RESEARCH ARTICLE Open Access

Gema Lingkungan Kesehatan
Vol. 23, No. 3 (2025), pp 392-401
e-ISSN 2407-8948 p-ISSN 16933761
doi: https://doi.org/10.36568/gelinkes.v23i3.306 Journal Homepage: https://gelinkes.poltekkesdepkes-sby.ac.id/

Respiratory Impact of PM_{10} and $PM_{2.5}$ Exposure among Furniture Workers in Tegal

Neli Annisah[1]*, Onny Setiani[2], Yusniar Hanani Darundianti[2]

[1] Master of Environmental Health, Diponegoro University, Semarang, Indonesia
[2] Faculty of Public Health, Diponegoro University, Semarang, Indonesia

*Correspondence: anissahneli@gmail.com

The furniture industry has a high potential for particulate matter (PM_{10} and $PM_{2.5}$) exposure, which may lead to impaired lung function and occupational diseases. Dust from cutting, sanding, and finishing processes can be inhaled and accumulate in the respiratory tract, increasing the risk of respiratory dysfunction. This study aimed to determine the relationship between PM exposure and impaired lung function among furniture industry workers in Tegal Regency. This study was an analytical observational study with a cross-sectional approach involving 100 production workers. PM concentration was measured using the Haz Dust EPAM-5000, and lung function was assessed using spirometry. Bivariate analysis was conducted using the chi-square test, and multivariate analysis was performed using logistic regression. A total of 57% of respondents experienced impaired lung function. Bivariate analysis showed a significant relationship between PM 10 concentration (p=0.001; OR=4.725), PM 2.5 concentration (p=0.007; OR=3.580), inhalable dust concentration (p=0.034; OR=2.478), duration of employment (p=0.003; OR=3.929), and working hours (p=0.001; OR=4.143) with impaired lung function. A total of 57% of respondents experienced impaired lung function, consisting of mild restriction, moderate restriction, and mild obstruction. There was a significant association between PM 10 concentration (p = 0.001), PM 2.5 concentration (p = 0.007), and duration of employment (p = 0.003) with impaired lung function. Logistic regression analysis identified PM 10 concentration as the dominant factor associated with impaired lung function (p = 0.002; OR = 3.976; 95% CI: 1.641–9.637.

Keywords: Furnitue Industry, PM Exposure, Impaired Lung Function

INTRODUCTION

The furniture industry is a sector that processes wood into various high-value products such as chairs, tables, cabinets, and other items. In this industry, wood is processed through several stages, including cutting, pattern shaping, assembly, and sanding. Each production stage generates wood dust, which can pollute the workplace air and potentially harm workers' health. The rapid development of the wood processing industry is driven by modern machinery that makes the process faster and more efficient. However, the use of such machines also produces dust as a pollutant. This dust consists of solid particles resulting from material breakdown, which may originate from human activities or natural processes (Chiqita, 2020).

One of the health issues affecting workers is occupational disease. Occupational disease is a condition caused by work activities or the work environment, such as respiratory function disorders resulting from dust exposure. According to data from the International Labour Organization (ILO), approximately 1.9 million people die each year due to work-related causes, with chronic obstructive pulmonary disease (COPD) being the leading cause of death. The greatest risk factor is long working hours (750,000 deaths), while air pollution, including dust exposure, accounts for 450,000 deaths (Herdianti et al., 2018; WHO, 2023).

Wood dust is categorized as solid particulate matter that may originate from both human activities and natural processes. One of the primary components of wood dust is Particulate Matter (PM), specifically PM 10 and PM 2.5. PM 10 consists of particles with a diameter of ≤10 micrometers, while PM 2.5 includes particles with a diameter of ≤2.5 micrometers. These fine particles are approximately 30 times smaller than the diameter of a human hair, allowing them to penetrate deep into the respiratory system and potentially cause health problems (Environmental Protection Agency, 2024). Due to their extremely small size, especially PM 2.5, these particles can reach the alveoli and even enter the bloodstream, posing potential risks to lung function. It is estimated that 50–60% of airborne dust particles are classified as respirable particulate matter, which can be easily inhaled and tend to accumulate in the respiratory tract (Cintya et al., 2020; Primasanti & Herawati, 2022).

Furniture industry workers generally work in enclosed spaces and are continuously exposed to wood dust. This dust can trigger various health complaints such as sneezing, coughing, shortness of breath, and even chronic respiratory disorders such as asthma. Wood dust also has allergenic properties, which come from natural chemical compounds in the wood or from additives used in the production process. Long-term exposure to this dust can cause inflammation of the respiratory tract, airway obstruction, and reduced lung function (Arief, 2019; Chaeruddin et al., 2021).

Respiratory diseases or functional impairments can result from exposure to wood dust particles, which enter the respiratory system. This exposure activates non-specific defense mechanisms, including coughing, sneezing, and disruptions in mucociliary transport as well as macrophage phagocytosis. When wood dust, particularly fine particles smaller than 5 µm, is inhaled, these particles may bypass the filtering process of the upper respiratory tract and reach the lungs. This can lead to inflammation, possible scarring, and a decline in lung function (K. Hosseini et al., 2020; Kulkani et al., 2016).

