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ORIGINAL ARTICLE

Lead (Pb) Exposure on Hemoglobin Levels and Decreasing Lung Function of Fuel Station Workers Banjarmasin

Muhamad Taufiqurrahman[1], Isa Ansori[2], Meitria Syahadatina Noor[3], Haryati Haryati[4], Ali Assagaf[5], Mohamad Isa[6]

[1,2,4,5,6]Department of Pulmonology and Respiratory Medicine, Faculty of Medicine Lambung Mangkurat University/Ulin General Hospital, Indonesia
[3]Departement of Public Health Master Program, Faculty of Medicine, Lambung Mangkurat University, Indonesia
Banjarmasin, South Kalimantan 70234 Indonesia

ABSTRACT

Introduction: Exposure to airborne pollutants such as lead (Pb) can cause health problems. Fuel stations are one of the places with a high risk of Pb exposure sourced from fuel or motor vehicle exhaust emissions. This research aims to know the effect of Pb exposure on hemoglobin levels and lung function in fuel station workers. **Methods:** This study was observational, analytical, and cross-sectional on 40 fuel station workers in South Banjarmasin District. Urinary Pb measurement was carried out by spectrophotometry, then the relationship to peripheral blood hemoglobin (Hb) levels and lung function was analyzed based on FEV1 (%), FVC (%), and FEV1/FVC ratio with a simple linear regression test. The data met the classical assumptions of normality, heteroscedasticity, and with no autocorrelation. If abnormal distribution was found, data transformation was carried out. **Results:** Study obtained urinary Pb levels below the normal threshold of 0.0356±0.0074 ppm. Respectively, urinary Pb levels did not have a significant effect on Hb levels (mean±SD:14.39±1.41, adjusted R2:6.2%, p=0.067), FEV1 (94.15±6.93, 5.8%, p=0.074) and FVC (89.68±6.24, 0.5%, p=0.380). However, urinary Pb significantly correlated with decreasing the FEV1/FVC ratio (90.87±3.36, 10%, p=0.026) with the equation y=96.550-159.454x even without any obstruction value. **Conclusion:** This study showed that urinary Pb levels were normal. An increase in urinary Pb levels has a significant effect on decreasing the FEV1/FVC ratio. Prevention to reduce the health impacts of Pb needs to be taken. More research on at-risk populations with longer years of service needs to be done.

Keywords: hemoglobin, lead, lung function

Corresponding Author:
Muhamad Taufiqurrahman
Email: myfiqrana@gmail
Telephone: +6285386941264

INTRODUCTION

The International Labor Organization (ILO) 2016 estimates that 2 million of the 2.5 billion workers die due to accidents or one-third due to occupational lung disease every year (International Labor Organisation, 2021). The most significant cause of death was Chronic Obstructive Pulmonary Disease (COPD), with 450,000 deaths (International Labor Organization, 2021). Exposure to airborne pollutants such as lead (Pb) can cause health problems such as anemia and respiratory tract disorders. Fuel stations are one of the places with a high risk of Pb exposure sourced from fuel or motor vehicle exhaust emissions. Fuel station workers with continuous exposure to Pb can result in increased Pb levels in the blood, urine, saliva, and hair of fuel station personnel (Bawaskar and Bawaskar, 2020; Qafisheh *et al*., 2021).

Fuel station workers with Pb exposure are known to have a high risk of experiencing pulmonary disorders. Previous studies concluded that fuel station staff are at risk of having pulmonary disorders with a restrictive pattern (Awadallah *et al*., 2020). A recent study found that each 10-fold increase in urinary Pb was associated with changes in FEV1 and per cent predicted FEV1 by 159 and 3.63% (95% CI: 6.48-8.78%), respectively (Wei *et al*., 2020).

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Fuel exposure at fuel station can cause a decrease in lung function characterized by a significant decrease in forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and FEV1/FVC ratio (Rahhal, 2022). Other studies have also found a significant relationship between vital capacity (VC) and the length of work time of fuel station workers (Ramadhany, Yunus and Susanto, 2020). Banjarmasin is one of Indonesia's industrial cities and the capital of South Kalimantan province. South Banjarmasin is a central industrial area with a high traffic density, and has the most significant number of fuel stations with the highest fuel usage distribution (Dinas Komunikasi dan Informatika Kalimantan Selatan, 2022). Industrial areas, a high density of distribution activity traffic, and a significant number of fuel stations are the reasons why South Banjarmasin is more crucial and is considered to be able to represent the initial population.

