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Ammonia Exposure Based on the Length of Work to Lung Function Abnormalities Among Traditional Scavengers

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Abstract

Lung function abnormalities can be caused by smoking habits or air pollution. Sanitary landfills can produce ammonia, which can cause lung function abnormalities. This study aimed to determine a relationship between ammonia exposure based on the length of work and lung function abnormalities among traditional scavengers at the Sumur Batu Landfill, Bekasi City, West Java Province, Indonesia. This analytical observational study applied quantitative methods and cross-sectional design. A total of 85 scavengers were selected using purposive sampling from March to May 2023. Data was obtained using a respondent characteristics questionnaire, spirometry, and spectrophotometer and analyzed using the Cox Regression Model. Most respondents (54.12%) had lung function abnormalities, and 79.17% had worked ≥8.5 years. The adjPR of ammonia exposure based on the length of work to lung function abnormalities was 3.413 (95% CI 1.51—7.71). There were confounding variables between ammonia exposure based on the length of work and lung function abnormalities: smoking status and lung disease record. In conclusion, ammonia exposure based on the length of work strongly correlates with lung function abnormalities in scavengers after adjusting for the lung disease record and smoking behavior.

Keywords: ammonia, length of work, lung function abnormalities, scavengers

Introduction

Lung function abnormalities are a combination of diseases and disorders that can affect lung function. This can be caused by smoking habits, exposure to radon, asbestos, air pollution, exposure to chemicals and dust in the workplace, as well as bacteria, viruses, and fungi.[1] Some mild symptoms of lung disorders often overlooked are persistent coughing, wheezing, and difficulty breathing.[2] Lung function abnormalities have several risk factors: smoking habits, including passive smoke, allergens, and occupational risks, including air pollution. Air pollution is a high-risk factor for respiratory diseases, including lung disorders such as asthma and chronic obstructive pulmonary disease (COPD). Air pollution can increase the COPD risk by 36.6% and asthma by 27.95%.[3]

Several lung disorders, such as COPD, asthma, and pulmonary fibrosis, are quite common cases in the world. In 2019, 3.23 million people in the world died from COPD.[4] Pulmonary fibrosis is estimated to have a prevalence of 13 to 20 per 100,000 people worldwide. In 2019, 262 million people worldwide suffered from asthma, which caused the deaths of 455,000 people.[5] While, in Indonesia, according to the 2013 Indonesian Basic Health Research, 9.2 million people (3.7%) experienced COPD.[6] In 2018, the prevalence of asthma reached around 1.2 million people or around 2.4%.[7] The COPD and asthma are also included in the 10 diseases with the most cases per 100,000 population.[3]

Based on the National Waste Management Information System data, the highest waste composition in Indonesia is food waste (41.55%).[8] Food waste belongs to organic waste, which is easily decomposed. This process will produce gases that can pollute the air. Some of them are irritants, especially ammonia (NH_3). Landfill gas contains between 1,000,000 and 10,000,000 ppb ammonia, or 0.1% to 1% ammonia by volume.[9] Low ammonia levels in ambient air (50 ppm) can lead to eye and respiratory tract irritation, throat inflammation obstructing the airway, cough, and pulmonary edema.[10]

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The Sumur Batu Landfill is located in Bekasi City, West Java Province, Indonesia. The landfill still implements an open dumping method and has been piled up for dozens of years without management. The landfill has also exceeded capacity (overloaded), affecting the roads at the landfill being filled with rubbish and leachate.[7] Waste accumulation at the landfill can be the source of air pollution. This can occur due to various dangerous gases, including ammonia, which comes from the decomposition of accumulated organic waste.[11]

Ammonia, an air pollutant, can affect public health. Scavengers at the Sumur Batu Landfill have a rest area located on site. This situation allows them to breathe air pollutants continuously while working or resting. To date, no previous study has examined ammonia exposure based on the length of work and its impact on lung function abnormalities in scavengers at this location. Therefore, this study aimed to determine a relationship between ammonia exposure based on the length of work and lung function abnormalities among traditional scavengers at the Sumur Batu Landfill, Bekasi City, West Java Province, Indonesia.

