



Air Quality and Correlation of Exhaled Carbon Monoxide Level with Lung Function among Petrol Station Attendants in Banda Aceh

Rika Hardisa, Ferry Dwi Kurniawan*, Sri Dianova, Budi Yanti, Nurrahmah Yusuf

¹Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Syiah Kuala University, Zainoel Abidin Hospital, Banda Aceh

Corresponding Author:

Ferry Dwi Kurniawan | Department of Pulmonary and Respiratory Medicine, Faculty of Medicine, Syiah Kuala University, Zainoel Abidin Hospital, Banda Aceh | ferrydwikurniawan@usk.ac.id

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Abstract

Background: Risks of developing respiratory diseases due to pollutant exposures at petrol stations are high. The pollutants, such as particulate matter, carbon monoxide (CO), and volatile organic compounds emitted from vehicle exhaust and gasoline vapours, may affect the lung function of petrol station attendants. This study aimed to assess the levels of particulate matter, total volatile organic compounds, and the correlation of CO level and lung function among petrol station attendants in Banda Aceh.

Method: An analytical observational study with a cross-sectional design involved 114 attendants from 12 petrol stations in Banda Aceh. Lung function was evaluated using spirometry, and CO exhalation levels were measured using a Smokerlyzer. In addition, particulate matter and total volatile organic compounds levels were measured in the petrol station area using an air quality monitor.

Results: Most participants were male (82.5%) with a mean age of 30 years. The duration of work was under 5 years in 68 participants (59.6%). Approximately 61.4% (70 samples) were active smokers, with the most common Brinkman index indicating mild smoking habits for 50 samples (43.9%). The Pearson chi-square test revealed no significant relationship between CO exhalation levels and decreased lung function ($P=0.118$). The level of TVOC exceeded safe limits at all gas stations (>0.601 mg/m³), with an average TVOC level of 7.53 mg/m³. Most participants showed above-normal expiratory CO levels (53.6%). The average of the PM2.5 level was moderate.

Conclusion: This study found no significant correlation between exhaled CO levels and decreased lung function among petrol station attendants, likely due to their shorter duration of work and age under 40 years.

Keywords: exhaled CO, lung function, particulate matter, petrol station, volatile organic compound



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INTRODUCTION

Environmental pollution has been a global issue for decades. Various causes of air pollution include increasing

industrialization, rising energy demands, and the growing number of vehicles traversing the streets daily. To address these needs, there has been a surge in the

construction of public fuel filling stations.^{1,2} Gas stations, however, pose numerous risks and threats to both employees and the environment.²⁻⁴

Air pollutants emanating from vehicle exhaust, such as Particulate Matter (PM), carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), ozone (O₃) and benzene, classified as Volatile Organic Compounds (VOCs) or volatile substances, play a role in the pathogenesis of respiratory diseases.^{1,2,4}

Inhalation of CO is considered potentially toxic to the body, resulting in a decrease in the ability to transport oxygen, as indicated by elevated carboxyhaemoglobin (COHb) levels. Jadoon et al demonstrated that high carbon monoxide saturation in the blood is associated with several diseases. Breathing problems are the most commonly reported issues.⁵

Gasoline is categorized within the VOC group due to its volatile nature. The concentration of gasoline vapor in the atmosphere (approximately 2000 parts per million) poses a risk when inhaled, even for short periods (seconds). In their research, Temam et al revealed a significant decrease in FVC, FEV₁, %FEV₁, and FEF_{25-75%} among the study group (petrol station operators) compared to the control group.² PM_{2.5} air pollution levels in Indonesia are a good level in 0-15 µg/m³, a moderate level in 16-65 µg/m³, unhealthy in 66-150 µg/m³, very unhealthy in 151-250 µg/m³, and a hazardous level in >250 µg/m³.¹⁻⁴

The purpose of this study is to determine the levels of PM, total VOC

(TVOC), and the relationship between carbon monoxide exhalation and the lung function of petrol station operators in Banda Aceh.

METHOD

This study adopts an observational research design with cross-sectional approaches to analyze PM and TVOC at gas stations in Banda Aceh and has received ethical approval from the Research Ethics Committee of Zainoel Abidin Hospital with the approval number 070/ETIK-RSUDZA/2023. Additionally, it aims to investigate the influence of CO on operators' lung function. The population under consideration comprises all petrol station operators in Banda Aceh.