Pb is one of the gas emissions from fuel stations, but until now there has been no routine measurement. Therefore, it is important to recognize the need to measure Pb emissions by knowing the effects of lead emissions. This study aimed to analyze the effect of Pb exposure on hemoglobin levels and lung function in fuel station workers.

METHODS

This study was observational analytic with a cross-sectional design from February to August 2023. This study was conducted by total sampling with subjects of field officers at five fuel stations in South Banjarmasin District. The current analysis was of 40 individuals who finished the health assessment survey, which included urinary Pb measurement, hemoglobin measures, and lung function testing by spirometry. Eight participants were excluded because they were unwilling to complete the procedure. During the health interview, data on age, duration of employment, smoking status, past medical history, and treatment history were gathered. Participants were measured for height and weight while wearing loose-fitting clothes and removing their shoes. The age was stated at the health interview. There were two groups based on smoking status: smokers and never-smokers. Based on participants' self-reported cigarette usage, smoking status was determined. Never-smokers had smoked fewer than 100 cigarettes in their lifetime, whereas those who had smoked 100 or more were categorized as smokers. Personal protective equipment was defined by using FFP2 mask during work.

Pb exposure was assessed through urinary Pb levels. Urinary Pb levels were determined in ppm units, measured from urine samples taken from participants, and then analyzed using the spectrophotometry method at the biochemistry laboratory of Lambung Mangkurat University, Banjarmasin. Lung function assessment was determined by measurement of FEV1%, FVC%, and FEV1/FVC ratio through a spirometry test by a professional doctor with Lungtest Mobile MES® device. Hb levels were measured through peripheral blood by an ACCUchek® device, determined in mg/dL.

Categorical data are presented in the form of frequency and percentage. Numerical data are presented in the form of mean and standard deviation. Each variable was tested for normality using Shapiro-Wilk. The relationship between urinary Pb levels with hemoglobin and pulmonary function was analyzed by simple linear regression by SPSS 26.0. Data have qualified classical assumptions with normality, linearity, heteroscedasticity, and autocorrelation tests. If data distribution was unexpected, a transformation was done to make the linear regression equation. Significance was considered with a p-value < 0.005. This research has received an ethical certificate with the number 322/KEPK-FK ULM/EC/X/2023 from the Lambung Mangkurat University ethics committee.

RESULT

General Descriptions of the Population

The general characteristics of 40 subjects in this study are summarized in Table 1. The subjects were 40 males with an average age of 25.38±5.65 years. Body weight was 67.28±14.45 kg, and height was 165.65±4.85 cm. Subjects worked an average of 4±2.07 months with the majority working less than six months (77.5%). All the length of work was more than 8 hours/day. The majority of subjects, 92.5%, were smokers. There was one subject with a history of pneumonia and one subject who took paracetamol regularly, while the other 39 subjects had no respiratory-related diseases or medication consumption.

The average urinary lead level in South Banjarmasin Sub-district fuel station attendants was 0.0356±0.0074 ppm. The average hemoglobin level of fuel station workers was 14.39±1.41 mg/dl. Based on the results of the spirometry examination, the FEV1 value was 94.15 ± 6.93, FVC 89.68 ± 6.24, and FEV1 / FVC ratio 90.87 ± 3.36. These results can be seen in Table 2. Urinary Pb, hemoglobin, FEV1%, FVC%, and ratio FEV1/FVC% are still in the normal range. In the Shapiro-Wilk test, a normal distribution was found in all variables with p-value > 0.05 except for the FVC%. As fulfillment of the classical assumption test in the linear regression test, the linear equation in FVC% was tested by logarithmic transformation for FVC.

Analysis of Urinary Pb on Hemoglobin and Lung Function

Based on simple linear regression analysis (Table 3), there is no significant relationship with urinary Pb with adjusted R 6.2% in the equation y = 16.382- 55.732x (p-value = 0.067). Higher urinary Pb levels tend to have low Hb levels.