The Indonesian government has established occupational exposure limits to protect workers from the dangers of dust exposure. According to Government Regulation of the Republic of Indonesia No. 22 of 2021, the permissible limit for PM 10 is 75 µg/m³ (24-hour average) and 40 µg/m³ (annual average), while for PM 2.5 it is 55 µg/m³ (24-hour average) and 15 µg/m³ (annual average). These threshold values are used as guidelines for assessing air quality safety levels in the workplace environment, including in the furniture industry sector (Pemerintah Republik Indonesia, 2021).

This research was conducted at a furniture manufacturing company located in Tegal Regency, Central Java. The company produces various types of wooden furniture, such as tables, chairs, cabinets, and other household items. During the production process, several work areas generate wood dust. The factory's daily production volume varies, with an average of 430 units of furniture produced per day, depending on the type and size of the products being manufactured. This relatively high production volume has the potential to increase the amount of wood dust particles generated during work activities. Due to the nature of the production process, which generates a significant amount of wood dust, workers in this furniture factory are classified as a high-risk group for continuous and direct exposure to dust particles. Prolonged exposure to wood dust particles may affect workers' health, particularly their lung function. Observations and interviews with 10 workers revealed that all respondents (10 out of 10) experienced shortness of breath while working. Additionally, it was found that several workers used personal cloth masks or did not wear any masks, and spirometry tests showed that 9 out of 10 workers suffered from restrictive lung function disorders. These findings indicate the presence of health issues related to dust particle exposure in the workplace. Based on this background, the researcher aims to investigate the relationship between exposure to PM 10 and PM 2.5 and impaired lung function among furniture industry workers in Tegal Regency.

METHODS

This study employed an analytical observational design with a cross-sectional approach, carried out from February to March 2025 at a furniture manufacturing company in Tegal Regency. The research subjects were production-line workers selected through purposive random sampling based on inclusion criteria: male, under 50 years old, a minimum of one year of work experience, and no history of pulmonary disease. The focus on male workers is because the workforce in the production department is predominantly male. According to the Lemeshow formula, the minimum required sample size was calculated as 92 participants, however, to increase the statistical power of the analysis, a total of 100 respondents were included.

Primary data were collected via interviews using structured questionnaires, measurements of PM 10 and PM 2.5 concentrations using the Haz-Dust EPAM-5000 device, and pulmonary function tests using spirometry. Dust sampling was performed at 12 measurement points across work areas with high dust exposure potential: one in the sawmill section, one in reparation, one in roughmill, four in assembling, two in finishing, and three in machining. Measurements were taken at a height of 1.5 meters and a distance of 1 meter from the activity source, for one hour in both the morning and afternoon to reflect the variation in production activities. All measuring instruments were calibrated beforehand to ensure the accuracy of the results. Lung function assessment followed standard spirometry procedures, and the questionnaire was pretested to guarantee its validity and reliability.

The independent variables in this study included PM 10 concentration, PM 2.5 concentration, work tenure, physical activity, and body mass index (BMI). The dependent variable was pulmonary function impairment, as determined by spirometry results. Data analysis proceeded in three stages: univariate analysis to describe respondent characteristics, bivariate analysis using the chi-square test to examine the relationship between independent variables and pulmonary function impairment, and multivariate analysis using logistic regression to identify the most influential factors associated with pulmonary function impairment among furniture industry workers.

RESULTS AND DISCUSSION

The results of this study are presented in the form of tables and narratives to describe the characteristics of the respondents, particulate exposure (PM 10, PM 2.5), as well as lung function status based on the spirometry results. Subsequently, association between each independent variable and lung function disturbances will be analyzed using bivariate statistical tests, and the dominant factors influencing the respondents' lung health will be examined using multivariate statistical tests. The findings of this study will then be discussed with reference to theories and previous research findings to strengthen the interpretation of the data and its scientific relevance.

Overview of Respondent Characteritics

Table 1

Table of Worker Characteristics in the Furniture Industry of Tegal Regency

No.	Variables	Frequency	Percentage (%)
1.	**Age**		
	≥ 40 Years	31	31,0
	< 40 Years	69	69,0
	Min= 19 Years Max = 48 Years Mean = 33.02		
2.	**Duration of Employment**		
	≥ 5 Years	66	66.0
	< 5 Years	34	32.0
	Min = 1 Years Max = 20 Years Mean = 7.57		
3.	**Body Mass Index**		
	Overweight	27	27.0
	Normal	73	73.0
	Min = 18.59 Max = 35.26 Mean = 23.00		
4.	**Physical activity**		
	No	41	41.0
	Yes	59	59.0

Table 1 describes the characteristics of the study respondents. In this study, 100 male respondents were involved. The majority of respondents in this study were under the age of 40, totaling 69 individuals (69.0%), while the remaining 31 respondents (31.0%) were aged 40 years and above. The average age of respondents was 33.02 years, with the youngest being 19 years old and the oldest 48 years old. Based on length of employment, most respondents had been working for five years or more, totaling 66 individuals (66.0%), while 34 individuals (34.0%) had worked for less than five years. The average duration of employment was 7.57 years, ranging from 1 to 20 years. Nutritional status, assessed using Body Mass Index (BMI), showed that most respondents had a normal BMI, totaling 73 individuals (73.0%), while 27 individuals (27.0%) were categorized as overweight. Respondents' BMI ranged from 18.59 to 35.26, with an average of 23.00. In terms of physical activity, 59 respondents (59.0%) reported engaging in regular physical activity, while 41 respondents (41.0%) did not.

