lung function in brick artisans in Aceh Besar.

Keywords: length of exposure, lung function disorder, particulate matter (PM), respiratory complaint

INTRODUCTION

Air pollution poses a significant global health challenge, with detrimental effects on respiratory function, especially in low- and middle-income countries.¹ According to the World Health Organization (WHO), air pollution accounts for over 7 million deaths annually, with most occurring in low- and middle-income nations.²

Exposure to air pollution has been linked to impaired lung function, particularly in people who are exposed continuously for an extended time.³ Air pollution may arise both outdoors and indoors. A common source of outdoor air pollution comes from industrial fields, such as brick factories.⁴

The brick manufacturing industry is a significant source of air pollution due to particulate emissions from burning bricks during production.⁵ Bricks are defined as stones made of clay, with or without added substances, that have been sun-dried for several days and then burned at high temperatures to harden and prevent breaking when soaked in water.⁶ The brick-making process is divided into three stages: preparation of basic materials, molding, and burning.⁷

The brick-burning process can cause substantial health concerns for workers due to particle expulsion during the process.⁸ Dust particles from Brick-making degrade air quality and can cause chronic obstructive pulmonary disease (COPD), asthma, bronchitis, silicosis, and other pulmonary issues. Silica exposure is one of the most vital risks linked to brick dust

inhalation, as the material itself is carcinogenic.⁹ Continuous exposure over an extended time can result in impaired lung function and respiratory problems among workers.¹⁰

Particulate matter, a major air pollutant, consists of fine particles like PM_{2.5} and PM₁₀, which can penetrate deep into the respiratory system and cause severe health issues.^{2,11} The size of PM determines its capacity to penetrate the respiratory tract, skin, and mucosa.² PM_{2.5} also known as fine air particles, are dust particles with a diameter of 2.5 µm produced by anthropogenic activities such as motor vehicles, biomass burning, and gasoline combustion. Brick-making processes emit the major pollutant, particulate matter with a diameter of ≤10 µm (PM₁₀), which poses a significant health risk to workers.¹²

In 2016, it appeared that PM pollution caused around 4 million deaths (or 7.5% of all-cause mortality). A 2018 study by Guo et al found that every 5 µg/m² increase in PM_{2.5} was associated with a decrease in forced vital capacity (FVC) by 1.18%, forced expiratory volume in 1 second (FEV₁) by 1.46%, and the FEV₁/FVC ratio by 0.21%. Long-term exposure to PM_{2.5} is linked to lung function disorders and an increased risk of COPD. This emphasizes the importance of a global effort to reduce air pollution, enhance lung health, and prevent COPD.¹³

In Indonesia, a study was conducted on red brick craftsmen in the Badung district that resulted in most craftsmen being exposed to dust exceeding the

threshold value (3 mg/m³), with an average of 9.8 mg/m³, and having impaired lung function capacity (92.86%), with the kind of impairment being mixed restrictive and obstructive.¹⁴ Then, a study on merchants in Kampung Rambutan reveals a risk of reduced respiratory function after 30 years of exposure to PM_{2.5} particles.¹⁵

The brick industry in Aceh Besar, established in the 1980s, has expanded rapidly, raising concerns about occupational health risks due to high PM exposure and inadequate use of protective equipment. Occupational health and safety issues continue to arise, including the fact that many industrial workers do not wear personal protective equipment (PPE) like masks or nose protectors. The brick industry can emit air pollutants, including particulate matter (PM).^{16,17}

Exposure to PM has been linked to decreased lung function, the appearance of respiratory complaints such as coughing and shortness of breath, as well as increased systemic inflammation and oxidative stress, but more research is needed to determine the relationship between PM and lung health in brick craftsmen.¹⁶

Spirometry is a physiological test that measures the ability to inhale and exhale air over time. It is commonly used as a diagnostic approach for evaluating respiratory disorders, especially to assess the risk of drug exposure in smokers and workers at the workplace. Spirometry yields three key results: FVC, FEV₁, and the FEV₁/FVC ratio.¹⁸

Age, medical history, working hours, smoking history, and the use of PPE at work all affect lung vital capacity. The existence of this brick industry can produce air pollutants, one of which is PM), which is very dangerous for the airways.

