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The Influence of Airborne Lead (Pb) and Individual Characteristics on Subjective Complaints Among Petrol Station Operators in Surabaya: A Cross-Sectional Study

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ABSTRACT Airborne lead (Pb) is a hazardous air pollutant commonly found in particulate form and is known to pose significant health risks through cumulative exposure. Petrol station operators are considered a vulnerable occupational group due to their routine exposure to motor vehicle emissions, a primary source of airborne lead. Despite regulatory limits on Pb exposure, health complaints persist among workers, indicating the potential influence of both environmental and individual factors. This study aims to examine the effect of airborne lead (Pb) concentrations and individual characteristics including age, work tenure, personal protective equipment (PPE) usage, and smoking habits on the subjective health complaints reported by petrol station operators in Surabaya. A cross-sectional observational design was employed with a total of 28 respondents selected through simple random sampling. Data were collected via air Pb measurements using Atomic Absorption Spectrophotometry (AAS), direct observations, and structured interviews. The relationship between variables and subjective complaints was analyzed using the chi-square test. The average measured airborne Pb concentration was 0.00043725 mg/m³, which remains below the permissible threshold (0.05 mg/m³) stipulated in Permenaker No. 5 of 2018. Statistical analysis revealed that work tenure ($p = 0.001$) and PPE usage ($p = 0.008$) had significant effects on subjective complaints, while airborne Pb levels, age, and smoking habits showed no significant association ($p > 0.05$). The most commonly reported complaints were fatigue (61%) and headaches (57%). In conclusion, individual behavioral factors, particularly longer work duration and lack of PPE use, contribute more significantly to health complaints than measured airborne lead concentrations. It is recommended that petrol station operators consistently use N95 masks and undergo periodic health evaluations to mitigate potential health risks.

INDEX TERMS Airborne lead, Gas station operators, Subjective complaints, Personal protective equipment, Occupational exposure

I. INTRODUCTION

Lead (Pb) is a heavy metal that is widely recognized as both an environmental and occupational pollutant, posing substantial risks to human health due to its toxic properties. In particulate form, lead can be easily inhaled or ingested, allowing it to enter the human body where it may accumulate over time and result in systemic toxicity affecting multiple organ systems [1], [2]. Despite the global phase-out of leaded gasoline, residual lead emissions from motor vehicles continue to persist, especially in urban environments characterized by dense traffic and high rates of fuel consumption [3]. This ongoing exposure presents a particular concern for certain occupational groups, notably petrol station operators, who face increased risk due to their routine proximity to fuel vapors and vehicular emissions during the refueling process [4], [5]. These occupational exposures underscore the importance of continued monitoring and risk assessment to protect vulnerable worker populations from the adverse health effects associated with lead.

According to the Indonesian Ministry of Manpower Regulation No. 5/2018, the occupational threshold limit value (TLV) for airborne Pb exposure is set at 0.05 mg/m³ [6]. Chronic exposure, even at sub-threshold levels, has been associated with a wide range of adverse effects, including hematological disorders, neurological symptoms, cardiovascular issues, and reproductive dysfunctions [7]–[9]. Pb absorption primarily occurs through inhalation (85%), followed by oral ingestion (14%) and dermal absorption (1%) [10]. Once absorbed, Pb binds to erythrocytes and is distributed to soft tissues and bones, where it may remain for decades [11]. Clinical

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manifestations of lead poisoning include headaches, fatigue, irritability, cognitive impairment, anemia, and sleep disturbances [12], [13]. Recent studies highlight the importance of not only environmental exposure but also individual behavioral and demographic factors such as age, job tenure, personal protective equipment (PPE) usage, and smoking habits as modifiers of health outcomes in occupational settings [14]–[16]. Health risk assessments in gas station environments have often focused on quantitative Pb measurements while neglecting the subjective complaints of workers, which can serve as early indicators of subclinical toxicity [17], [18]. Although some research has investigated the biological effects of lead among industrial workers, there remains limited literature examining the synergistic impact of airborne Pb and individual characteristics among gas station personnel.