Concentration of Dust in the Work Environment

Table 2

Table of PM 10 Concentration Measurement Results

Section	Sampling point	PM 10 Result (mg/m³) Quality Standard 75 µg/m³		Average (mg/m³)	Average (µg/m³)
		(Morning)	(Afternoon)		
Saw mill	1	0.020	0.054	0.037	37
Reparation	2	0.014	0.056	0.035	35
Rough mill	3	0.035	0.021	0.028	28
Assembling	4	0.081	0.107	0.094	94
Assembling	5	0.265	0.307	0.286	286
Assembling	6	0.344	0.189	0.2665	266.5
Assembling	7	0.098	0.101	0.0995	99.5
Finishing	8	0.110	0.048	0.079	79
Finishing	9	0.090	0.084	0.087	87
Machining	10	0.070	0.067	0.0685	68.5
Machining	11	0.087	0.099	0.093	93
Machining	12	0.074	0.096	0.085	85

Table 2 displays the outcomes of PM 10 concentration measurements taken at 12 sampling locations. Based on Government Regulation No. 22 of 2022, the standard limit for PM 10 concentration is set at 75 µg/m³. The average was 104.875 µg/m³, with a minimum of 28 µg/m³, a maximum of 286 µg/m³, and a standard deviation of 83.84 µg/m³. The PM 10 concentration measurements in 12 production area points of the furniture industry, it is known that the level of dust exposure varies depending on the activities taking place at each point. The highest PM 10 concentration was found in the assembling area, specifically at point 5 (286 µg/m³) and point 6 (266.5 µg/m³), followed by point 7 (99.5 µg/m³) and point 4 (94 µg/m³). These four points exceeded the threshold limit (75 µg/m³); these areas are dominated by manual sanding activities that produce a large amount of fine dust. The concentration differences in these areas are due to higher activity intensity compared to other points, where more products are processed and sanding is performed more frequently and for longer durations. Furthermore, point 8 (79 µg/m³) is located near the manual scraping process, and point 9 (87 µg/m³) is near final sanding activities; both are in the finishing area and also exceed the threshold limit. Point 10 (68.5 µg/m³), located near the drilling machine, has a concentration that is still considered safe. However, point

11 (93 µg/m³), which is near the Bowen and CNC machines, and point 12 (85 µg/m³), near the sanding machine, show concentrations that exceed the recommended TLV. In the sawmill area, the concentrations are relatively lower. Point 1 (37 µg/m³) is near the whole wood cutting machine, while point 2 (35 µg/m³), near the crosscut saw in the preparation area, also shows a concentration still within the safe category. The lowest concentration was found at point 3 (28 µg/m³) in the smotmill area, near the wide belt sander. The low concentration at this point is due to minimal activity and the presence of machines equipped with automatic dust extraction systems, which effectively reduce airborne particles.

Table 3

Table of Frequency Distribution of PM 10 Concentration

PM 10 Concentration	Frequency	Percentage (%)
Above the TLV	58	58.0
Below the TLV	42	42.0

Table 3 shows the results of PM 10 concentration measurements, which indicate that 58 respondents (58.0%) were exposed to PM 10 concentrations above the threshold limit value (TLV), while 42 respondents (42.0%) were exposed to PM 10 concentrations below the TLV. This shows that nearly half of the respondents were exposed to particulate matter (PM) measuring 10 micrometers, which poses a potential risk to the respiratory system. Particles of this size can reach the middle airways, such as the bronchi, through mechanisms like impaction, sedimentation, and Brownian diffusion, thereby increasing the risk of respiratory issues such as chronic cough, airway irritation, and worsening asthma conditions.

PM 10 is classified as a primary air pollutant, which is a type of pollutant directly released into the atmosphere from pollution sources (Gunawan et al., 2018). hese particles are less than 10 micrometers in size. Exposure to PM 10 is often used as a key indicator to assess particulate air pollution because it is closely linked to its effects on the respiratory system (Wangsa et al., 2022).

Table 4

Table of PM 2.5 Concentration Measurement Results

Section	Sampling point	PM 2.5 Result (mg/m³) Quality Standard 55 µg/m³		Average (mg/m³)	Average (µg/m³)
		(Morning)	(Afternoon)		
	1	0.010	0.055	0.0325	32.5
Saw mill	2	0.036	0.050	0.043	43
Reparation	3	0.031	0.020	0.0255	25.5
Rough mill	4	0.108	0.17	0.139	139
Assembling	5	0.304	0.216	0.26	260
Assembling	6	0.095	0.189	0.142	142
Assembling	7	0.109	0.071	0.09	90
Assembling	8	0.060	0.095	0.0775	77.5
Finishing	9	0.089	0.074	0.0815	81.5
Finishing	10	0.063	0.057	0.06	60
Machining	11	0.056	0.123	0.0895	89.5
Machining	12	0.114	0.05	0.082	82