In the spirometry results, the relationship between urinary Pb and FEV1, FVC, and FEV1/FVC values are shown in Table 3. Increased urinary Pb levels were found to have no significant effect on the percentage of FEV1 with an adjusted R trend of 5.8% influence on changes in FEV1 values in the equation y = 103.717-268.277x (p-value = 0.074) and were not statistically significantly different. Urinary Pb levels on FVC values were also not statistically significant with log(y)=1.972-577x (p-value = 0.380) and a very weak correlation of 2.0% on changes in FVC values. Meanwhile, lead levels were statistically significant, with an adjusted R of 10% contributing to the decrease in FEV1/FVC ratio values with the equation y= 96.550-159.454x (p=0.026). Thus, an increase in urinary Pb is associated with a statistically significant decrease in FEV1/FVC ratio but not substantially significant in FEV1 and FVC percentages.

Table 1. Characteristics of Research Subjects

Characteristic Subject	Total (N=40)
Age (years), mean±SD	25.38 ± 5.65
Body Weight kg, mean±SD	67.28±14.45
Height cm, mean±SD	165.65±4.85
Duration of employment month, mean±SD	4 ± 2.07
< 6 months	31 (77.5)
> 6 months	9 (22.5)
Smoking status	
Smoking	37 (92.5)
No smoking	3 (7.5)
Past Medical History	
Pneumonia	1 (2.5)
None	39 (97.5)
Treatment History	
Paracetamol	1 (2.5)
None	39 (97.5)
Personal Protective Equipment	
Using Mask	33 (82.5)
Not using	7 (17.9)

DISCUSSION

General Descriptions of the Population

This characteristic shows that the samples in this study tend to have been homogeneous. All

Table 2. Description of Research Variables and Data Normality Test

Variables	Average	Standard Deviation	p-value*
Urinary Pb (ppm)	0.0356	0.0074	0.224
Hemoglobin mg/dl	14.39	1.41	0.064
FEV1 %	94.15	6.93	0.703
FVC %	89.68	6.24	0.040
FEV1/FVC %	90.87	3.36	0.093

*Shapiro-Wilk normality test, FEV1: Forced Expiratory Volume in the first 1 second, FVC: Forced Vital Capacity, FEV1/FVC: Forced Expiratory Volume/Forced Vital Capacity

Table 3. Regression Analysis of the Effect of Urinary Lead (Pb) Levels on the Dependent Variable

Variable Analysis	p-value	R	R2	Adjusted R2	Equation
Urinary Pb→ Hemoglobin	0.067	0.293	0.086	0.062	y=16.382-55.732x
Urinary Pb→FEV1	0.074	0.286	0.082	0.058	y=103.717-268.277x
Urinary Pb→FVC	0.380	0.143	0.020	0.005	log(y)=1.972-577x
Urinary Pb→ FEV1/FVC ratio	0.026	0.351	0.123	0.100	y=96.550-159.454x

FEV1: Forced Expiratory Volume in the first 1 second, FVC: Forced Vital Capacity, FEV1/FVC: Ratio of Forced Expiratory Volume in the first 1 second / Forced Vital Capacity

subjects were young adult males with an average age of 25 years. Age is also known to affect by which high lead levels in older persons may cause interference due to decreased excretion and filtration functions of the kidneys. In this study, the average age of participants was 25 years, which shows the effect of decreasing clearance in old age has been avoided in this study (Van der burgh *et al*., 2021).

Several factors that influenced the result were homogeneous in this study, such as the overall working duration of 8 hours/day and a dominant working length of more than six months. Almost all workers were also smokers and there were no lung diseases and no previous routine drug use that could affect the diversity of the sample.

Cigarette smoke is said to be a likely source of Pb accumulated in house dust and Pb is a constituent of cigarette smoke that lingers long after smoking has ended (Matt *et al*., 2021). Previous study found that lead level can be deciphered in that age, length of work, and length of smoking can be variables that can increment lead levels within the respondent's blood, separated from the smoking propensity itself (Elisa *et al*., 2024). Research suggests that exposure time and duration affect lead levels. It documents new evidence about the duration, amount, and exposure of lead, where earlier exposure had a negative effect. A person with the same continuous exposure over a long period of time is said to have more harm (Hollingsworth *et al*., 2020).

