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# Factors Related to Vital Lung Capacity of Workers at Fertilizer X Factory in Indonesia

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**Abstract**

Fertilizer industry workers are at risk of developing lung function disorders, especially from exposure to ammonia and urea dust. This study aimed to determine the vital lung capacity of workers at Fertilizer Factory X, Indonesia, and the influencing factors. This was a cross-sectional analytic observational study on 78 workers who work as an ammonia unit operators in the factory area who met the inclusion and exclusion criteria. Sampling was done consecutively from December 2019 to January 2020. Data were collected using a questionnaire while the pulmonary function measurement was performed using spirometry. Research variables included age, length of work, smoking habits, nutritional status, use of Personal Protective Equipment (PPE), and assessment of vital lung capacity. Data were analyzed using the Chi-Square test and the results showed that the vital lung capacity of most respondents was classified as normal (55.1%). There were significant relationships between vital capacity and risk factors for age (p=0.001), length of work (p=0.009), use of PPE (p=0.012), and smoking habits (p=0.020). It is concluded that there is a relationship between vital capacity and age, length of work, use of PPE, and smoking habits in workers of Fertilizer Factory X, Indonesia.

**Keywords**: Ammonia exposure, personal protective equipment (PPE), vital capacity

# Analisis Faktor-faktor yang Berhubungan dengan Kapasitas Vital Paru pada Pekerja Pabrik Pupuk X di Indonesia

**Abstrak**

Pekerja industri pupuk memiliki resiko terkena gangguan fungsi paru khususnya akibat paparan ammonia dan debu urea. Penelitian ini bertujuan mengetahui kapasitas vital paru pada pekerja di Pabrik Pupuk X dan faktor-faktor yang memengaruhinya. Jenis penelitian ini adalah observasional analitik dengan pendekatan potong lintang. Penelitian dilakukan pada 78 orang pekerja di area pabrik sebagai operator unit ammonia yang telah memenuhi kriteria inklusi dan eksklusi. Sampel penelitian ini diambil dengan cara *consecutive sampling*, data diambil bulan Desember 2019 sampai dengan Januari 2020. Pengumpulan data menggunakan kuesioner dan pengukuran fungsi paru dengan spirometri. Variabel penelitian meliputi usia, lama kerja, kebiasaan merokok, status gizi, penggunaan Alat Pelindung Diri (APD) serta parameter kapasitas vital paru. Teknik analisis data dengan menggunakan uji *chi-square*. Hasil penelitian menunjukkan bahwa kapasitas vital paru sebagian besar responden termasuk dalam klasifikasi normal (55,1%), terdapat hubungan bermakna antara kapasitas vital paru dengan faktor risiko usia (p=0,001), lama kerja (p=0,009), pemakaian APD (p=0,012), dan kebiasaan merokok (p=0,020). Simpulan, terdapat hubungan kapasitas vital paru dengan usia, lama kerja, pemakaian APD dan kebiasaan merokok pada pekerja pabrik Pupuk X di Indonesia.

**Kata kunci**: Alat Pelindung Diri (APD), kapasitas vital paru, paparan ammonia

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## Introduction

Lung function is influenced by age, nutritional status, gender, and ethnicity. Age is a crucial variable in the occurrence of pulmonary dysfunction because it affects lung elasticity.[1] The vital capacity of the lungs is also influenced by smoking habits, length of exposure, use of Personal Protective Equipment (PPE), and the work environment. A polluted work environment such as the fertilizer industry can affect lung function.[2]

Fertilizer industry produces several pollutants such as ammonia gas, urea dust, smoke, particulates from complex plant fertilizers, sulfur oxides, and acid fog of plant origin containing sulfuric acid, nitrogen oxides from nitric acid, and fluorides from phosphoric acid. Several studies have declared a significant relationship between the length of work and the occurrence of lung function disorders. Most respondents who have worked for fifteen years or more experience lung function disorders (70%) and have four times the possibility of suffering from lung function disorders than respondents who has been working for less than fifteen years in the industry. Respondents aged fifty years or more also experience impaired lung function by 60%.[3]

The vital capacity of the lung reflects the change in the maximum volume of the lung, which is useful for confirming the functional capacity of the lung. Vital capacity of the lungs is the maximum amount of air which can be expelled from the lungs after maximum inhalation. The vital capacity of the lungs can be measured using a pulmonary function test kit with spirometry as the most basic one.[4,5]

In Indonesia, efforts to maintain occupational health are often not optimum, including in the industrial sector. Fertilizer factory "X" produces various types of products in the form of liquid ammonia, urea, and NPK8 fertilizers. Workers in the ammonia unit in factory X are susceptible to chemical factors such as urea and ammonia dust and an exposure control program is required to maintain their health. Therefore, it is necessary to conduct a study by measuring the vital capacity of the lung in fertilizer factory workers X and the risk factors of changes in the vital capacity of the lungs.