A preliminary investigation at a Surabaya gas station revealed that 50% of interviewed workers reported fatigue and headaches, while 75% experienced sleep disturbances. Notably, more than half of these operators did not consistently use PPE, particularly face masks. Despite Pb concentrations remaining within regulatory limits, these complaints raise concerns about possible cumulative exposure and the role of modifiable factors in occupational health outcomes. This study therefore aims to analyze the effect of airborne lead (Pb) exposure and individual characteristics specifically age, job tenure, PPE usage, and smoking habits on the subjective health complaints of petrol station operators in Surabaya. By incorporating both environmental and individual-level variables, this study seeks to provide a more holistic understanding of occupational health risks in this sector. The key contributions of this study are as follows:

1. Multifactorial Risk Assessment: The study integrates environmental monitoring with worker-specific variables, allowing for a nuanced understanding of exposure-related health risks.
2. Empirical Evidence for Preventive Action: The research offers evidence-based recommendations on the importance of PPE and regular health screening, especially for long-tenured workers.
3. Local Contextualization: It fills a research gap in the Indonesian occupational health literature by providing location-specific data that can inform public health interventions and policy regulations.

II. METHODS

A. STUDY DESIGN AND SETTING

This study utilized an analytical observational design with a cross-sectional approach, conducted between January and May 2024 at a petrol station in Surabaya, Indonesia. The design was chosen to allow simultaneous analysis of exposure (airborne Pb and individual characteristics) and outcome (subjective complaints) at a single point in time, which is suitable for assessing prevalence and correlations [31], [32].

B. POPULATION AND SAMPLING

The target population consisted of petrol station operators working in Surabaya. From a total of 30 eligible workers, 28 respondents were selected through simple random sampling. Inclusion criteria included active employment at the station, willingness to participate, and absence of pre-diagnosed chronic illness. Exclusion criteria involved any inability to complete the questionnaire or participate in interviews. This non-randomized design limits generalizability but provides valid internal comparisons and facilitates risk identification in specific occupational settings [33].

C. DATA COLLECTION

Data were gathered through **three primary techniques**: environmental measurement, structured observation, and guided interviews.

1) AIRBONE LEAD (Pb) MEASUREMENT

Air sampling was conducted at two station points, with sampling durations of 1 hour per session, conducted in both the morning (07:30–08:30) and afternoon (16:00–17:00) over two consecutive days. A total of four repetitions were performed at each point. Air samples were collected using Whatman filter paper and analyzed with an Atomic Absorption Spectrophotometer (AAS) in accordance with standardized procedures for airborne metal detection [34]. The obtained values were compared against the National Threshold Limit Value (NAB) for Pb in air (0.05 mg/m³) as stipulated in Permenaker No. 5/2018 [6].

2) OBSERVATION

Field observations were carried out to assess environmental conditions, including traffic density, proximity to the highway, and availability of PPE. Observers used a checklist to document operator behaviors and PPE usage (mask-wearing practices).

3) QUESTIONARE AND INTERVIEW

Structured interviews were conducted using a rigorously validated questionnaire to obtain comprehensive data on both demographic characteristics and subjective work- related complaints. Demographic variables included age categorized as ≤30 or >30 years tenure of employment dichotomized as ≤2 or >2 years smoking status, and the regularity of personal protective equipment use, specifically mask wearing. Subjective complaints were solicited through self- reports of symptoms experienced while on duty, encompassing fatigue, headaches, irritability, difficulties with concentration, and sleep disturbances. To ensure the clarity and consistency of the data collected, all instruments underwent pre- testing to assess reliability and comprehensibility prior to their deployment in the field [35].

D. VARIABLES

In this study, the independent variables consisted of several factors that were hypothesized to influence health outcomes, including airborne lead (Pb) concentration in the workplace environment, the age of the workers, length of work tenure, smoking habits, and the frequency of personal protective equipment (PPE) usage, particularly mask-wearing. These variables were selected based on their potential relevance to occupational health risks in industrial settings. The dependent variable was the presence or absence of subjective health complaints, as reported directly by the respondents during

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structured interviews. These complaints included a range of self-perceived symptoms such as fatigue, headaches, irritability, difficulty concentrating, and sleep disturbances, which were analyzed in relation to the aforementioned independent variables to explore possible associations and risk patterns.

E. DATA ANALYSIS

Data were processed and analyzed using IBM SPSS Statistics version 26. Descriptive statistics (frequencies and percentages) were used to summarize respondent characteristics and measurement outcomes. The Chi-Square (χ^2) test was applied to examine associations between independent variables and subjective complaints. A p-value ≤ 0.05 was considered statistically significant [36]. The Chi-Square test was appropriate due to the categorical nature of the variables and sample size assumptions being met [37].