Therefore, this study investigates the association between PM_{2.5} exposure, duration of exposure, respiratory complaints, and lung function abnormalities among brick craftsmen in Aceh Besar. This research is intended to serve as a basis for future prevention efforts at work.

METHOD

This study was carried out on nine brick manufacturers in Darussalam District, Aceh Besar Regency, in September 2023. This observational, cross-sectional study was conducted in nine brick manufacturing units in Darussalam District, Aceh Besar, in September 2023. All eligible brick craftsmen (N=68) were included using a total sampling technique. This study was approved by the Health Research Ethics Committee of Zainoel Abidin Hospital and the Faculty of Medicine, Universitas Syiah Kuala (171/ETIK-RSUDZA/2023).

The study participants were brick craftsmen who did not currently or had previously suffered from lung function disorders such as pulmonary TB, COPD, and asthma, and also had no contraindications for spirometry. A questionnaire was used to determine general characteristics, length of exposure,

and respiratory complaints; lung function was evaluated using spirometry; and PM levels were quantified using an air quality monitor detector. The Spearman test and multivariate logistic regression were used to determine the causal relationship between PM and duration of exposure, respiratory symptoms, and lung function. A 95% confidence interval (CI) and $\alpha=0.05$ value suggest a significant difference between variables ($P\leq 0.05$).

RESULTS

This study was conducted in nine brick factories in Aceh Besar Regency, with a total of 68 brick craftsmen as participants. Table 1 shows the overall characteristics of the research subjects.

Of the 68 participants, 58.8% were female, and 76.5% were aged 30 years or older. Most participants (67.7%) had a normal BMI, while 14.7% were overweight, and 10.3% were classified as obese. Most participants (97.1%) did not use masks while working, and 64.7% were non-smokers. PM_{2.5} levels were hazardous in all nine brick factories (100%). PM₁₀ levels were hazardous in 44.4% of factories and very unhealthy in 55.6%.

Based on a lung function test among brick craftsmen, normal lung function was reported by 25 participants (36.8%), while restrictive lung type disorder affected 32 people (47.1%). The mean percentage FVC of 68 participants was 78.85, with a standard deviation of 17.03. The average FEV₁ percentage was 78.24±17.49, while

the average FEV₁/FVC ratio was 84.49±16.14. Tables 2 and 3 show the frequency distributions of pulmonary function and spirometry examination results.

Table 1. Characteristics of Research Subject (N=68)

| Characteristic | N | % |
|----------------------------|----|------|
| Sex | | |
| Male | 28 | 41.2 |
| Female | 40 | 58.8 |
| Age | | |
| <30 years old | 16 | 23.5 |
| ≥30 years old | 52 | 76.5 |
| BMI | | |
| Very underweight | 1 | 1.5 |
| Underweight | 4 | 5.9 |
| Normal | 46 | 67.6 |
| Overweight | 10 | 14.7 |
| Obesity | 7 | 10.3 |
| Using a mask while working | | |
| Yes | 2 | 2.9 |
| Nos | 66 | 97.1 |
| Smoking | | |
| Smoker | | |
| Mild | 9 | 13.2 |
| Moderate | 7 | 10.3 |
| Severe | 8 | 11.8 |
| Non Smoker | 44 | 64.7 |
| Job at the brick factory | | |
| Molding | 46 | 67.6 |
| Burning | 22 | 32.4 |

Furthermore, the PM value was measured with an air quality monitor detector. According to Table 2, PM_{2.5} levels from the nine brick factories are hazardous, while four factories have PM₁₀ levels in the hazardous category, and the rest are categorized as very unhealthy.

Table 2. PM2.5 dan PM10 Level at Brick Factories in Aceh Besar

| Characteristic | N | % |
|----------------|---|-------|
| PM2.5 Index | | |
| Good | 0 | 0.0 |
| Moderate | 0 | 0.0 |
| Unhealthy | 0 | 0.0 |
| Very Unhealthy | 0 | 0.0 |
| Hazardous | 9 | 100.0 |
| PM10 Index | | |
| Good | 0 | 0.0 |
| Moderate | 0 | 0.0 |
| Unhealthy | 0 | 0.0 |
| Very Unhealthy | 5 | 55.6 |
| Hazardous | 4 | 44.4 |

The length of exposure was calculated using the subject's exposure time and work period in the brick-producing area, as shown in Table 3. The study indicated that 51 individuals (75%) have been working for more than three years, with 68 subjects (100%) working at least eight hours per day.