Table 4 shows the results of PM 2.5 concentration measurements at 12 sampling points. According to Government Regulation No. 22 of 2022, the quality standard for PM 2.5 concentration is 55 µg/m³. The average was 93.54 µg/m³, with a minimum of 25.5 µg/m³, a maximum of 260 µg/m³, and a standard deviation of 63.76 µg/m³. The results of the PM 2.5 concentration measurements at 12 points in the furniture industry production area show that dust exposure levels vary depending on the activities taking place at each point. The highest PM 2.5 concentrations were found in the assembling area, with point 5 at 260 µg/m³ and point 6 at 142 µg/m³, followed by point 4 at 139 µg/m³ and point 7 at 90 µg/m³. These four points exceeded the threshold limit value (55 µg/m³), and these areas were dominated by manual sanding activities that generated large amounts of fine dust. The differences in concentration in these areas were due to the higher intensity of activity compared to other points, where more products were being worked on, and the sanding process occurred more frequently and for longer durations. Next, point 8 (77.5 µg/m³) was near the manual scraping process, and point 9 (81.5 µg/m³) was around the final sanding activity; both were located in the finishing area and showed values above the threshold limit. Point 10 (60 µg/m³) was near the drilling machine, point 11 (89.5 µg/m³) was near the Bowen and CNC machines, and point 12 (82 µg/m³) was near the sanding machine.

These three points were located in the machining area, which showed concentrations exceeding the recommended threshold limit (TLV). In the sawmill area, the concentrations were relatively lower. Point 1 (32.5 µg/m³) was near the wood cutting machine, while point 2 (43 µg/m³) was near the crosscut saw in the preparation area, both showing concentrations still within the safe category. The lowest concentration was found at point 3 (25.5 µg/m³) in the sawmill area, near the wide belt sander machine. The low concentration at this point was due to the minimal activity and the presence of machines equipped with automatic dust collection systems, which effectively reduced the amount of particles in the air.

Table 5

Table of Frequency Distribution of PM 2.5 Concentration

PM 2.5 Concentration	Frequency	Percentage (%)
Above the TLV	67	67.0
Below the TLV	33	33.0

Table 5 shows the results of the PM 2.5 concentration measurements, revealing that 67 respondents (67.0%) were exposed to PM 2.5 concentrations above the threshold limit value (TLV), while 33 respondents (33.0%) were exposed to concentrations below the TLV. This indicates that more than half of the total respondents were exposed to particulate matter with a diameter of 2.5 micrometers. Particulate matter (PM) 2.5 consists of very fine particles and has the ability to penetrate deeper into the respiratory system, reaching the alveoli in the lungs. From the alveoli, these particles can enter the bloodstream through pulmonary circulation and then spread throughout the body via systemic circulation. PM 2.5 consists of fine airborne particles that are extremely small and can be easily inhaled, measuring 2.5 micrometers or less in diameter (Maksum & Tarigan, 2022). Often referred to as "fine particles," PM 2.5 poses serious health threats because of its minute size, roughly 1/3 the width of a human hair. Due to their microscopic nature, these particles can travel deep into the respiratory system and may even reach the lungs (Nirmala & Prasasti, 2016).

The high concentrations of PM 10 and PM 2. in the work environment are influenced by the intensity of work activities, particularly those that generate dust, such as sanding. This condition is worsened by the absence of dust extraction systems in most work areas. Only a few large machines are equipped with dust collectors, while tools like handheld sanding machines have no dust extraction at all. In addition, the semi-enclosed design of the workspace leads to poor air circulation, allowing dust particles to accumulate easily in the air and increasing workers' exposure.

Lung Function Impairment Among Workers

Table 6

Table of Frequency Distribution of Pulmonary Function Disorders Among Workers

Pulmonary Function Disorder	Frequency	Percentage (%)
Presence of lung function impairment	57	57.0
Absence of lung function impairment	43	43.0

Table 6 shows the results of pulmonary function tests on 100 respondents, with 57 respondents (57.0%) experiencing pulmonary function disorders, while 43 respondents (43.0%) did not have any disorders. In addition to pulmonary function test results, some workers reported recurring mild respiratory symptoms such as coughs and colds, occurring almost every month. This may indicate early airway irritation due to continuous exposure to workplace pollutants. Unfortunately, the company does not have a regular pulmonary function screening program. The absence of routine check-ups highlights the lack of early detection and prevention efforts for occupational diseases, particularly respiratory disorders. Regular screening is essential to identify issues early and prevent deterioration, serving as a preventive measure to protect workers from the long-term effects of hazardous exposures.

The lungs are crucial organs that facilitate the exchange of oxygen and carbon dioxide, a process essential for the body's metabolism. Pulmonary disorders can disrupt metabolism and decrease quality of life (Pinugroho & Kusumawati, 2017). Dust exposure can lead to pulmonary dysfunction in the form of restrictive (narrowing of the airways due to allergens such as dust or fungi), obstructive (blockage due to dust accumulation), or a combination of both (mixed). Symptoms include coughing, shortness of breath, and fatigue (Setyaningsih et al., 2023). The factors causing respiratory disorders due to dust include the characteristics of the dust (size, shape, concentration, solubility, chemical properties, and exposure duration) and individual factors such as lung defense mechanisms, airway anatomy, and immunity. Exposure assessment should also take into account the source, duration, daily activities, and other factors such as age, gender, and smoking habits (Anes et al., 2015).

Bivariate analysis was conducted to examine the relationship between independent variables such as PM 10 concentration, PM 2.5 concentration, duration of employment, body mass index (BMI), and physical activity and lung function impairment among furniture industry workers in Tegal Regency. The statistical test used was the chi-square test, and the results are presented in Table 7.