The above is in line with research conducted by Huwaida Rahardjo and Setiani (2016) which expressed that smoking propensities are not essential, in impacting blood lead levels as other variables such as sexual orientation, age, work environment, and working hours, can also be trigger components that can impact blood lead levels (Huwaida, Rahardjo and Setiani, 2016). The distinct physiological states of an individual can impact the level of and rate of assimilation of inorganic lead from stomach-related and respiratory frameworks.

In this study with homogeneous characteristics, the assessment of exposure effects is expected to be more representative. Based on the normality test of urine Pb levels, lung function, and hemoglobin are also eligible for analysis.

Effect of Urinary Pb Levels on Hemoglobin (Hb) and Lung Function

The first effect of impairment due to prolonged exposure to lead is the disruption of hemoglobin synthesis so that hemoglobin levels decrease (Balali-Mood *et al*., 2021; Pessoa *et al*., 2023). In theory, 95% of the Pb in the blood is bound by erythrocytes before being distributed to various organs. In human studies, anemia can result from Pb poisoning through inhibition of ferrochelatase and δ-aminolevulinic acid dehydratase (ALAD), two enzymes involved in heme biosynthesis. Inhibition of ferrochelatase and ALAD by lead decreases heme synthesis, leading to anemia (Balali-Mood *et al*., 2021). Another study revealed that exposure to lead causes oxidative stress, which in turn causes a systemic iron deficit (Liu *et al*., 2020).

No anemia condition in this study can be due to the level of lead exposure not being able to affect blood cell abnormalities. Insignificant values may be due to the study subjects' length of Pb exposure and age. The length of work in the fuel station was quite short (an average of four months). It is known that Pb toxicity occurs if there is long-term exposure. The World Health Organization (WHO) recommends taking action if blood lead level (BLL) is greater or equal to 5 μg/d (World Health Organization, 2023). In workplace settings, a concentration of BLL of 20 μg/dL is considered to be an excessive level of exposure (Satarug *et al*., 2020), and should be terminated if exposure is 20 μg/dL (Nag and Cummins, 2022). Previous studies have found that the chronic effects of cumulative doses of lead can be prevented by keeping cumulative blood lead levels below 200-400 μg/dL/year (equivalent to 20 μg/dL or 0.2 ppm for 10-20 years) (Centers for Disease Control and Prevention, 2023).

The absorbability of lead is also strongly associated with mineral status. Deficiencies are considered to be a predisposition to an increased Pb uptake. The high risk of anemia is both lead poisoning and iron deficiency (Słota *et al*., 2021).

Lead can be inhaled, interfere with physiological functions and cause various harmful effects on the respiratory system, such as chronic obstructive pulmonary disease (COPD). There is little toxicological evidence on the mechanism of lung function impairment due to lead. Lead may have a role in direct reactive oxygen species (ROS) formation, depletion of cellular antioxidant stores, and other effects. A study with a whole-body exposure system for six months exposed mice to Pb and Cd, causing decreased lung compliance and progressive emphysematous changes to fibrosis. Furthermore, Pb/Cd-exposed mice's lungs produced significant amounts of reactive oxygen species (ROS) over time (Lee and Lee, 2024).

Occupational exposure to Pb also exhibits altered immune markers, characterized by a decrease in lymphocyte total count, lymphocyte subsets (CD3+, CD4+, CD4+/CD8+ ratio), IFN-γ and IgG levels, while CD8+, IgM, IgA, IgE, and cytokines (IL-4, IL-6IL-10, and TNF-α) levels were relatively higher (Kalahasthi *et al*., 2022).