Method

A cross-sectional study was conducted on traditional scavengers as they are informal workers with less information on the risks of occupational diseases due to suboptimal use of personal protective equipment (PPE). This study took place at the Sumur Batu Landfill site in March-May 2023. The population of this study was all the scavengers working at the location. The samples were determined using a purposive sampling technique. This technique was employed because the data was population-based, and in this study, the total population was unknown for certain. Scavengers working at the location and agreeing to participate were included in this study. However, those refusing to be interviewed, using spirometry, and providing incomplete data were excluded. The sample size was calculated using the Lemeshow two-proportion formula, based on an odds ratio (OR) of 2.48 from Amerta and Wirawan[12] and a P2 of 0.4 from Dwicahyo.[13] The number of scavengers who participated as samples in this study was 85 people.

The dependent variable examined in this study was lung function abnormalities in the Sumur Batu Landfill scavengers, while the independent variables were ammonia exposure based on the length of work. The length of work variable was included as an independent variable because this variable could influence the exposure to ammonia among the landfill scavengers. Confounding variables included age, sex, education level, body mass index (BMI), lung disease record, smoking status, and habit of using masks.

The primary data used were ammonia levels in the air, temperature, humidity, and wind speed at the Sumur Batu Landfill as measured using a spectrophotometer; the lung function was measured using spirometry; and characteristics of respondents (the length of work, age, sex, education level, BMI, lung disease record, smoking status, and habit of using masks) and data related to respiratory symptoms were measured using a questionnaire. STATA statistical software (free version) was employed to analyze the frequency and proportion distribution of each variable. This study used $\alpha = 0.05$, power of 80%, prevalence ratio (PR), and confidence intervals (CI) of 95%. Data were analyzed using the Cox Regression Model.

Interviews were held in one of the rest areas at the location. Initially, the scavengers' consent was asked if they were willing to participate in the interview and the spirometry test. After they gave their consent, they were directed to go to the assigned interview place. They were asked to rest while being interviewed about their characteristics (the length of work, age, sex, education level, BMI, lung disease record, smoking status, and habit of using masks). After the interview, the scavengers were given an explanation and instructions for carrying out the spirometry test maneuver three times. The average value of the measurement was collected.

Results

Ammonia data was collected on May 10, 2023, from 11:30 a.m. to 4:00 p.m. (GMT+7/Western Indonesian Time). Based on the results in Table 1, the highest level of ammonia (NH_3) at the Sumur Batu Landfill is at 0.960 ppm, located in the area behind the landfill close to residential areas. The four measurement points for ammonia levels were still below the quality standard, according to the Decree of the Indonesian Minister of Environment and Forestry (KEP-50/MENLH/11/1996) concerning Odor Level Standards, at 2 ppm.[14] In Table 1, the temperature measures at four points are 34.1°C, 34.2°C, 36.6°C, and 34°C, respectively. These results showed a quite consistent temperature from the four measurement points. The highest temperature was 34°C, and only at the Sumur Batu Landfill Ticket Post reached 36.6°C. By measuring air humidity, the highest figure was obtained behind the landfill close to residential areas at 61.3%, and the lowest was at the Sumur Batu Landfill Ticket Post area (51.4%). For the wind speed, the highest figure was at the Sumur Batu Landfill Ticket Post, reaching 1.17 m/s, and the lowest was found behind the landfill close to residential areas at 0.24 m/s.

