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Relationship between Duration of Sand Dust Exposure and Symptoms of Respiratory Disorders in Sand Mine Workers of Batukuda Village, Mancak District

Bella Candrakanti[1], Siti Darifah[2], Erni Trisnasari[3]
[1]Faculty of Medicine and Health Science, Sultan Ageng Tirtayasa University, Banten, Indonesia

Correspondence: candrakantibella@gmail.com, +6285212509516)

ABSTRACT

Respiratory symptoms are conditions that are felt to indicate disruption of airflow due to problems in the oxygen binding process or instability of gas exchange in the circulation which can describe an occupational lung disease. Cases of occupational lung disease are still common among mine workers in the world, especially in developing countries. Exposure to sand dust in sand mines can cause symptoms of respiratory disorders. This study discusses the relationship between the duration of exposure to sand dust and symptoms of respiratory disorders in sand mine workers in Batukuda Village, Mancak District. This study included analytic observational research with a cross-sectional study design approach and convenience sampling technique with the aim of evaluating the relationship between the duration of exposure to sand dust as an independent variable with symptoms of respiratory disorders as the dependent variable. he proportion who experienced symptoms of respiratory problems in sand mining workers in Batukuda Village was 86.6%. Most of the sand mine workers in Batukuda Village had a duration of sand dust exposure ≤8 hours/day (59.7%). The proportion of most respondents aged <30 years (52.2%), abnormal BMI (50.7%), did not use PPE while working (82.1%), had a smoking habit (92.5%), and a work period <5 years (71.6%). There is no significant relationship between the duration of exposure to sand dust and symptoms of respiratory disorders in sand mine workers in Batukuda Village, Mancak District (p = 0.785). Significant results were shown in the relationship between smoking habits (p = 0.002) and the use of PPE masks (p = 0.002).

Keywords: ***Respiratory symptoms; duration of exposure; sand dust; sand mine workers***

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INTRODUCTION

Symptoms of respiratory distress are subjective evidence of a disease or change in conditions felt and complained of by workers that can describe an occupational lung disease.[1] Occupational lung disease is still a major problem of respiratory system disorders and a priority issue in occupational health, especially in developing countries.[2] Exposure to dust in the workplace can attack the respiratory system so that it can cause symptoms of respiratory distress. The disorder is proportional to the duration of dust exposure in mine workers.[3] According to the *World Health Organization* (WHO) and *the International Labor Organization* (ILO), occupational diseases contribute to a significant number of mortality of about 1.9 million people recorded in 2016.[4] Based on a review by Ambiya *et al*. in 2022, cases of Occupational Diseases (OPD) in the world stated that the prevalence of >30% of OPD is pulmonary disease.[5] The high mortality rate due to PAK is inseparable from the lack of supporting structures and health management that is less considered in mine workers who are included in the informal sector.[6] In informal workers of limestone miners, 71.4% experienced pulmonary obstruction.[7] In line with the research by Rumchev *et al*., 6.3% of miners have potential airway obstruction due to dust exposure.[8] Similarly, research in China in 2020 stated that the proportion of occupational lung disease caused by dust was around 36.46% experiencing pneumoconiosis.[9] Meanwhile in Indonesia in 2018, based on data from the Indonesian Directorate General of Disease Control for the proportion of occupational lung disease, namely, 33% bronchial asthma, 35% chronic obstructive pulmonary disease, 30% lung cancer and 2% other diseases.[10]

Long duration of exposure to dust will cause workers to experience lung damage and fibrosis so that it can reduce the elasticity of the lung muscles and the volume of air accommodated will also decrease, this causes the oxygen binding capacity to decrease, causing symptoms of respiratory disorders.[5] Based on this, the researcher is interested in conducting research, namely the relationship between the duration of exposure to sand dust and symptoms of respiratory disorders in sand mine workers in Batukuda Village, Mancak District. Research in the informal industry sector is still rarely discussed, especially related to sand mining. Sand mine workers who are informal sector workers were chosen as research subjects because they are often exposed to sand dust directly every day while working and rarely carry out routine health checks. Sand mining in Batukuda Village was chosen because it has never been studied and sand mining in the village has a very large area so that sand dust pollution is high.[11]