## Methods

This was a cross-sectional analytic observational study conducted at fertilizer factory "X" in Palembang, Indonesia, from December 2019 until January 2020. This study has received ethical clearance from the research ethics committee of *Unit Bioetika dan Humaniora Kedokteran Islam* (UBHKI), Faculty of Medicine Universitas Muhammadiyah Palembang No. 107/EC/UBHKI/FK-UMP/X/2019. Sampling was performed consecutively based on the following inclusion criteria: factory worker, aged 20 years or above, and willing to be included in the study. Participants were excluded if they were suffering from cardiovascular system disease, spinal disorders, chest wall disorders, and lung diseases, such as pulmonary tuberculosis, COPD, and pleural effusions. Seventy-eight (78) workers who work in the factory area as ammonia unit operators participated in this study.

Study's variables consisted of vital capacity of the lungs, age, length of work, nutritional status, smoking habits, and PPE use. Data collected in this study were primary data that were collected using a questionnaire to determine age, length of work, and direct measurements to assess the vital capacity using a pulmonary function measuring instrument, namely a spirometer. The vital capacity of the lungs was deemed normal if the value was >4,500 mL. Data were analyzed by univariate analysis to determine the explanation of dependent and independent variables and bivariate analysis to determine the relationship between each variable using the Chi-Square test. Fischer test was used when the variables did not meet the requirement for Chi-Square.

## Results

Seventy-eight workers were found to meet the criteria and participated in the study. The characteristics of the respondents are described in Table 1. From the Table 1, it can be concluded that the characteristic factors of respondents based on age, length of work, use of PPE, and smoking habits were normally distributed ($p=0.05$). Most of the respondents had the characteristics of in early adulthood (78.2%), 5–10 years of work (59%), always wearing PPE (62.8%), light smokers (42.3%), and with normal nutritional status (47.4%).

The distribution of vital capacity among the respondents demonstrated that there were more respondents with normal vital capacity than those with abnormal vital capacity (55.1% vs. 44.9%, $p>0.05$). When the relationship between respondents' characteristics and vital capacity of

**Table 1 Respondent Characteristics**

| Respondent Characteristics | Frequency (n=78) | Percentage (%) | p |
|---|---|---|---|
| Age | | | |
| Early adulthood (26–35 years) | 61 | 78.2 | |
| Late adulthood (36–45 years)* | 15 | 19.2 | 0.765 |
| Elderly (≥46 years)* | 2 | 2.6 | |
| Length of work | | | |
| 5–10 years | 46 | 59.0 | 0.166 |
| >10 years | 32 | 41.0 | |
| Use of Personal Protective Equipment (PPE) | | | |
| Always | 49 | 62.8 | 0.233 |
| Sometimes | 29 | 37.2 | |
| Smoking habbit | | | |
| Non-smoker* | 16 | 20.5 | 0.182 |
| Light smoker* | 33 | 42.3 | |
| Heavy smoker | 29 | 37.2 | |
| Nutritional status | | | |
| Underweigt* | 6 | 7.7 | |
| Normal* | 37 | 47.4 | 0.038 |
| Overweight* | 17 | 21.8 | |
| Obesity* | 18 | 23.1 | |

*: In the bivariate analysis. samples were combined

the lungs was analyzed, a significant relationship was identified between vital lung capacity and age, length of work, use of PPE, and smoking habits ($p<0.05$).

## Discussion

This study demonstrated that there are four factors that are linked to lung function: age, length of work, use of PPE, and smoking habits. This study's results are in line with the theory that smoking can cause alteration to lung function due to changes in the anatomy and physiology of lung tissue caused by exposure to cigarette smoke. The decline in lung function will get worse if a person has smoking habits and

**Table 3 Relationship between Characteristics of Respondents and Vital Capacity of the Lungs**

| Risk Factor | Vital Capacity | | p |
|---|---|---|---|
| | Normal (n=43) | Abnormal (n=35) | |
| Age | | | |
| Early adulthood | 34 | 27 | 0.001 |
| Late adulthood + elderly | 9 | 8 | |
| Length of work | | | |
| 5–10 years | 26 | 20 | 0.009 |
| >10 years | 17 | 15 | |
| Use of Personal Protective Equipment | | | |
| Always | 30 | 19 | 0.012 |
| Sometimes | 13 | 16 | |
| Smoking habbit | | | |
| Non+Light smokers | 31 | 18 | 0.020 |
| Heavy smoker | 12 | 17 | |
| Nutritional Status | | | |
| Underweight+Normal | 23 | 20 | 0.515 |
| Overweight+Obesitas | 20 | 15 | |

*:fischer test

lack of exercise or physical activities.[4]

The habit of using personal protective equipment (PPE) is the second factor that is shown to be affecting lung function disorders with an OR of 9.48. Workers who always wear mask (PPE) properly at the worksite can minimize the amount of exposure to ammonia and urea dust inhaled. A dusty environment is also one of the factors that can worsen a person's lung function.[6]