Inclusion criteria for participant selection encompass operators who willingly consent to be part of the study and petrol station operators with a work experience of ≥1 year who have no history of comorbid pulmonary disease. Exclusion criteria involve operators contraindicated for spirometry.

The primary data for this study is derived from the assessment of lung function utilizing spirometry, measurement of expiratory carbon monoxide using Smokelyzer, TVOC measurement using the Ambient Air Quality Pollution Meter (AQM-01), and basic demographic information from a questionnaire.

The procedure is carried out at the end of the worker's shift to assess lung function utilizing spirometry, measurement of expiratory carbon monoxide using a

smokerlyzer, TVOC measurement using the Ambient Air Quality Pollution Meter (AQM-01), and basic demographic information from a questionnaire. This study has been ethically approved using humans as research subjects and approved by Syiah Kuala University.

Data analysis is conducted using the Statistical Package for the Social Sciences (SPSS). Univariate analysis is employed to examine frequency distribution, proportion of variables, and sample characteristics. Bivariate analysis is utilized to explore the association between expiratory carbon monoxide levels and lung function. The chi-square test is applied for bivariate analysis, where $P > 0.05$ indicates no significant association between the two variables.

RESULT

A total of 114 samples met the inclusion criteria for this study. However, three samples were excluded due to a working period of less than one year or a history of asthma. Table 1 shows the characteristics of the subjects.

Regarding smoking habits, the majority of subjects were active smokers (70 samples; 61.4%), with the most common Brinkman index (BI) falling into the mild category (50 samples; 43.9%). Approximately 61.4% of subjects exhibited normal nutritional status. Body mass index (BMI) classification was based on national standards.

The use of masks was prevalent among subjects, with 91 subjects (79.8%) reporting regular use. The majority of

samples had a length of service ranging from 1 to 5 years (68 samples; 59.6%).

Table 1. General characteristics of subjects

Characteristic	n	%
Gender		
Male	94	82.5
Female	20	17.5
Age (years)		
18-25 years	48	42.1
26-35 years	42	36.8
36-45 years	15	13.2
>45 years	9	7.9
Smoking History		
Smoker	70	61.4
Smoked before	9	7.9
Non-smoker	35	30.7
Brinkman index		
Mild	50	43.9
Moderate	16	14.0
Severe	4	3.5
Non-smoker	44	38.6
BMI		
Underweight (<18.5)	9	7.89
Normal (18.5-25.0)	70	61.4
Overweight (≥ 25.1)	35	30.7
Using Mask		
No	23	20.2
Yes	91	79.8
Working Time		
1-5 years	68	59.6
6-10 years	40	35.1
>10 years	6	5.3

Out of the 12 gas stations studied, 2 had PM_{2.5} levels classified as good, 9 had the moderate category, and only 1 had the unhealthy category, exceeding the threshold value (68 $\mu\text{g}/\text{m}^3$) (Table 2).

Table 2. Particulate Matter 2.5 μm TVOC levels in a petrol station at Banda Aceh (n=12)

PM _{2.5}	n	%
Good	2	16.7
Moderate	9	75
Unhealthy	1	8.3
Very unhealthy	0	0.0
Hazardous	0	0.0

Table 3. Total Volatile Organic Compound (TVOC) levels at Banda Aceh gas stations (n=12)

TVOC	n	%
Below the safe threshold	0	0
Above the safe threshold	12	100

The TVOC levels were found to be above the safe threshold ($>0.601 \text{ mg/m}^3$) at all gas stations studied, as shown in Table 3.

Table 4. Expiratory carbon monoxide (CO) levels and lung function of petrol station operators at Banda Aceh gas stations (n=114)

Indicators	n	%
Expiratory CO Category		
Normal (0-6 ppm)	53	46.5
Mild (7-10 ppm)	15	13.2
High (≥ 11 ppm)	46	40.4
Lung Function		
Normal	89	78.1
Obstruction	3	2.6
Restriction	21	18.4
Mixed	1	0.9

Expiratory CO levels were above normal in the majority of samples, with 15 subjects (13.2%) mildly increased and 46 subjects (40.4%) highly increased. A significant proportion of subjects exhibited normal lung function (78.1%), with lung function disorders predominantly characterized by restriction abnormalities (18.4%), as shown in Table 4.