In this study, urinary Pb had a statistically significant relationship with a mild FEV1/FVC ratio decrease. In another study that examined the relationship of urinary Pb levels with lung function in a community living for more than three years in Klang Valley, Malaysia, urinary Pb showed no significant correlation with lung function. However, urine Pb levels were normal, with a FEV1 of 79.8±13.04% and an FVC of 78.4±11.84%, which showed a mild decrease below normal (Haddi *et al*., 2022). Several other studies have shown that lung function results differ based on the amount of lead exposure. Research by Pan *et al*. (2020) with an average Pb level in normal blood, 37.27 μg/L equivalent to 0.037 ppm, found it did not decrease lung function. Although a significant decrease was found in the FEV1 percentage with a p-value of 0.02, the FVC percentage was insignificant with a p-value of 0.09. The study did not test the effect on the FEV1/FVC ratio but showed a significant decrease in FEV1 without a significant decrease in FVC leading to obstruction condition (Pan *et al*., 2020). Research in US adults found there was a strong correlation between serum lead and lower FVC% predicted and FEV1/FVC in all individuals, regardless of past or present smoking history. Preserved ratio impaired spirometry individuals had higher levels of serum lead than those with normal spirometry (1.62±1.81 vs 1.51±1.87, p=0.0003) (Chen *et al*., 2023). Some differences in the results of these studies show different significance, but changes in lung function are influenced by whether or not there are abnormalities in Pb levels in urine or blood.

In this study, the amount of Pb exposure that may have been inhaled was unknown because airborne Pb measurements were not taken. The duration of exposure is a dominant factor in high lead concentrations due to the accumulative nature of lead in the lungs. Exposure to 1-2 mg/m3 of lead particles can result in complaints after 5-15 years. Another study showed that a person with a working life of more than five years has an 8.3 times greater risk of lung function abnormalities than a working life of fewer than five years. Meanwhile, the subjects in this study had a median length of exposure of four months and no subjects with more than one year of exposure. In addition, at a young age, such as in subjects ranging from 25 years old, the magnitude of functional decline due to exposure may not be significant (Novitasari and Wijayanti, 2018; CDC, 2023).

Lung function is also affected by smoking habits, which can show differences in a person's lung function. Daily exposure to cigarette smoke, direct or secondhand smoke outside will cause changes in lung function, such as a decrease in FVC and FEV1. This condition can result in restriction and obstruction (Inomoto *et al*., 2019; Caiyun *et al*., 2022). However, COPD development and progression may involve both complex gene-by-environment interactions to multiple inhalational exposures and a variety of molecular pathways rather than a single cause (direct inhalation of tobacco products) (Curtis, 2023).

In this study, the lung function measured was on the subject of petrol station attendants with 94.5% being smokers. Previous studies have found a striking association with urinary lead in smokers but not in non-smokers (Alkufi, Oleiwi and Abojassim, 2024). In this study, the subjects were predominantly active smokers. So, lead levels and decreased lung function in this study population are adaptive to the conditions of petrol station workers who also smoke.

To address this risk issue, comprehensive precautions and mitigation measures are necessary to ensure the safety of individuals working in close proximity to fuel stations. These measures may include regular air and water quality monitoring, the implementation of strict handling protocols for hazardous materials, the use of personal protective equipment such as masks by workers, and regular lung function monitoring according to the duration of the impact based on existing research. Similar research is important to describe the population risk and to use it as a consideration for policy making.

This study was cross-sectional, so changes in variables before and after exposure could not be assessed. Prospective studies that can analyze the processes that occur in subjects due to lead exposure are needed. The variation in samples with less than one year of work may not show the accumulative impact of lead exposure with a longer duration. Studies with a larger population and multi-center fuel station locations may be more representative of the general population.

CONCLUSION

This study showed that urinary Pb levels and lung function were normal. Based on regression analysis, it was found that an increase in urinary Pb levels has a significant effect on decreasing the FEV1/FVC ratio. Meanwhile, the relationship of urinary Pb with other variables was not significant, and there was a negative correlation in the equation. This study clarifies previous research on Hb and pulmonary function change patterns in at-risk subjects based on findings of Pb exposure. Based on this study, appropriate prevention can be determined to reduce the health impacts of lead exposure in at-risk areas. More research on at-risk populations with longer years of service needs to be done.

CONFLICT OF INTEREST

The authors declare that there are no significant competing financial, professional, or personal interests that might have affected the performance.

AUTHORS' CONTRIBUTION

All authors declare that they are participating actively in research and article writing and are partly responsible for the content, including in the preparation and writing of concepts, designs, analysis, or revision of the article. MT: Conceptualization, Data curation, Writing- Original draft preparation, Investigation. IA: Data curation, Investigation. MS: Methodology, Software. AA: Investigation, Validation. HH, MI: Writing-Reviewing and Editing.

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