F. ETHICAL CONSIDERATIONS

This research received ethical clearance from the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya. Prior to data collection, informed consent was obtained from all respondents. Participants were assured of confidentiality, anonymity, and the voluntary nature of their involvement. The study was conducted in line with the ethical standards outlined in the Declaration of Helsinki and national regulations for occupational health research [38].

G. STUDY LIMINATIONS AND QUALITY CONTROL

Given the cross-sectional design, the study can only establish associations, not causality. The relatively small sample size and focus on a single gas station may limit external validity. Additionally, subjective complaints were self-reported and may be influenced by recall or response bias [39]. Nevertheless, the study offers practical insights for occupational health risk assessments and highlights the value of integrating environmental and personal risk factors in workplace evaluations. All instruments used for air sampling were calibrated according to manufacturer specifications prior to fieldwork. Observers were trained to ensure consistency in field protocols. Data entry was double-checked by two independent researchers to minimize transcription errors.

III. RESULT

A. INDIVIDUAL CHARACTERISTICS OF GAS STATION OPERATORS

1) AGE

TABLE 1
Age Frequency Distribution of Gas Station Operators

No	Age	N	Precentage (%)
1.	≤ 30 year	19	69
2.	> 30 year	9	32
	Total	**28**	**100**

Based on TABLE 1, the majority of gas station operators are aged 30 years or younger, totaling 19 individuals (69%), while those over 30 years old account for only 9 individuals (32%). This indicates that the workforce is predominantly composed of younger individuals, reflecting a youthful demographic trend in this occupation.

2) WORKING PERIOD

TABLE 2
Frequency Distribution of Working Period of Gas Station Operators

No	Working Period	N	Precentage (%)
1.	≤ 2 year	13	46
2.	> 2 year	15	54
	Total	**28**	**100**

Based on the research results presented in TABLE 2, 54% of gas station operators (15 individuals) have worked for more than two years, while the remaining 46% (13 individuals) have less than two years of work experience. This suggests a relatively balanced distribution between experienced and less-experienced operators in the workforce.

3) USING PERSONAL PROTECTIVE EQUIPMENT (PPE)

TABLE 3
Frequency Distribution of PPE Habit

No	Using PPE	N	Precentage (%)
1.	Not Using PPE	15	54
2.	Using PPE	13	46
	Total	**28**	**100**

TABLE 3 shows that the majority of gas station operators do not use personal protective equipment (PPE), totaling 15 individuals (54%), while the remaining 13 individuals (46%) do use PPE. This finding highlight a concerning lack of compliance with safety protocols among more than half of the operators observed.

4) SMOKING HABITS

TABLE 4
Frequency Distribution of Smoking Habits of Gas Station Operators

No.	Smoking Habits	N	Precentage (%)
1.	Non Smoker	6	57
2.	Smoker	12	43
	Total	**28**	**100**

Based on the distribution of smoking habits of gas station operators in TABLE 4, it shows that the majority of gas station operators do not smoke as many as 16 people (57%) and the rest smoke as many as 12 people (43%).

B. AIR LEAD (Pb) MEASUREMENTS

TABLE 5
Air Pb Measurement Results at 2 Points at Gas Stations

No	Measurement Date	Point	Pb Measurement Result (mg/m³)		Average
			Morning	Afternoon	
1	March 7, 2024	1	0,0008064	0,0002710	0,0005387
		2	<0,00043	<0,00043	<0,00043
2	March 8, 2024	1	0,0002706	<0,00043	0,0003503
		2	<0,00043	<0,00043	<0,00043
Overall Average					0,00043725

The process of taking Pb air samples was carried out for 1 hour at each location point and repeated the next day with the same time and location point. After the sampling was completed, the samples were taken to the laboratory and analyzed using an Atomic Absorption Spectrophotometer

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(AAS). Based on TABLE 5, it can be concluded that the results of air lead (Pb) measurements at gas stations were carried out at 2 points with each point carried out 4 measurements (2 days) in the morning at 07.30 - 08.30 WIB and afternoon at 16.00 - 17.00 WIB. The measurement results show that the average overall air lead (Pb) level is 0.00043725 mg/m^3. This finding shows that the overall air lead (Pb) level is still below the permitted NAB in accordance with Permenaker No. 5 of 2018 of 0,05 mg/m^3. Differences in lead (Pb) levels in the air can be influenced by different human activities, which cause changes in ambient air quality. One of the main factors is the transportation sector, especially emissions from motor vehicles. Several factors that affect motor vehicle emissions include increasing number of vehicles, routine vehicle maintenance, vehicle age, vehicle speed, engine capacity, and fuel consumption. More vehicles mean more exhaust gas produced, while routine maintenance can reduce the amount of exhaust gas [11].