Table 5. The correlation between expiratory carbon monoxide levels and lung function at petrol station operators in Banda Aceh (n=114)

Expiratory CO	Lung Function		Total	P
	Normal	Abnormal		
Normal	43 (81.1%)	10 (18.9%)	53 (100.0%)	0.118
Mild	14 (93.3%)	1 (6.7%)	15 (100.0%)	
High	32 (69.6%)	14 (30.4%)	46 (100.0%)	
Total	89 (78.1%)	25 (21.9%)	114 (100.0%)	

However, the analysis revealed no significant relationship between expiratory carbon monoxide levels and the lung function of petrol station operators in Banda Aceh ($P=0.118$), as shown in Table 5.

DISCUSSION

This study, involving 114 petrol station operators in Banda Aceh, aimed to analyze levels of PM, TVOC and determine the correlation between exhaled carbon monoxide and the lung function of petrol station operators across 12 gas stations. The research found that 2 gas stations had PM_{2.5} levels in the good category, while had levels in the medium category ($16\text{-}65 \text{ }\mu\text{g/m}^3$, still below the threshold, and only 1 petrol station had PM levels in the unsafe category.

These findings contrast slightly with Ramadhany et al's research in Jakarta, where all research locations had PM_{2.5} levels in the safe category.³ The difference may be attributed to the location of gas stations in Banda Aceh, primarily situated on provincial roads congested with vehicles, unlike the predominantly district road locations in Jakarta.

PM_{2.5} is generated not only by vehicles queuing for refuelling, but also by dust and fumes from vehicles traversing the highway. With an aerodynamic diameter of $2.5 \text{ }\mu\text{m}$ or less, PM_{2.5} contains various toxic chemicals that can penetrate deep into the peripheral respiratory tract, posing a significant health risk, for example, decreased lung function, an

accelerated annual decline in lung function, and an increased risk of developing chronic obstructive pulmonary disease (COPD).^{3,6}

The measurement of TVOC levels at all gas stations indicated unsafe levels ($>0.601 \text{ mg/m}^3$). Comparisons with research conducted by Salama et al on the concentration levels of benzene, toluene, and xylenes (BTX) around gas stations showed levels exceeding air quality standards.⁷ Similarly, studies in Japan and Sudan found elevated VOC levels around gas stations.^{8,9}

Gasoline, diesel, and burning fossil fuels are primary sources of benzene-containing VOCs. Numerous studies have investigated the association between benzene exposure and decreased lung function, with evidence pointing towards an increased risk of impaired lung function in exposed workers.^{10,11}

Recent research has revealed inflammatory and oxidative imbalances that influence the expression of genes directly involved in hyperresponsiveness, airway hyperplasia, and airway remodelling in both atopic and nonatopic subjects.^{10,11} Personal protective equipment, including standard masks, becomes crucial in minimizing VOC exposure to the respiratory tract.¹²

From our research, a substantial number of subjects exhibited abnormal expiratory CO levels, with 15 subjects (13.2%) having mild levels (7-10 ppm) and approximately 46 subjects (40.4%) having high levels (≥ 11 ppm). These findings align with research by Ana et al, which demonstrated significantly higher average

COHb levels in petrol station attendants compared to WHO guidelines.¹³

A study by Okeke and Kelechi comparing COHB levels among smokers, petrol station attendants, and control subjects found that COHb was significantly higher in smokers than in petrol station attendants and the control group. Continuous exposure to carbon monoxide from vehicle exhaust fumes can contribute to increased exhaled carbon monoxide levels in petrol station attendants.¹⁴

This aligns with previous research in Salatiga, which established a strong correlation between COPD patients' levels of obstruction and smoking severity.¹⁵ Education on the significance of quitting smoking is crucial to reduce exposure to CO gas for petrol station operators who are also active smokers.

Exhaled carbon monoxide measurement in this study utilized a CO detector (Smokelyzer), offering a non-invasive and cost-effective means of assessing CO levels in breath. CO concentrations vary with distance from traffic, and concentrations near motorized vehicles can be 2-5 times higher than in the surrounding air. Gasoline, a major source of CO, produces elevated levels in exhaust fumes, particularly if the engine is not working correctly. This underscores the importance of monitoring CO levels, especially for petrol station attendants.¹⁶

The majority of samples in this study exhibited normal lung function (78.0%), influenced by the characteristics such as a predominantly male sample, the age range of 18-25 years (a period of maximum lung

development), and a higher proportion of smokers with a mild Brinkman index. BMI and working period also play roles in lung function. Underweight individuals may experience decreased respiratory muscle strength, while excess body weight can burden the thorax and abdomen, reducing lung volume.^{15,17,18}