Table 1. Results of Measurement of Ammonia Concentrations at Sumur Batu Landfill

Variable	Point 1	Point 2	Point 3	Point 4
Sampling location	Behind the landfill (close to residential areas)	Semi-permanent settlement	Sumur Batu Landfill Ticket Post Area	The landfill's main area where new waste comes in
Ammonia concentration (ppm)	0.960	0.818	0.272	0.215
Temperature (°C)	34.1	34.2	36.6	34.0
Humidity (%)	60.8	58.1	51.4	61.3
Wind speed (m/s)	0.17-0.24	0.76-1.11	0.57-1.17	0.43-1.06

For each spirometry measurement result, forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC), lower and upper limits, interquartile range, outliers, and mean or median are calculated and presented in a box diagram in Figure 1. The box shows the interquartile range (IQR, 25-75th percentile), and a horizontal line inside the box represents the median; circles indicate outlier values for FVC. FEV_1 presents a normal distribution, while FVC presents an abnormal distribution. In contrast, the data on the length of work is not normally distributed, as seen in Figure 2.

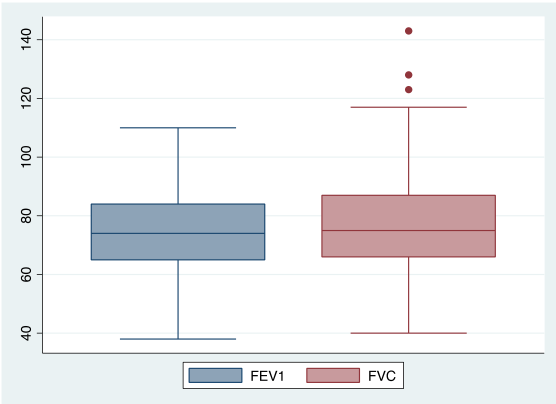

Figure 1. Boxplot of FEV1 and FVC Spirometry Results

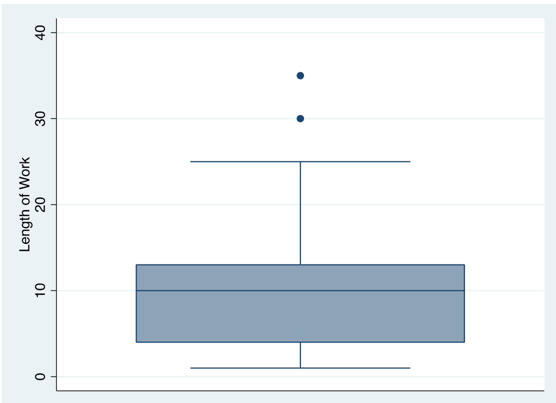

Figure 2. Boxplot of Ammonia Exposure Based on the Length of Work

Table 2 shows that 54.12% of the 85 scavengers suffer from lung function abnormalities. The most common category of lung function abnormalities is restriction, with a total of 33 respondents (38.82%). This data shows that more than half of respondents at the Sumur Batu Landfill suffer from lung function abnormalities, possibly due to pollutants in the landfill, including ammonia. However, it does not rule out the possibility of some other influential factors. Respondents who are landfill scavengers are mostly aged under 40 years (52.94%), males (61.18%), have a low level of education or ≤junior high school education (92.94%), with a normal BMI (65.88%), have no record of lung disease (87.06%), and have non-smoking status (54.12%). In addition, they do not use masks or nose coverings while working (74.12%).

Table 2. Distribution of Variables

Variable	N	%
Lung Function Abnormalities		
Normal	39	45.88
Obstruction	8	9.41
Restriction	33	38.82
Combination	5	5.88
Ammonia Exposure Based on the Length of Work	37	43.53
Junior (<8.5 years)	48	46.47
Senior (≥8.5 years)		
Age		
Old (≥40.5 years)	40	47.06
Young (<40.5 years)	45	52.94
Sex		
Male	52	61.18
Female	33	38.82
Education Level		
Low education (≤junior high school)	79	92.94
Secondary education (senior high school)	6	7.06
Higher education (>senior high school)	0	0
Body Mass Index		
Very thin (<17)	4	4.71
Skinny (17-<18.5)	13	15.29
Normal (18.5-25.0)	56	65.88
Overweight (25-27)	4	4.71
Obesity (>27)	8	9.41
Lung Disease Record		
No	74	87.06
Yes	11	12.94
Smoking Status		
Non-smoker	46	54.12
Light smoker (≤199)	20	23.53
Medium smoker (200-599)	14	16.47
Heavy smoker (≥600)	5	5.88
Habit of Using Masks		
Yes	22	25.88
No	63	74.12
Total	**85**	**100**