METHODS

This study used an observational analytic method with a *cross-sectional* study design approach. The data for this study were collected by interviewing respondents directly using the ATS-DLD-78A questionnaire. The population for this study were sand mine workers in 5 sand mines in Batukuda

Village, Mancak District, Serang Regency, with the number of respondents who had been calculated using the 2 proportion test formula as many as 67 respondents. The respondent sampling technique was carried out using *convenience sampling* technique which is a type of *non probability* or *non random sampling.* This research has been approved based on the results of ethical review by KEPK with letter number 14/UN43.20/KEPK/2025 issued on January 22, 2025. After obtaining approval, the authors will conduct this research based on the principles of research ethics to sand mine workers in Batukuda Village, Mancak District.

RESULTS

Table 1. Respondent Characteristics

Respondent Characteristics	Frequency (n)	Percentage (%)
Age		
≥30 years	32	47,8%
<30 years	35	52,2%
IMT		
Not normal	34	50,7%
Normal	33	49,3%
Use of PPE		
No	55	82,1%
Yes	12	17,9%
Smoking Habit		
Yes	62	92,5%
No	5	7,5%
Length of service (years)		
≥5 years	19	28,4%
<5 years	48	71,6%

Berdasarkan analisis univariat tabel 1 mengenai distribusi karakteristik responden didapatkan bahwa, proporsi sebagian besar responden berusia <30 years old as many as 35 people (52.2%), more respondents had abnormal BMI (*underweight* 10.4%), *overweight* (16.4%), and obesity (23.9%)) as many as 34 people (50.7%), the majority of respondents did not use PPE while working as many as 55 people (82.1%), almost all respondents had a smoking habit because they had smoked more than 100 cigarettes during their lifetime and were still actively smoking, namely 62 people (92.5%), and respondents who had a work period <5 years as many as 48 people (71.6%).

Table 2. Distribution of Sand Dust Exposure Duration

Duration of Sand Dust Exposure (hours)	Frequency (n)	Percentage (%)
>8 hours/day	27	40,3%
≤8 hours/day	40	59,7%

Based on the univariate analysis in Table 2, the proportion for the duration of exposure to sand dust ≤8 hours / day is more dominant, as many as 40 people (59.7%) compared to the duration of exposure to sand dust >8 hours / day.

Table 3. Distribution of Respiratory Distress Symptoms

Symptoms of Respiratory Disorders	Frequency (n)	Percentage (%)
Yes	58	86,6%
No	9	13,4%

Based on the univariate analysis in Table 3, the proportion of those who experienced symptoms of respiratory distress was more dominant, as many as 58 people (86.6%) than those who did not experience symptoms of respiratory distress.

Table 4. Frequency Distribution of Respiratory Distress Symptoms

Symptoms of Respiratory Disorders	Yes	No
Cough	55 (80,60%)	12 (17.91%)
Phlegm	40 (16,42%)	27 (40.30%)
Cough and Phlegm	38 (56.72%)	29 (43.28%)
Wheezing	4 (5.97%)	63 (94.03%)
Chest pressure/pinch	7 (10.45%)	60 (89.55%)
Shortness of breath	2 (2.99%)	65 (97.01%)

Based on the results of the analysis, the most common symptom of respiratory disorders felt by sand mine workers is cough (80.60%). Other symptoms were also felt such as phlegm (16.42%), cough and phlegm (56.72%), wheezing (5.97%), chest pressure/pinch (10.45%), and shortness of breath (2.99%).

Table 5. Relationship between Duration of Sand Dust Exposure and Respiratory Symptoms

		Total workers	Symptoms of respiratory distress		*p-value*	OR (95% CI)
			Yes n(%)	No n(%)		
Sand dust exposure duration (hours)	>8 hours/day	27	23 (85,2%)	4 (14,8%)	0,785	0,821 (0,199-3,385)
	≤8 hours/day	40	35 (87,5%)	5 (12,5%)		
Total		67	58 (86,5%)	9 (13,43%)		

Based on the distribution of data results of bivariate analysis using the *chi-square* test that connects the independent variable (duration of exposure to sand dust) and the dependent (symptoms of respiratory disorders). The data in table 5 shows that[1] a there is no significant relationship between the duration of exposure to sand dust and the incidence of respiratory symptoms, which is indicated by a *p-value* = 0.785 (significant if the *p-value* <0.05, 95% CI does not cut 1).