Table 7 presents the results of bivariate analysis between the independent variables and respondents' lung function impairment. Respondents who worked in areas with PM 10 concentrations exceeding the Threshold Limit Value (TLV) experienced lung function impairment at a rate of 72.4%, which was higher compared to respondents working in areas with PM 10 concentrations below the TLV (35.7%). The chi-square test showed a p-value of 0.001 ($p < 0.05$), indicating a significant association between PM 10 concentration and lung function impairment. The Odds Ratio (OR) was 2.028 with a 95% Confidence Interval (CI) of 1.311–3.135, suggesting that respondents exposed to PM 10 levels above the TLV had twice the risk of experiencing lung function impairment. This result aligns with a study by Yanti in 2023, which found that 71.9% of PM 10 measurement points exceeded the threshold. Statistical tests indicated a relationship between wood dust exposure and Acute Respiratory Infections (ARI) ($p = 0.001$), where PM 10 concentrations above the threshold increased the risk of ARI in furniture workers (Yanti, 2023). Furthermore, research by Cahyani and Khurniawan in 2023 showed a link between PM 10 exposure and vital lung capacity in furniture production workers (Cahyani & Khurniawan, 2023). Particles of this size can reach and become trapped in the upper to middle respiratory tract, such as the trachea and bronchi. The accumulation of PM 10 particles in the upper and middle respiratory tract can cause mucosal irritation, increased mucus production, and local inflammation. This inflammation is characterized by typical responses such as pain (dolor), heat (calor), redness (rubor), and swelling (tumor). The buildup of mucus and tissue swelling can narrow the airways, obstruct airflow to the lungs, and reduce lung elasticity, potentially leading to impaired lung function (L€ofstedt et al., 2017).

Table 7

Results of the bivariate analysis

No.	Variable	Pulmonary Function Disorder				Total		P value	PR (95 % CI)
		Presence of lung function impairment		Absence of lung function impairment					
		n	%	n	%	n	%		
1.	PM 10 Concentration								
	Above TLV	42	72.4	16	27.6	58	100	0.001	2.028 (1.311 – 3.135)
	Below TLV	15	35.7	27	64.3	42	100		
2.	PM 10 Concentration								
	Above TLV	45	67.2	22	32.8	67	100	0.007	1.847 (1.141 – 2.889)
	Below TLV	12	36.4	21	63.6	33	100		
3.	Duration of Employment								
	≥ 5 Years	45	68.2	21	31.8	66	100	0.003	1.932 (1.191 – 3.135)
	< 5 Years	12	35.3	22	64.7	34	100		
4.	Body Mass Index								
	Overweight	17	63.0	10	37.0	27	100	0.614	1.149 (0.804 – 1.641)
	Normal	40	54.8	33	45.2	73	100		
5.	Physical activity								
	No	23	56.1	18	43.9	41	100	1	0.973 (0.687 – 1.379)
	Yes	34	57,6	25	42,4	59	100		

PM 2.5 concentration, 67.2% of respondents exposed to levels above the TLV experienced lung function impairment, compared to 36.4% of respondents exposed to levels below the TLV. The statistical test yielded a p-value of 0.007 ($p < 0.05$), with an OR of 1.847 (95% CI: 1.141–2.889), indicating that exposure to PM 2.5 above the TLV nearly doubled the risk of lung function impairment. This result is consistent with a study by Anjelicha et al. in 2022, which found PM 2.5 concentrations of 0.067 mg/m³ during sawing and sanding processes, and 0.32 mg/m³ during painting processes. The study found that 73.3% of furniture industry workers experienced symptoms of Chronic Obstructive Pulmonary Disease (COPD), and 33.33% of workers were exposed to health risks due to PM 2.5 dust while working (Anjelicha et al., 2022). Additionally, research by Azizah found that the PM 2.5 concentration exceeded the threshold limit (>3 mg/m³) in workers at the research site. The average environmental PM 2.5 level also exceeded the threshold limit, and 40% of workers experienced pulmonary function disorders (Azizah, 2019). Dust particles measuring ≤2.5 microns have the ability to penetrate the respiratory tract and reach the alveoli. Within the alveoli, these particles undergo Brownian motion, which keeps them suspended

and eventually allows them to adhere to the alveolar walls. The accumulation of particles in this area can trigger a chronic inflammatory response and activate immune cells, such as alveolar macrophages. This response has the potential to cause pathological changes, such as fibrosis or hardening of the alveolar tissue, leading to a decrease in lung elasticity. As a result, the lungs' ability to inhale and exhale air becomes impaired, which, over time, can lead to reduced lung function (Li et al., 2018; Sari et al., 2020).

Respondents with ≥ 5 years of work experience had a lung function impairment rate of 68.2%, while those with less than 5 years of experience had a rate of 35.3%. There was a significant association between work duration and lung function impairment (p = 0.003), with an OR of 1.932 (95% CI: 1.191–3.135), meaning that respondents with ≥ 5 years of work experience had almost twice the risk of experiencing lung function impairment. This finding is consistent with the study by Nurmayanti et al. (2022), which reported that respiratory complaints were most commonly experienced by workers with a work tenure of more than five years (51.9%). The statistical test result showed a p-value of 0.006, indicating a significant relationship between work tenure and respiratory complaints (Nurmayanti et al., 2022). Similarly, Purba et al. (2019) found that among 31 woodworkers, the majority (80.65%) had been working for more than five years. Of these, 58.06% experienced restrictive lung function impairment, while 41.94% had normal lung function (Purba et al., 2019). The duration of employment is associated with the risk of impaired lung function. The longer the work tenure, the longer an individual is exposed to occupational hazards, which may trigger health problems due to prolonged exposure. Continuous exposure to dust over a long period significantly increases the likelihood of developing respiratory disorders (Afgrianti et al., 2020). Based on field observations, it was found that no formal job rotation system is routinely implemented for all workers at the site. Each worker tends to remain in their designated work area for extended periods without any regular position changes or task variation. Although occasional transfers occur to assist other sections, these are temporary, short in duration, and unscheduled. As a result, all workers experience consistent and repeated exposure to the risks associated with their primary work areas.