Table 3 shows the distribution of lung function abnormalities based on length of work, age, sex, education level, BMI, smoking status, lung disease record, and habit of using masks. Scavengers working for ≥8.5 years have a high proportion of lung function abnormalities (79.17%). Most respondents suffering from lung function abnormalities are aged 40.5 years and older, males, overweight-obese, medium-heavy smokers, have a record of lung disease, and do not wear masks while working. These results showed a significant relationship between length of work, lung disease record, and medium-heavy smoking status with lung function abnormalities. Meanwhile, age, sex, education level, BMI, light smoking, and habit of using masks are not found to have a significant relationship with lung function abnormalities (Table 3).

The Cox Regression Model shows the risk value of ammonia exposure based on the length of work for lung function abnormalities (Table 4). Crude risk is the crude PR of length of work to lung function abnormalities without controlling for confounding factors, with a p-value of 0.001. Adjusted risk is a PR adjustment for ammonia exposure based on the length of work for lung function abnormalities after controlling for lung disease record and smoking status, with a p-value of 0.003. Both showed significant associations with strong risk. This study found that ammonia exposure based on the length of work was significantly related to impaired lung function with an adjPR of 3.413 (95%CI: 1.51-7.71) after being controlled for lung disease record and smoking status. Therefore, scavengers working for ≥8.5 years have a 3.4 times greater risk of experiencing lung function abnormalities compared to those working for <8.5 years.

Table 3. Distribution of Each Factor to Lung Function Abnormalities According to Groups of Exposure

Variable	Lung function abnormalities				Total		p-value
	Abnormal		Normal				
	N	%	N	%	N	%	
Ammonia Exposure Based on the Length of Work							
≥8.5 years	38	79.17	10	20.83	48	100	0.001
<8.5 years	8	21.62	29	78.38	37	100	
Age							
≥40.5 years	26	65	14	35	40	100	0.201
<40.5 years	20	44.44	25	55.56	45	100	
Sex							
Male	30	57.69	22	42.31	52	100	0.574
Female	16	4848	17	51.52	33	100	
Education Level							
Low	35	3.03	31	46.97	63	100	0.8
High	11	57.89	8	42.11	19	100	
Body Mass Index							
Overweight-Obesity	7	58.33	5	41.67	12	100	0.839
Thin	9	52.94	8	47.06	17	100	0.975
Normal	30	53.57	26	46.43	56	100	
Lung Disease Record							
Yes	11	100	0	0	11	100	0.030
No	35	47.30	39	52.70	74	100	
Smoking Status							
Medium-heavy	19	100	0	0	19	100	0.025
Light	4	20	16	80	20	100	0.091
Non-smoker	23	50	23	50	46	100	
Habit of Using Masks							
No	37	58.73	26	41.27	63	100	0.331
Yes	9	40.91	13	59.09	22	100	

Table 4. Comparison of the Association between Unadjusted and Adjusted Prevalence Ratio of Ammonia Exposure Based on the Length of Work for Lung Function Abnormalities

Variable	Unadjusted Risk (95% CI)	Adjusted Risk (95% CI)
Ammonia Exposure Based on the Length of Work	3.661 (1.71-7.85)	3.413 (1.51-7.71)

Discussion

The results of ammonia measurements at four points of location found that the ammonia levels at the Sumur Batu Landfill were below quality standards at <2 ppm. Several meteorological factors can influence ammonia concentrations. According to Ayathollah *et al.*,[14] these factors are temperature, humidity, and wind speed. Measurements of these four points were carried out during the day, from 11:30 a.m. to 04:00 p.m. (GMT+7/Western Indonesian Time). This causes the temperature at the Sumur Batu Landfill to be quite high, ranging from 34°C-36°C. If the air temperature is high, it can cause the air to become loose, resulting in low concentrations of pollutants in the air.[14–16]