Table 6: Relationship between confounding variables and the incidence of symptoms of respiratory disorders

		Total workers	Symptoms of respiratory distress		*p-value*	OR (95% CI)
			Yes n(%)	No n(%)		
Age	≥30 years	32	27 (84,4%)	5 (15,6%)	0,615	0,697 (0,170-2,861)
	<30 years	35	27 (81,8%)	6 (18,2%)		
IMT	Not normal	34	30 (88,2%)	4 (11,8%)	0,684	1,339 (0,326-5,497)
	Normal	33	28 (84,8%)	5 (15,2%)		
Usage PPE	No	55	51 (92,7%)	4 (7,3%)	0,002	9,107 (1,964-42,222)
	Yes	12	7 (58,3%)	5 (41,7%)		
Habits Smoking	Yes	62	56 (90,3%)	6 (9,7%)	0,002	14,000 (1,938-101,134)
	No	5	2 (40,0%)	3 (60,0%)		
Length of service	≥5 years	19	17 (89,5%)	2 (10,5%)	0,661	1,451 (0,273-7,710)
	<5 years	48	41 (85,4%)	7 (14,6%)		

The results of bivariate analysis data on confounding variables were also carried out to analyze the relationship between age, BMI, smoking habits, and tenure of work on the incidence of respiratory

symptoms. Data from Table 6 shows the results of the *chi-square* test that smoking habits (p = 0.002) and the use of PPE (p = 0.002) have a statistically significant relationship with the incidence of respiratory symptoms in sand mine workers in Batukuda Village, Mancak District. Meanwhile, the variables of age (p = 0.615), BMI (p = 0.684), and tenure (p = 0.661) were not statistically significant.

DISCUSSION

A. Relationship between Duration of Exposure to Sand Dust and Symptoms of Respiratory Disorders in Sand Mine Workers in Batukuda Village, Mancak District

Based on the results of the *chi-square* test, *a p-value* of 0.785 was obtained, indicating that there was no statistically significant relationship between the duration of sand dust exposure and symptoms of respiratory disorders in sand mine workers in Batukuda Village. The *odds ratio* (OR) value of 0.821 (95% CI 0.199-3.385) is not statistically significant. These results are in line with research by Fauziah *et al.* which did not show a significant relationship between work duration and symptoms of respiratory problems in mine workers.[12] These results are also supported by Wildayani's research that, there is no significant relationship between exposure duration and ARI disease in mine workers (*p-value=0*.056).[13] However, in contrast to research by Apsari *et al.* on sand and stone mine workers in Semarang City which states that exposure duration > 8 hours has a chance of experiencing lung function disorders 5.238 times greater than workers who only have exposure duration ≤ 8 hours. The study showed significant results of the relationship between exposure duration and lung function impairment that occurred in mine workers with a *p-value* of 0.046.[14]

In theory, the duration of dust exposure is directly proportional to the daily dust dose received by workers. The longer the duration of dust exposure, the greater the respiration problems caused by dust. The contaminant limit for acceptable dust exposure without causing disease is no more than 8 hours/day.[13,15] However, the results of this study do not fully support this theory. One of the main reasons is the size and type of sand dust particles inhaled during work activities. However, in this study, the type of sand and the physicochemical characteristics of sand dust, such as particle size and constituent content, were not obtained, so the specific influence of sand dust characteristics on respiratory symptoms cannot be clearly ascertained. Sand at mining sites ranges in size from 0.1 mm - 1 mm, which can be counted with a caliper. Particles of this size are classified as large particles that can settle in the upper respiratory tract and can cause irritating effects.[16] On the other hand, mining activities can also produce smaller dust particles that have the potential to be inhaled into the deeper airways. In theory, sand is a natural aggregate consisting of grains ranging in size from 2 mm to 0.0625 mm with the main component being silica oxide (SiO_2).[17] Therefore, it is possible that smaller sand dust particles may enter the lower respiratory tract and cause respiratory symptoms.