The working period, especially over 5 years, is associated with decreased lung function, emphasizing the cumulative impact of long-term exposure to pollutants. A study by Novtasari et al demonstrated that workers with work periods ≥ 5 years exhibit 8.3 times greater risk of developing abnormal pulmonary function compared to someone who has worked < 5 years. These results are consistent with the theory that individuals working in environments with high levels of pollutants over an extended period are at risk of decreased lung function.^{19,20}

In this study, lung function disorders were primarily characterized by restriction disorders (18.4%). This aligns with previous studies conducted on petrol station attendants, indicating that most observed lung function disorders were restrictive. Restriction refers to a disturbance in lung expansion for any reason, resulting in stiffened lungs, increased force for expansion, and subsequent chest wall shrinkage.^{1,3,15}

The study also measured spirometry results, including Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), FEV_1/FVC , %FVC, and % FEV_1 . The average FVC value of the 114 research subjects was 3065.43 ml with a

standard deviation (SD) of 471 ml. The mean value of FEV_1 was 2719.64 ± 465 ml, and the mean %FVC was $87.03 \pm 10.38\%$. The average % FEV_1 was $90.17 \pm 13.77\%$, and the average value of FEV_1/FVC was $99.85 \pm 11.49\%$.

The research results indicate that the average FVC value of 114 petrol station operators was 3065.43 ml with SD of 471 ml. The mean %FVC was $87.03 \pm 10.38\%$. This finding contrasts with the study by Ramadhany et al, which reported an average FVC of 2868.4 ± 733.74 ml and an average %FVC value of $81.6 \pm 15.0\%$. One possible explanation for this difference is the higher proportion of male respondents in your study (82.5%) compared to the Ramadhany study.³

Gender differences play a significant role in lung capacity, as lung volume and capacity in women are approximately 20-25% smaller than in men. The mean value of FEV_1 is 2719.64 ± 465 ml. This result is comparable to the findings of Zafar's research in Pakistan, which reported an average FEV_1 of 2430 ± 890 ml.²¹

In this study, the average % FEV_1 was $90.17 \pm 13.77\%$, and the average value of FEV_1/FVC is $99.85 \pm 11.49\%$. This result is lower than those reported by Shonga and Siziya in Zambia, who found % FEV_1 to be $98.8 \pm 23.2\%$ and FEV_1/FVC to be $110.2 \pm 12.42\%$.²²

The chi-square analysis indicated that there was no significant relationship between exhaled carbon monoxide levels and the lung function of petrol station operators in Banda Aceh, with $P=0.118$. This finding aligns with similar results

obtained from Novtasari's research in Semarang, where no significant relationship was found between carbon monoxide exposure and lung function characteristics in petrol station attendants ($P=0.720$).²⁰

However, the study findings differ from those of Awadallah et al in Egypt, which revealed a significant reduction in pulmonary function parameters, including FEV₁, FVC, PEFR, and FEFR_{25%-75%} among petrol station workers (group II) compared with a control group (group I). Additionally, they observed a statistically significant increase in the mean value of CO in the study group (petrol station workers) compared to values in the control group (0.33 ± 0.15).¹

The results of the analysis by Esha et al in Riau present a significant correlation ($r= -0.795$) between exposure to CO pollutant gas and lung function. Prolonged exposure to CO has been associated with asthma exacerbations, chronic bronchitis (chronic obstructive pulmonary disease or COPD), and an increased susceptibility to respiratory diseases.¹²

The terminal bronchioles and respiratory bronchioles are crucial locations where emissions from vehicle exhaust, including CO, can have a significant impact. These particles, with their large surface area, can carry various toxic substances, remaining in the atmosphere for extended periods, and depositing in the small airways of the lungs.¹

One limitation of this study is that the researchers did not personally measure the levels of particulate matter and total

volatile organic compounds at each petrol station operator, aiming to avoid bias. This limitation arises from constraints related to the measuring instruments.

CONCLUSION

In conclusion, this study reveals that the levels of PM_{2.5} and TVOC in Petrol station areas exceed acceptable levels, posing potential harm. The majority of subjects in this study exhibit expiratory CO levels above the normal range, with the most prevalent lung function abnormality being restriction. To mitigate health risks associated with chronic exposure to fuel, it is recommended to implement periodic health checks and pre-work examinations. These measures include lung function assessments using spirometry, monitoring expiratory CO levels with Smokelyzer, and the use of protective masks. Additionally, encouraging smoking cessation is advised to reduce the risk of exposure to carbon monoxide.

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