Regarding Body Mass Index (BMI), 63.0% of overweight respondents experienced lung function impairment, compared to 54.8% of those with normal BMI. The chi-square test showed a p-value of 0.614 (p > 0.05), with an OR of 1.149 (95% CI: 0.804–1.641), indicating no significant association between nutritional status and lung function impairment. This result aligns with a previous study by Permatasari et al. in 2017, which found no correlation between nutritional status and lung function impairment, reporting a significance value of 0.128 (p-value > 0.05) among wood processing workers at CV Indo Jati Utama, Semarang (Permatasari et al., 2017). Similarly, a 2019 study by Helmy reported a p-value of 0.767 (> 0.05), indicating no relationship between nutritional status and lung function among traders (Helmy, 2019). Nutritional status is an individual factor that can affect respiratory complaints. With balanced nutrition, the body's physiology can function optimally, energy needs are met, and the immune system works at its best. This allows antibodies to function properly when physiological disturbances occur (Dwicahyono, 2018). Body Mass Index (BMI) affects lung volume, where obesity can lead to a reduction in lung volume. The increase in body fat in obese individuals can accumulate in various parts of the body, eventually reducing both static and dynamic lung volumes (Sembel et al., 2024).

Meanwhile, 56.1% of respondents who did not engage in physical activity experienced lung function impairment, compared to 57.6% of those who did. The analysis showed a p-value of 1.000 (p > 0.05) and an OR of 0.973 (95% CI: 0.687–1.379), indicating no significant association between physical activity and lung function impairment. This finding is consistent with a study by Pujiono in 2023, which showed a p-value of 0.132 (> 0.05), indicating no significant relationship between exercise habits and lung function impairment among industrial workers (Pujiono, 2023). Furthermore, a study by Zakiyyah in 2024 found no significant relationship between exercise habits and lung capacity in furniture workers in Samata Village (p-value = 1.000 > 0.05) (Zakiyyah, 2024). Nevertheless, physical activity remains important for maintaining overall lung health. Regular physical activity can strengthen respiratory muscles, improve vital lung capacity, and enhance forced expiratory volume in one second (FEV_1), thus helping to prevent fatigue and maintain respiratory system endurance (Lontoh & Rini, 2022). Therefore, although no statistically significant relationship was found in this study, physical activity habits are still recommended as part of a healthy lifestyle to support optimal lung function.

Based on the bivariate analysis, three variables had p-values less than 0.25, PM 10 concentration, PM 2.5concentration, and duration of employment. These variables were considered for inclusion in the multivariate logistic regression model. However, since PM 10 and PM 2.5 concentrations are statistically correlated (collinear), including both in the same model could result in multicollinearity, potentially biasing the estimates. To address this, only one of the two was selected. In this study, PM 10 concentration was chosen for further analysis along with duration of employment. This decision was based on the scientific rationale that larger particles like PM 10 tend to deposit in the upper and central respiratory tracts and are more reflective of overall particulate exposure in woodworking environments. Furthermore, PM 10 levels varied more noticeably between different work areas, making it a more representative variable for evaluating risk in this context. Therefore, the multivariate analysis included PM 10 concentration and duration of employment to identify the dominant factors contributing to lung function impairment among workers.

Table 8
Dominant Factors Affecting Lung Function Impairment Among Workers in the Furniture Industry, Tegal Regency

Variable	P value	OR (95% CI)
PM 10 Concentration	0.002	3.976 (1.641 – 9.637)
Duration of Employment	0.015	3.146 (1.250 – 7.922)

Based on table 8 the results of the multivariate analysis, two variables were found to have a significant effect on lung function impairment among furniture industry workers in Tegal Regency PM 10 concentration and duration of employment. PM 10 concentration showed a p-value of 0.002 ($p < 0.05$) with an Odds Ratio (OR) of 3.976 and a 95% Confidence Interval (CI) of 1.641–9.637. This indicates that respondents exposed to PM 10 levels above the Threshold Limit Value (TLV) had nearly four times the risk of experiencing lung function impairment compared to those exposed to levels below the TLV. In addition, duration of employment also showed a significant association with lung function impairment, with a p-value of 0.015 ($p < 0.05$). The OR was 3.146 with a 95% CI of 1.250–7.922, indicating that respondents who had worked for five years or more had approximately three times the risk of lung function impairment compared to those who had worked for less than five years. Thus, PM 10 concentration is the most dominant factor influencing lung function impairment among furniture industry workers in Tegal Regency.