In addition, most workers do not wear PPE masks, increasing the risk of direct dust inhalation. Smoking also worsens respiratory conditions and accelerates the onset of respiratory symptoms. Therefore, the combination of sand dust exposure, not using PPE, and smoking can explain the high prevalence of respiratory problems (86.6%) among sand mine workers in Batukuda Village, although it does not show significant results due to the duration of sand dust exposure.

B. Relationship between Age and the Incidence of Respiratory Symptoms in Sand Mine Workers

This study used the *Chi-square* test to analyze the relationship between age and symptoms of respiratory disorders in sand mine workers in Batukuda Village, Mancak District, getting a *p-value* of 0.615 (p>0.05) which indicates there is no significant relationship between age and symptoms of respiratory disorders. The *odds ratio* (OR) value of 0.697 (95% CI 0.170-2.861) showed no statistical significance. These results are in line with research by Apsari *et al.* that found no relationship between age and lung function disorders in sand and stone mine workers (*p-value* = 1.00).[14] Also supported by research by Fauziah *et al.* which states that there is no significant relationship between age and symptoms of respiratory disorders in coal workers (*p-value = 0*.255).[12] The insignificant relationship between age and respiratory symptoms in this study may be due to several factors. First, the distribution of respiratory symptoms in both age groups was relatively similar, namely 84.4% in the ≥30 years age group and 81.8% in the <30 years age group. Second, sand dust exposure was relatively uniform among all workers, regardless of age. Therefore, the high and uniform environmental exposure among all respondents likely reduced the influence of age differences on the onset of respiratory symptoms. This suggests that both younger and older workers are at high risk, so the effect of age is not apparent in the statistical analysis. Thirdly, the age range of respondents in this study was not too wide, and most were in the productive age group, so the difference in lung physiological capacity was not too obvious between age groups.

Based on theory, the respiratory system generally reaches its maximum level until the age of 20 years in women and 27 years in men.[18] After that, lung capacity begins to decline after the age of 30 years and 40 years for the decline in the function of respiration muscles.[14] In addition, less effective mucociliary clearance of large and small respiratory tracts due to decreased respiratory muscle strength and reduced body clearance of particles in the respiratory tract.[18] Although no significant association was found between age and symptoms of respiratory problems, it is still important to implement dust exposure prevention efforts in all age groups, considering the risk of respiratory symptoms is very high among sand mine workers.

C. The Relationship between BMI and the Incidence of Respiratory Symptoms in Sand Mine Workers

This study used the *Chi-square* test to analyze the relationship between BMI and symptoms of respiratory disorders in sand mine workers in Batukuda Village, Mancak District, getting a *p-value* of 0.684 (p>0.05) which indicates there is no significant relationship between age and symptoms of respiratory disorders. The *odds ratio* (OR) value of 1.339 (95% CI 0.326-5.497) showed no statistical significance. These results are in line with research by Apsari *et al.* that there is no relationship between BMI status and lung function disorders in sand and stone mine workers (*p-value* = 1.00).[14] Also supported by research by Fauziah *et al.* which states that there is no significant relationship between BMI status and symptoms of respiratory disorders in coal workers (*p-value = 0*.614).[12] Another study by Okthora *et al.* showed no relationship between IMT status and the incidence of ARI in coal mine workers (*p-value=1*.000).[19] The insignificant relationship between IMT and respiratory symptoms in this study can be caused by several factors. First, the distribution of BMI experiencing symptoms of respiratory disorders is relatively balanced (abnormal BMI of 88.2% and normal BMI of 84.8.3%). The relatively homogeneous working conditions in the sand mine resulted in the same level of sand dust exposure among all workers, regardless of the BMI status of the workers. This uniformity of exposure may make the effect of BMI status less visible in the analysis. Secondly, although some respondents had a normal BMI, this does not necessarily reflect good and optimal nutritional status. This may contribute to the occurrence of respiratory symptoms, thus minimizing the effect of differences between the normal and abnormal IMT groups in this study.