Age factor is the third factor which also shows its effect on lung function in workers, with an OR of 8.89. This result is in agreement with the theory stating that physiologically, with increasing age, the ability of human organs to function will naturally decrease, which may lead to function disorders, including pulmonary function disorders. Respiratory function and blood circulation will improve in childhood and reach a maximum value at the age of 19–21 years. After 19–21 years, the respiratory function will continue to decline with age. Respiratory muscle strength will decrease by 20% after the age of 40 years. The decrease in vital lung capacity occurs after the age of 30 and even declines more rapidly after the age of 40 years.[7,8]

These results are consistent with research on the relationship between age, duration of dust exposure, and smoking habits with impaired lung function of fertilization officers. Moreover, in Kalijambi Sragen, Indonesia, a relationship has also been found between age and an impaired lung function.[8,9] The above result is also consistent with the study that stated a relationship between age and lung function capacity (p-value=0.006).

The prevalence of respiratory disorders increases in workers who have prolonged exposure to the substance in the contaminated environment. Duration of employment determines the length of exposure a person has to the risk factors. The longer a worker spends working in his work area, the more he is exposed to the hazards posed by the work environment; therefore, the possibility of pulmonary function disorders will also be higher.[10]

The work environment of the fertilizer industry, which produces several pollutants such as ammonia gas, urea dust, and smokes, can also affect lung function, resulting in a decrease in the value of vital capacity of the lungs.[3] Urea dust contains chemicals that can disrupt workers' vital capacity of the lungs. Dust particles with a size of 1–3 microns are called respirable dusts, which will be trapped and accumulated from the terminal bronchioles to the alveoli. The longer a person is exposed to a dust level that exceeds the threshold value in the work environment, the faster that person will experience a decrease in the vital capacity of the lungs.[11,12]

Besides dust, there is also ammonia gas which is the main ingredient of fertilizer. This gas is colorless but has a strong smell and corrosive.[12] Chronic exposure to a low level of ammonia in the air (<25 ppm) gives a low effect on lung function and causes odor sensitivity to workers in some factories. Studies on farmers affected by ammonia and other pollutants in the farm indicated a relationship between exposure to pollutants, including ammonia, and increased respiratory symptoms such as bronchial reactivity, inflammation, coughing, wheezing, or shortness of breath, and/or decreased lung function parameters. Exposure to an ammonia level that exceeds 50 ppm results in direct irritation of the nose and throat. Tolerance for ammonia develops with repeated exposure.[10,11]

The nutritional status of the respondents is a factor that is not related to lung function disorders. This insignificant result is deemed to be caused by workers with overweight and obesity status are still using their PPE properly in the work to minimize the exposure effect to dust. This result is in contrast with the theory that overweight and obesity status can affect lung function. [13,14]

Lung capacity is the maximum volume of oxygen that can enter the body or lung of a person. The oxygen volume that can enter the lung is determined by the respiratory system's ability to expand and collapse. The better the respiratory system works, the more oxygen volume is obtained. The main factors affecting the vital capacity include the anatomical shape of the body, the position during the measurement of vital capacity, the strength of the respiratory muscles, and the development of the lungs and chest frame.[15]

Air in the environment that is contaminated with ammonia and urea dust causes pollutant particles to be inhaled, and some will enter the lungs and settle in the alveoli, damaging the alveolar walls and causing a decrease in lung function.[16] The crucial effects of acute exposure to ammonia include oronasal and bronchial irritation, airway obstruction, and pulmonary edema. This gas is intensely reactive with moist mucosal surfaces of the eyes, nose, lungs, throat, and skin, and it produces ammonium hydroxide causing liquefaction necrosis.[17]

The dust particles that enter the lungs will form a focus and collect at the beginning of the pulmonary lymph channels. The dust will play a crucial role in the order of collagen connective tissue, and the household deposition of the connective tissue is phagocytosed by macrophages. Dust that is toxic to macrophages will stimulate the formation of new macrophages, leading to continuous formation and destruction of macrophages. This fibrosis occurs in the lung parenchyma, which is on the alveoli walls and the interstitial connective tissue. Pulmonary fibrosis will cause a decrease in the elasticity of the lung tissue (i.e., shifting of lung tissue) and it will disrupt lung expansion. When the hardening of the alveoli reaches 10%, there will be a decrease in lung elasticity, which causes the vital capacity to decrease.[16]

This study has a limitation that it does not measure the level of pollutants in the work environment. As a result, it cannot assess the level of air pollution in the work environment. Moreover, the researchers only conducted a one-time examination of lung function, without before-and-after work examination. Also, the analysis of vital capacity of the lungs in this study was performed without measuring Forced Vital Capacity (FVC) and ratio FEV1/FVC. Therefore, the types of lung disorders, whether it is obstructive or restrictive, cannot be determined.

It is concluded that there is a significant relationship between age, length of work, use of PPE, smoking habits, and the vital capacity of workers' lungs in fertilizer factory "X" Palembang, Indonesia.

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