CONCLUSIONS

The study found that the average concentrations of PM 10 and PM 2.5 in the furniture industry work environment in Tegal Regency were 97.28 µg/m³ and 87.79 µg/m³, respectively. A total of 57% of respondents experienced impaired lung function. There was a significant association between lung function impairment and exposure to PM 10, PM 2.5, and duration of employment. The most dominant factor influencing lung function impairment was PM 10 concentration ($p = 0.002$; OR = 3.976). However, this study has several limitations, including the use of a cross-sectional design that cannot establish causality, and the exclusion of variables such as ventilation systems, psychosocial working conditions, and prior exposure history that may affect workers' respiratory health.

REFERENCE

Afgrianti, Y., Sulistiyani, S., & Wahyuningsih, N. E. (2020). Karakteristik Pekerja pada Penggilingan Padi di Kecamatan Rowosari Kabupaten Kendal. *Media Kesehatan Masyarakat Indonesia*, *19*(5), 338–344. [Crossref] [Publisher]

Anes, N. I., Kawatu, P. A. T., & Umboh, J. M. L. (2015). Factors Associated With Impaired Lung Function In Workers at PT. Tonasa Line Bitung City. *Jurnal Ilmu Kesehatan Masyarakat Unsrat*, *5*(3), 600–607. [Publisher]

Anjelicha, D., Riviwanto, M., & Wijayantono, W. (2022). Analisis Risiko Penyakit Paru Obstruksi Kronis Akibat Paparan Debu PM 2.5 pada Pekerja Mebel Kayu CV Mekar Baru Kota Padang. *Jurnal Sehat Mandiri*, *17*(1), 115–125. [Crossref] [Publisher]

Arief, M. L. (2019). Lingkungan Kerja Faktor Debu. In *Universitas Esa Unggul Press*. [Publisher]

Azizah, I. T. N. (2019). Analysis The Level of PM 2,5 and Lung Function of Organic Fertilizer Industry Workers In Nganjuk. *Jurnal Kesehatan Lingkungan*, *11*(2), 141–149. [Crossref] [Publisher]

Cahyani, S. D., & Khurniawan, F. (2023). Jurnal Higiene Sanitasi Hubungan Pajanan Particulate Matter (PM10) Dengan Kapasitas Vital Paru pada Pekerja Produksi Mebel. *Jurnal Higiene Sanitasi*, *3*(1), 4–8. [Crossref] [Publisher]

Chaeruddin, A. D. R. D., Abbas, H. H., & Gafur, A. (2021). Analisis Risiko Kesehatan Lingkungan Pajanan Debu Kayu pada Pekerja Mebel Informal Antang. *Window of Health : Jurnal Kesehatan*, *2*(2), 314–327. [Publisher]

Chiqita, N. Q. (2020). Hubungan Paparan Debu Kayu terhadap Gangguan Fungsi Paru pada Pekerja. *Jurnal Medika Hutama*, 206–212. [Publisher]

Cintya, R. E., Budiyono, B., & Joko, T. (2020). Paparan Debu Terhirup dan Gangguan Fungsi Paru pada Pedagang Tetap di Terminal Kota Tegal. *Media Kesehatan Masyarakat Indonesia*, *19*(3), 189–194. [Crossref] [Publisher]

Dwicahyono, H. B. (2018). Analysis of NH3 Content, Individual Characteristics and Respiratory Scavenger Complaint in Landfills Benowo Rubbish and Not Scavenger Around Landfills Benowo Surabaya. *Jurnal Kesehatan Lingkungan*, *9*(2), 135. [Crossref] [Publisher]

Environmental Protection Agency. (2024). *Particulate Matter (PM) Basics*. [Publisher]

Gunawan, H., Ruslinda, Y., Bachtiar, V. S., & Dwinta, A. (2018). Model Hubungan Konsentrasi Particulate Matter 10 (PM10) di Udara Ambien Dengan Karakteristik Lalu Lintas di Jaringan Jalan Primer Kota Padang. *Jurnal UMJ Seminar Nasional Sains Dan Teknologi 2018*, 1–11. [Publisher]

Helmy, R. (2019). Hubungan Paparan Debu dan Karakteristik Individu dengan Status Faal Paru Pedagang di Sekitar Kawasan Industri Gresik. *Jurnal Kesehatan Lingkungan*, *11*(2), 150–157. [Crossref] [Publisher]

Herdianti, Fitriyanto, T., & Suroso. (2018). Paparan Debu Kayu dan Aktivitas Fisik terhadap Dampak Kesehatan Pekerja Meubel. *Jurnal Kesehatan Manarang*. [Crossref] [Publisher]

K. Hosseini, D., Malekshahi Nejad, V., Sun, H., K. Hosseini, H., Adeli, S. H., & Wang, T. (2020). Prevalence of respiratory symptoms and spirometric changes among non-smoker male wood workers. *PLOS ONE*, *15*(3), 1–10. [Crossref] [Publisher]

Kulkani, C. M., Karigoudar, M. H., & Aithala, M. (2016).