Based on theory, BMI status affects the onset of respiratory symptoms. In *overweight* and obese individuals, the accumulation of fat tissue around the rib cage and chest wall increases pressure on the respiratory muscles, reduces muscle function and chest wall flexibility, thereby decreasing lung capacity and airway *compliance*. Meanwhile, in *underweight* individuals, malnutrition negatively affects the structure and function of the respiratory tract, including a decrease in respiratory muscle strength, lung capacity, airway flexibility, as well as a decrease in the immune system and respiratory regulation, which overall increases the risk of respiratory disorders.[20,21] Although the relationship between BMI and symptoms of respiratory disorders was not significant in this study, monitoring nutritional status is still important to maintain the optimal physical condition of workers in dealing with workload and potential dust exposure in the mining environment.

D. Relationship between the Use of PPE and the Incidence of Respiratory Symptoms in Sand Mine Workers

This study used the *Chi-square* test to analyze the relationship between the use of PPE (masks) with symptoms of respiratory problems in sand mine workers in Batukuda Village, Mancak District, getting a *p-value* of 0.002 ($p < 0.05$) which indicates that there is a significant relationship between the use of PPE and symptoms of respiratory problems. The *odds ratio* (OR) value of 9.107 (95% CI 1.964-42.222) indicates that workers who do not use PPE (masks) have a 9.107 times greater chance of experiencing symptoms of respiratory problems than workers who use PPE. These results are in line with research by Fauziah *et al.* which states that there is a significant relationship between the use of PPE masks and symptoms of respiratory disorders in coal workers (*p-value=0*.006).[12] Another study by Okthora *et al.* also showed a relationship between the use of PPE masks and the incidence of ARI in coal mine workers (*p-value=0*.002).[19]

Based on theory, PPE in the form of masks aims to protect the respiratory organs from harmful chemicals, micro-organisms, and particles (dust, fog, vapor, smoke, gas) by holding / filtering them in fabric materials with certain pore sizes and then channeling clean air to the body.[22] The use of personal protective equipment (PPE) in the form of masks plays an important role in influencing the amount of dust particles that enter and accumulate in the lung organs. Masks function to prevent the accumulation of pollutant particles in the respiratory tract, so as to reduce the possibility of lung fauna disorders.[7] The results of this study are in line with this theory, where the use of masks is proven to be an effective effort in reducing the number of dust particles inhaled by workers. With reduced dust exposure to the respiratory tract, the risk of developing respiratory symptoms such as coughing, shortness of breath, and sputum production can be minimized. Therefore, the routine and consistent use of masks while working plays an important role in protecting the respiratory health of sand mine workers.

Direct observation in the field shows that most workers do not use masks. However, some workers still use cloth masks while working. The main reason given by workers is because they feel that the air ventilation in the mining area is good enough, and they feel uncomfortable and claustrophobic if they have to constantly wear masks. In addition, limited education regarding the importance of using PPE masks and the lack of regulation or supervision from the sand mine management also contribute to the low compliance of mask use.

Cloth masks are generally unable to filter fine particles efficiently due to their relatively large fiber diameter and wide pore size. The filtration efficiency of cloth masks can vary and can be improved in several ways, including by increasing the number of fabric layers, reducing fiber diameter, and improving fiber density and structure. Cloth masks have the ability to filter particles up to 1 μm.[23] The effectiveness of mask protection is strongly influenced by the frequency of use and the type of mask used. N95 masks, for example, have the ability to filter

particles with a size of 0.3 μm up to 95%, thus providing more optimal protection than cloth masks or ordinary medical masks.[24] Although the PPE masks used by most workers are cloth masks that are still not up to standard, they are still better than not wearing a mask at all. Based on labor regulations in article 2, employers are obliged to provide PPE in accordance with standards (SNI or other applicable standards) free of charge to workers.[25] On the other hand, workers are also obliged to use PPE when entering and being in the work area according to the potential hazards and risks that exist.