Table 3. Length of Exposure and Working Period among Brick Craftsmen in Aceh Besar

| Characteristic | N | % |
|--------------------|----|-------|
| Length of Exposure | | |
| <8 hours/day | 0 | 0.0 |
| ≥8 hours/day | 68 | 100.0 |
| Work Period | | |
| <1 years | 2 | 2.9 |
| 1-3 years | 15 | 22.1 |
| >3 years | 51 | 75.0 |

Brick craftsmen's respiratory issues were evaluated based on the presence of cough, shortness of breath, sputum production, or chest pain. Coughing was the most common symptom (23.5%) among brick craftsmen, followed by

shortness of breath (13.2%) and chest pain (2.9%).

Furthermore, bivariate analysis was carried out to assess the association between PM10 and PM2.5 with lung function disorder, as indicated in Table 4. The correlation test revealed a significant association between either PM_{2.5} or PM10 and lung function impairments (values of $P=0.002$ and 0.012 , respectively).

The correlation coefficient indicates a negative association between variables, implying that the higher the amounts of PM, the lower the lung function. In addition, a correlation test was performed between the work period and respiratory complaints as well as lung function disorder.

The investigation revealed that there was no link between work periods and respiratory complaints among brick craftsmen in Aceh Besar ($P=0.107$). The work period and lung function abnormalities had a significant association ($P=0.037$); the longer the patient worked, the more impaired the lung function. In this study, a multivariate logistic regression test was performed and found that there was no correlation between PM, work period, or respiratory problems among the study participants.

A multivariate analysis between particulate matter, work period, and lung function abnormalities revealed that a working period of 1-3 years was significantly associated with lung function abnormalities (FEV₁) in brick craftsmen in Aceh Besar ($P=0.026$).

Table 4. The Relationship between PM2.5 and PM10 with Lung Function Disorder among Brick Craftsmen in Aceh Besar

| | FVC (ml) | FEV₁ (ml) | FEV₁/FVC |
|-----------------------------|-----------------|-----------------------------|----------------------------|
| PM2.5 | | | |
| Correlation Coefficient (r) | 0.162 | -0.167 | -0.367 |
| P | 0.188 | 0.174 | 0.002 |
| PM10 | | | |
| Correlation Coefficient (r) | 0.118 | -0.145 | -0.304 |
| P | 0.336 | 0.237 | 0.012 |

Table 5. The result of Multivariate analysis between Particulate Matter, Work Period, and Lung Function among Brick Craftsmen in Aceh Besar

| Variable | Regression Coefficient (B) | | P | |
|-----------------------|-----------------------------------|------------------------|------------|------------------------|
| | FVC | FEV₁ | FVC | FEV₁ |
| PM2.5 | 0.051 | -0.012 | 0.179 | 0.756 |
| PM10 | -0.023 | -0.004 | 0.394 | 0.876 |
| Work period <1 years | 19.748 | -1.294 | 0.110 | 0.917 |
| Work period 1-3 years | 5.056 | 11.654 | 0.318 | 0.026 |

However, PM2.5, PM10, and working periods <1 year were not significantly associated with lung function abnormalities.

DISCUSSION

The brick factory emits air pollutants, such as particulate matter (PM). Exposure to PM among Brick Craftsmen has been linked to respiratory problems and reduced lung function. Workers and industry owners are unaware of the importance of personal protective equipment (PPE). The emergence of lung abnormalities is also influenced by the length of exposure and working time. Workers are more likely to acquire occupational lung disease if they are exposed often and for a long period.