Measurement of Wood Dust Particle Size by Optical Microscopy Technique and Long-Term Effect on Sawmill Workers: A Random Study. *Asian Journal of Pharmaceutical and Clinical Research*, *9*, 308–311. [Crossref] [Publisher]

L€ofstedt, H., Hagstr€om, K., Bryngelsson, I.-L., Holmstr€om, M., & Rask-Andersen, A. (2017). Respiratory Symptoms and Lung Function in Relation to Wood Dust and Monoterpene Exposure in the Wood Pellet Industry. *Upsala Journal of Medical Sciences*, *122*(2), 78–84. [Crossref] [Publisher]

Li, T., Hu, R., Chen, Z., Li, Q., Huang, S., Zhu, Z., & Zhou, L. F. (2018). Fine Particulate Matter (PM 2.5): The Culprit for Chronic Lung Diseases in China. *Journal Chronic Diseases and Translational Medicine*. [Crossref] [Publisher]

Lontoh, S. O., & Rini, R. (2022). Hubungan Kebiasaan Olahraga dengan Fungsi Paru Mahasiswa Fakultas Kedokteran Universitas Tarumanagara Angkatan 2019 dan 2020. *Jurnal Muara Medika Dan Psikologi Klinis*, *1*(2), 147. [Crossref] [Publisher]

Maksum, T. S., & Tarigan, S. F. N. (2022). Analisis Risiko Kesehatan Akibat Paparan Partikel Debu (Pm2.5) Dari Aktivitas Transportasi. *Jambura Health and Sport Journal*, *4*(1), 19–28. [Crossref] [Publisher]

Nirmala, D. S., & Prasasti, C. I. (2016). Concentration of PM2,5 and Characteristic Analysis of Workers with Health Complaints Smoked Fish Workers in Tambak Wedi Village Surabaya. *Jurnal Kesehatan Lingkungan*, *8*(1), 57. [Crossref] [Publisher]

Nurmayanti, D., Mufaizah, D., Suryono, H., Winarko, & Widodo, S. (2022). Pengaruh Kadar Debu terhadap Keluhan Pernapasan pada Karyawan Bagian Produksi Pakan Ternak. *Jurnal Penelitian Kesehatan Suara Forikes*, *13*(6), 957–962. [Crossref] [Publisher]

Pemerintah Republik Indonesia. (2021). *Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup. Lampiran VII* (Issue 1).

Permatasari, L. O., Raharjo, M., & Joko, T. (2017). Hubungan antara Kadar Debu Total dan Personal Hygiene dengan Gangguan Fungsi Paru pada Pekerja Pengolahan Kayu di CV Indo Jati Utama Semarang. *Jurnal Kesehatan Masyarakat*, *5*(5), 717–723. [Crossref] [Publisher]

Pinugroho, B. S., & Kusumawati, Y. (2017). Hubungan Usia, Lama Paparan Debu, Penggunaan Apd, Kebiasaan Merokok dengan Gangguan Fungsi Paru Tenaga Kerja Mebel Di Kec Kalijambe Sragen. *Jurnal Kesehatan*, *10*(2), 37–46. [Crossref] [Publisher]

Primasanti, Y., & Herawati, V. D. (2022). Analisis Paparan Debu pada Departemen Pemintalan Benang PT.PBTS. *Jurnal Ilmu Keperawatan Indonesia*, *15*(8), 14–20. [Crossref] [Publisher]

Pujiono. (2023). Hubungan Penggunaan APD, Kebiasaan Merokok, Kebiasaan Olahraga, dan Kadar Debu yang Terhirup terhadap Terjadinya Gangguan Fungsi Paru pada Pekerja. *Jurnal Riset Kesehatan Poltekkes Depkes Bandung*, *15*(1), 22–29. [Crossref] [Publisher]

Purba, A. C. S., Adiputra, L. M. I. S. H., & Muliarta, I. M. (2019). Gambaran Fungsi Paru Pengrajin Kayu di Desa Petulu Gianyar, Bali-Indonesia. *Jurnal Intisari Sains Medis*, *10*(3), 702–706. [Crossref] [Publisher]

Sari, J. A., Astuti, R., & Prasetio, D. B. (2020). Kapasitas Vital Paru pada Pekerja Tambal Ban Pinggir Jalan. *Higeia Journal Of Public Health Research Adn Development*, *4*(22), 223–232. [Crossref] [Publisher]

Sembel, I. M. J., Polii, H., & Engka, J. N. A. (2024). *Hubungan Indeks Massa Tubuh dengan Forced Vital Capacity pada Usia Remaja*. *12*(1), 583–588. [Crossref] [Publisher]

Setyaningsih, Y., Wahyuni, I., Kurniawan, B., & Ekawati. (2023). Kadar Debu Lingkungan Kerja dan Kapasitas Kerja sebagai Determinan Penurunan Kapasitas Fungsi Paru. *Jurnal Kesehatan Lingkungan Indonesia*, *22*(2), 214–220. [Crossref] [Publisher]

Wangsa, D., Bachtiar, V. S., & Raharjo, S. (2022). Uji Model Aeromod Terhadap Sebaran Particulate Matter 10 µm (PM10) di Sekitar Kawasan PT Semen Padang. *Jurnal Ilmu Lingkungan*, *20*(2), 291–301. [Crossref] [Publisher]

WHO. (2023). *WHO/ILO: Almost 2 Million People Die from Work-Related Causes Each Year*. Who.Go.Id. [Publisher]

Yanti, M. (2023). Hubungan Kadar Debu (PM10) dengan Kejadian Ispa Pada Industri Mebel Kayu Di Kelurahan Sungai Sapih Kecamatan Kuranji Kota Padang. *Jurnal Media Ilmu*, 126–131. [Crossref] [Publisher]

Zakiyyah, W. (2024). Faktor-Faktor yang Berhubungan dengan Kapasitas Fungsi Paru pada Pekerja Mebel Di Kelurahan Samata Kabupaten Gowa. In *UIN Alauddin Press*. [Publisher]