E. The Relationship between Smoking Habits and the Incidence of Respiratory Symptoms in Sand Mine Workers

This study used the *Chi-square* test to analyze the relationship between smoking habits and symptoms of respiratory problems in sand mine workers in Batukuda Village, Mancak District, getting a *p-value* of 0.002 ($p < 0.05$) which indicates that there is a significant relationship between smoking habits and symptoms of respiratory problems. The *odds ratio* (OR) value of 14.0 (95% CI 1.938-101.134) shows that workers with smoking habits have a 14 times greater chance of experiencing symptoms of respiratory problems than workers who do not have a smoking habit. These results are in line with research by Fauziah *et al.* which states that there is a significant relationship between smoking habits and symptoms of respiratory disorders in coal workers (*p-value=0*.005).[12] Another study by Okthora *et al.* also showed a relationship between smoking habits and the incidence of ARI in coal mine workers (*p-value=0*.004).[19]

In theory, workers who smoke have a higher risk of developing symptoms of respiratory or lung disorders. Smoking can cause changes in the structure and function of the respiratory tract and lung tissue. It triggers enlargement of mucosal cells (hypertrophy) and an increase in the number of mucus glands (hyperplasia) in the large airways. Furthermore, smoking can cause mild inflammation or narrowing of the small airways due to excessive build-up of inflammatory cells and mucus. These conditions lead to poor airflow, irritation of the respiratory tract, and a decrease in the capacity of the lungs to maintain optimal gas exchange.[12,18] The results of this study are in line with the theory, where a significant relationship was found between smoking and the onset of symptoms of respiratory disorders in sand mine workers. Therefore, the high prevalence of smoking among workers (92.54%) reinforces the notion that smoking is a major risk factor in triggering respiratory symptoms in this study.

Direct observation in the field shows that smoking among sand mine workers is very high. Many workers smoke dozens to dozens of cigarettes a day (10-80 cigarettes/day), both during working hours and during breaks. Smoking in a mining work environment, which already has a high risk of dust exposure, further increases the exposure load on the airway and

increases the potential for respiratory symptoms. In addition, observations and interviews show that most workers have started smoking since school age. Early smoking leads to long-term exposure to harmful substances from cigarettes, increasing the cumulative risk of respiratory damage. This long-term exposure, coupled with exposure to dust in the work environment, increases the potential for respiratory symptoms in sand mine workers.

F. The Relationship of Working Period to the Incidence of Respiratory Symptoms in Sand Mine Workers

This study used the *Chi-square* test to analyze the relationship between working period and symptoms of respiratory problems in sand mine workers in Batukuda Village, Mancak District, getting a *p-value* of 0.661 (p>0.05) which indicates that there is no significant relationship between working period and symptoms of respiratory problems. The *odds ratio* (OR) value of 1.451 (95% CI 0.273-7.710) showed no statistical significance. These results are in line with research by Fauziah *et al.* which states that there is no significant relationship between tenure and symptoms of respiratory disorders in coal workers (*p-value=0*.645).[12] Also supported by research by Apsari *et al.* that there is no relationship between tenure and lung function disorders in sand and stone mine workers (*p-value* = 0.691).[14]

The insignificant relationship between length of service and respiratory symptoms in this study may be due to several factors. First, the distribution of length of service of the respondents showed that most of the workers had a relatively short tenure (<5 years, up to 71.64%), so the cumulative exposure duration was not long enough to show a significant difference in the onset of respiratory symptoms. Secondly, high and evenly distributed daily exposure to dust, regardless of length of service, increases the risk of developing respiratory symptoms not only in workers with a long tenure, but also in workers with a short tenure. This makes the difference in risk between tenure groups invisible in the statistical analysis.

Based on theory, the longer the working period of workers, the more exposure to dust that is inhaled over the years, causing a decrease in lung function in workers.[26] Although no significant relationship was found between working period and symptoms of respiratory disorders, efforts to prevent dust exposure need to be applied uniformly to all workers, both workers with a working period of ≥5 years and <5 years, considering that the rate of respiratory symptoms is very high in all groups of work duration.

CONCLUSION

Most of the sand mine workers in Batukuda Village, Mancak Subdistrict have a duration of exposure to sand dust ≤ 8 hours / day (59.7%) and most of the sand mine workers in Batukuda Village, Mancak Subdistrict experience symptoms of respiratory problems (86.6%). There is no significant

relationship between the duration of exposure to sand dust and symptoms of respiratory problems in sand mine workers in Batukuda Village, Mancak District (*p-value=0*.785). Significant results were shown in the relationship between smoking habits (*p-value=0*.002) and the use of PPE masks (*p-value=0*.002).

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