Humidity and wind speed can also affect air pollutant concentrations. The measurement results showed that the point with the highest concentration had the highest humidity and the lowest wind speed. In humid air, pollutants will be trapped in water droplets, causing a decrease in the concentration of these pollutants. Besides, the wind speed can also affect pollutant concentrations. The weaker the wind speed, the greater the pollutant concentration. This is because weak air movement will cause small shocks. Hence, the concentration of polluting gases in the area will remain large because it will not be too affected by the shocks.[15–18]

This study found a strong relationship between length of work and lung function abnormalities (AdjPR=3.413) after controlling for lung disease record and smoking status. Length of work is a variable used to indirectly measure the accumulation of the exposure to ammonia in traditional scavengers. These findings suggested the possibility that long-term exposure to ammonia played an important role in causing lung function abnormalities, particularly in the traditional scavengers getting exposed to it each day. It is important to note that the participants resided in the landfill area.

These results are in line with a study conducted at Bantar Gebang Landfill, Bekasi City, Indonesia, which found a significant relationship between work experience and lung function, with a 3.5 greater risk level for scavengers with >10-year length of work.[19] Another study conducted in Puducherry, India, also showed a relationship between length of work and obstructive lung function. Of the total minimum sample of 264 waste management workers, 94 workers had worked for >5 years, and 54.3% (51 workers) showed obstructive lung results, with a two-times higher risk than workers who had worked for ≤5 years.[20]

Based on the results of these two previous studies, the length of work with symptoms of lung function abnormalities had a significant relationship and could be a risk factor for an individual to experience symptoms of lung disorders due to chemical hazards in the workplace. Ammonia found at the landfill is produced by bacteria decomposition of organic waste.[13] People exposed to air pollutants from waste for a long period could cause recurring respiratory tract disorders, leading to a decline in lung function.[18]

A study at the Jatibarang Landfill, Semarang City, Indonesia, stated that the non-carcinogenic risk would be negligible within 20 years. In a lifetime projection (exposure duration of 30 years), non-carcinogenic risks were considered unsafe for scavengers at the Jatibarang Landfill. The scavengers received an average intake of 0.032 mg/kg/day, with an average body weight of 55 kg.[20] Ambient air contaminated with ammonia can have a negative impact on the respiratory system. Ammonia is colorless but has a pungent odor and is very toxic, even at low levels. This substance can only be detected by human senses at a concentration of 0.003 ppm. Chronic impacts of exposure to ammonia with a concentration of higher than 35 ppm include lung, kidney, and brain function, growth and development disorders, and decreased blood quality.[21]

Exposure to ammonia gas or ammonium hydroxide can cause corrosive injuries to the conjunctiva of the eyes, lungs, digestive system, and skin due to the alkaline and hygroscopic properties of ammonia. Low ammonia levels (50 ppm) in the air can cause acute effects on the eyes and nose, as well as throat irritation, coughing, and bronchoconstriction. More severe clinical effects, including inflammation and narrowing of the throat, can obstruct the upper respiratory tract and cause pulmonary edema.[9] Chronic exposure to ammonia gas can irritate the respiratory tract, cause chronic cough, asthma, and pulmonary fibrosis, cause chronic irritation of the eye membranes, and cause dermatitis.[22]

Anhydrous ammonia, whether in gas or liquid form, reacts easily with body fluids, producing ammonium ions. This process is highly exothermic and can affect surrounding tissue. The resulting base causes necrosis in body tissue through protein denaturation and lipid saponification. In addition, this process also causes the extraction of water from body tissues, thereby triggering an inflammatory response.[22] The irritating impact of ammonia gas on the mucous membranes of the upper respiratory system and human eyes is usually detected at a concentration of 100 ppm with an exposure duration of 5-30 seconds.