In this study, the majority of the 68 participants were female (58.8%). This conclusion contrasts with Emilia's study in Central Aceh Regency, which indicated that 86.7% of participants were male.¹⁹ Dewi's

research in Semarang found that brick manufacturers were more likely to be men (53.3%).²⁰

According to the study, the gender frequency distribution varies because female workers are needed for brick shaping and men for brick burning. Because of variations in lung vital capacity, this gender distribution can influence lung function analysis results. Women have about 20–25% less lung vital capacity than men. Adult men have an average vital lung capacity of 4.8 L, while women have an average of 3.1 L.

Based on age characteristics, 76.5% of study participants were 30 years or older. This is consistent with Novianto's findings in Semarang and Pramesti in Badung, where the majority of brick craftsmen are above 30.^{14,21} Aging is connected with a decline in the structure and physiology of human organs, which can lead to a reduction in lung function.²¹

The majority of research participants had a normal nutritional state (67.6%). These findings are supported by Pramesti's Badung investigation, which discovered that 59.52% of respondents had a healthy nutritional status.¹⁴ Nutritional status influences a person's lung capacity; appropriate nutritional status promotes immunity, allowing the body to protect itself against hazardous exposures that reduce lung vital capacity. Novianto found a significant link between dietary status and lung function among brick workers in Semarang.²¹

Almost all study participants (97.1%) did not utilize masks as PPE, which is extremely harmful to workers because it can cause respiratory problems. These findings are consistent with a study by Yulianto et al in Pekanbaru, which discovered that 82.9% of respondents did not use masks while working in a brick production.²²

Emilia discovered similar results, with 76.7% of brick craftsmen not using PPE while working.¹⁹ The poor use of masks in this study could be attributed to a variety of variables, including workers' and brick factory owners' lack of awareness about the significance of utilizing PPE while working.

Personal protective equipment is a tool that workers can employ to protect part or all of their bodies from potential workplace hazards or accidents. PPE cannot eliminate potential workplace hazards or accidents; nevertheless, it can lessen or prevent the severity of occupational diseases. Special PPE for

breathing protection can take the form of masks that guard against bigger dust or particles that enter the respiratory tract.²¹

Based on smoking behavior, 64.7% of respondents claimed not to smoke. These findings are consistent with Dewi's research in Penggaron Kidul, which found that the majority of study participants (66.7%) did not smoke.²⁰ However, research conducted by Nazira found that 64.8% of brick workers smoked.²³

This disparity in outcomes is because women dominated the research subjects, whereas smokers are commonly seen in men. Smoking can impair lung function because the hazardous chemicals in cigarettes are poisonous to bodily tissues. Toxins in the blood hinder the exchange of O₂ gas with CO₂ in the alveoli. If cigarette exposure continues for an extended time, the alveolus will be destroyed, causing lung function to decline. Cigarette smoke increases mucus secretion, while nicotine paralyzes the cilia in the respiratory tract, affecting airway clearance.²¹

In this study, the study participant worked primarily in the brick molding section rather than the brick burning. The burning procedure is not done every day and is only for males, but brick molding requires a larger workforce, which is dominated by women.

Spirometry results suggest that the majority of lung function disorders are restrictive types, followed by obstruction and mixed types (obstruction and restriction). These findings are consistent with Dewi's research, which revealed that

20% of brick craftsmen suffered from restriction lung disorder.²⁰

There are two types of ventilation abnormalities: restriction and obstruction disorders. Restriction is defined as the halting of lung growth due to any cause. In restriction disorders, the lung becomes rigid, increasing the inward pull and shrinking the chest wall. This reduces lung volume and narrows the rib cage. Restriction disorders are identified by spirometry data when the FVC is less than 80% of the anticipated value. Obstruction disorders cause a decrease in expiratory flow velocity and normal vital capacity. Because airflow is increased, essential capacity may decrease due to trapped air. This lung condition is identified by spirometry readings of $FEV_1/FVC < 75\%$.²⁴

Measurements of particulate matter revealed that PM_{2.5} levels in the nine brick manufacturers were in the hazardous category, as were PM₁₀ levels in four factories, but the other five factories have PM₁₀ levels in the very unhealthy category. Dewi et al found that dust levels in all brick-making locations in the Tenayan Raya Sub-district exceeded the established threshold value, with an average PM₁₀ of 471.28 $\mu\text{g}/\text{Nm}^3$.²⁵