Long-term or frequent exposure causes individuals to experience chronic sinusitis, so they are not sensitive to the smell of ammonia.[23] The longer a person works in a place contaminated with ammonia gas, the more exposure they receive, even though the daily concentration is low. This causes a decrease in respiratory function characterized by low FEV_1 and FVC values. This observed decrease is a symptom of obstructive pulmonary disease, which is often accompanied by wheezing, coughing, and phlegm production.[24]

Smoking has been confirmed as a major cause of lung function abnormalities.[25] Lung disease records such as tuberculosis can also exacerbate lung function decline.[26] In this study, both variables distorted the association between ammonia exposure based on the length of work and lung function, becoming overestimated. Consistently, previous studies also suggested that smoking behavior, as well as lung disease records, could lead to lung function decline.[13,27–29] Smoking has detrimental health effects on every aspect of lung structure and function, including impairing the lung's defenses against infection and causing ongoing lung injury, leading to lung disorders.[15,16,28,30] Lung diseases caused by smoking include COPD, emphysema, and chronic bronchitis. If a person suffers from asthma, the tobacco smoke produced by cigarettes can trigger or worsen attacks.[31]

Another risk factor for symptoms of lung disorders is a record of lung disease. A person with a record of lung disease may experience a decrease in the muscles' ability in the respiratory system. This can disrupt the permeability of the respiratory tract and can end in a decrease in the function of the respiratory organs, leading to disorders in the respiratory tract, including the lungs.[32] A person with a record of respiratory disease such as asthma is more vulnerable to exposure to ammonia gas in landfills.[33] Several diseases which can affect the vital capacity of the lungs are asthma, pneumonia, chronic pulmonary emphysema, tuberculosis, and some other respiratory diseases.[13]

There are several limitations in this study. The non-response rate of respondents was 10.5% since the study was conducted during working hours. However, this problem was addressed and resolved by recruiting other scavengers to participate. This non-response rate had no impact on the results due to the similar characteristics of the respondents. Nevertheless, information bias can be caused by non-differential classification errors, which may underestimate the findings obtained. This could happen because the variable measurement of the habit of using masks was based on the answers given by respondents and observations during interviews.

The correct way of using masks and the habit of using masks outside the measurement period were not asked. The ammonia measurement results might be below the threshold value as the measurement time was influenced by the rainy weather conditions the previous night and wind direction. Therefore, continuous ammonia measurement is required. Other air pollutants can cause decreased lung function but were not examined in this study. For these limitations, this study has good internal validity so that it can be generalized to the target population and traditional scavenger populations in other areas that have the same characteristics as this study.

Conclusion

There is a strong relationship between the length of work and lung function abnormalities in traditional scavengers after controlling for smoking status and lung disease record. Ammonia levels measured during data collection are below the threshold value due to the influence of weather conditions and wind direction. Scavengers at the Sumur Batu Landfill are at high risk of developing lung problems from the accumulation of waste in the landfill, which has lasted for years without proper management and produces air pollutants, such as ammonia, from decomposing organic waste. This air pollution can cause lung function abnormalities. The landfill scavengers should always wear masks while working, and the local government must monitor ammonia levels regularly.

Abbreviations

COPD: chronic obstructive pulmonary disease; BMI: body mass index; PR: prevalence ratio; CI: confidence interval; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity.

Ethics Approval and Consent to Participate

This study has complied with the code of ethics of Universitas Pembangunan Nasional "Veteran" Jakarta Health Research Ethics Commission Number 208/V/2023/KEPK, established on May 15, 2023.

Competing Interest

The author declares that no significant competing financial, professional, or personal interests might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

Data are not available due to the ethical restrictions of the research. Participants of this study did not agree that their data should be shared publicly.

Authors' Contribution

MSJ, FN, NKF, and AB conceptualized and designed the study. MSJ and FN searched the literature. MSJ, FN, and NKF prepared the questionnaire and collected the data. MSJ, FN, and NKF analyzed the data and prepared the manuscript. FN, NKF, and AB reviewed the manuscript. All authors read and approved the final manuscript.

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