Rohmawati's investigation in Kaloran Village yielded similar results, with PM_{2.5} levels at the brick factory exceeding the threshold. Dust levels beyond the threshold can induce respiratory issues, eye irritation, allergies, and impaired lung function in workers.²⁶ The majority of individuals (75%) have worked for more than three years and work a minimum of eight hours

every day. This survey is consistent with research undertaken by Nazira in Talang Belido village, which found that 71.1% of respondents had worked for more than five years.²³

Siregar's investigation in Deli Serdang revealed that the majority of workers were exposed to dust for more than eight hours every day.²⁷ The longer the worker works, the more dust settles in their lungs. The effect of dust exposure is determined by the dose or concentration, as well as the location and timing of exposure.²¹

The most common respiratory problems in this study were coughing (23.5%) and shortness of breath (13.2%). These findings are consistent with Siregar's research, which found that 76.5% of brick-making workers reported coughing and shortness of breath while at work.²⁷

Ridayanti's study of people living near brickmaking factories found that 25.1% had shortness of breath, 30.6% frequently coughed, 35% had eye discomfort, and 9.2% had allergies. Exposure to PM_{2.5} produces coughing as a defensive mechanism to eliminate foreign bodies from the body. If this exposure persists, it can lead to ventilation problems and decreased lung function.²⁸

The findings revealed a strong link between PM_{2.5} and PM₁₀ levels and pulmonary function impairments in brick craftsmen in Aceh Besar. Harmanto's study, which discovered a link between exposure and lung function capacity in brick-burning workers in Karanganyar, supports these findings.²⁹

According to Pramesti's research, workers who are exposed to dust that exceeds the threshold ($>3 \text{ mg/m}^3$) are 1.45 times more likely to have decreased lung function capacity than those who are exposed to dust that is below the threshold.¹⁴ Mengkidi discovered contradicting results on employees of PT Semen Tonasa-Pangkep in 2006, indicating that dust levels and lung function abnormalities had no significant link.³⁰

The correlation test revealed that there was no association between length of exposure and respiratory complaints among brick craftsmen in Aceh Besar. This finding is consistent with Dewi's study, which found no link between length of exposure (work period) and respiratory problems. Siregar found that long exposure to dust in Brick-making workers was connected with the development of respiratory complaints (cough, shortness of breath, nasal congestion, and throat pain).²⁷

This disparity in results could be attributed to a variety of factors, including the fact that the study participants are dominated by female workers who work long hours, brick burning is not done by women, the brick-burning site is located far from the brick molding site, and no female workers who smoke.

In this study, the length of exposure was linked to lung function impairments determined by spirometry results. The findings of this study are consistent with prior research conducted by Novianto and Dewi in Semarang, where the work period is substantially associated with reduced

pulmonary function among brick craftsmen.^{20,21} The longer someone works, the more harmful compounds they are exposed to in the workplace that can impact and impair employees' lung function capacity.

A multivariate analysis revealed that PM and work period were not substantially associated with respiratory complaints. This finding is consistent with Dewi's research, which demonstrated no link between dust exposure and working hours with respiratory symptoms.²⁵ This condition can emerge because respiratory complaints are impacted by a variety of circumstances, including smoking habits, a history of respiratory disease, the use of PPE, etc.³¹ Furthermore, the demographic features of the respondents, who were overwhelmingly female, influenced the study's findings.

The multivariate test findings for lung function disorder (measured by FEV_1) showed that they were only connected with 1-3 years of employment, but not with dust exposure or <1 year of work duration. The longer workers are exposed to dust, the higher the risk of lung function problems, as indicated by this study's result that a working period of 1-3 years is related to lung function disorders. Based on these findings, it is possible to assume that working with dust exposure that exceeds the threshold over an extended time will impair lung function.

This study found no significant limitations that could affect the validity or reliability of the findings.

CONCLUSION

This study showed that Particulate Matter was associated with impaired lung function, although there was no significant association with respiratory complaints. Furthermore, a long working period is significantly associated with respiratory symptoms, especially for workers with 1-3 years, and is associated with impaired lung function in brick artisans in Aceh Besar. Since brick kilns generate pollutants, restricting kiln emissions and continuously implementing preventive measures while working is essential.

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