C. SUBJECTIVE COMPLAINTS OF GAS STATION OPERATORS

Subjective complaints are a person's recognition of the symptoms or health problems they are experiencing based on personal perception. Subjective complaints in this study are complaints felt by gas station operators during work. The results of questionnaires that have been distributed to 28 gas station operators about subjective complaints are presented in Figure 1 and the types of subjective complaints are presented in Figure 2 below:

1) SUBJECTIVE COMPLAINTS

Based on FIGURE 1, it shows that 17 respondents have subjective complaints due to airborne lead (Pb), with 11 people in the no complaints category and 17 people in the complaints category.

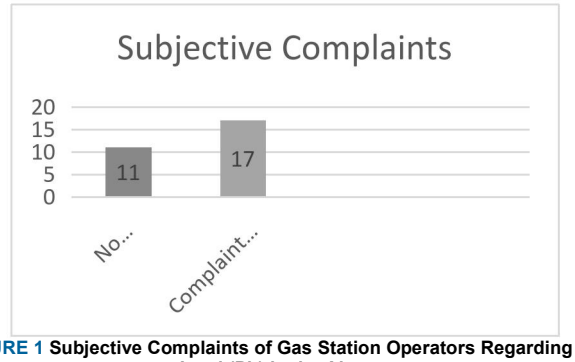

FIGURE 1 Subjective Complaints of Gas Station Operators Regarding Lead (Pb) in the Air

Air Pb contributes to subjective complaints after becoming a gas or small particles that are spread in the air and then settle on the ground. About 80% of lead (Pb) enters the body through breathing and reaches the blood vessels in the lungs. There, lead binds to the blood and spreads to various tissues and organs [12]. More than 90% of lead absorbed by the blood is bound to red blood cells. The rate of lead absorption is greatly influenced by the size of the Pb compound particles and the amount of air inhaled. Smaller dust particles and larger air volumes increase the amount of lead that can be absorbed by the body [13]. The rate of lead absorption is greatly influenced by the size of the Pb compound particles and the amount of air inhaled. Smaller dust particles and larger air volumes increase the amount of lead that can be absorbed by the body [13]. This study only asked about subjective complaints of gas station operators related to air Pb, namely fatigue, sleep disturbances, headaches, difficulty concentrating, and irritability without asking about subjective complaints about respiratory disorders. This is because air lead enters the body of gas station operators through cumulative inhalation. Furthermore, lead will enter the blood vessels of the lungs and bind to red blood cells.

2) TYPE OF SUBJECTIVE COMPLAINTS

Based on FIGURE 2, it shows that gas station operators with subjective complaints due to airborne lead (Pb) report the following types of complaints: fatigue in 17 people (61%), sleep disturbances in 10 people (36%), headaches in 16 people (57%), difficulty concentrating in 10 people (36%), and irritability in 8 people (29%). In conclusion, the most common subjective complaints experienced by gas station operators due to lead (Pb) exposure among the respondents are fatigue (61%) and headaches (57%).

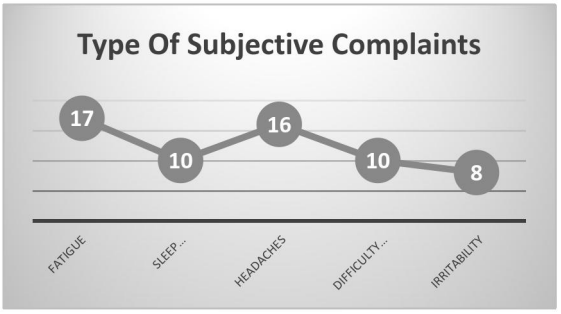

FIGURE 2 Types of Subjective Complaints of Gas Station Operators Regarding Lead (Pb) in the Air

D. ANALYSIS OF THE EFFECTS OF AIRBORNE LEAD, AGE, WORK TENURE, PPE USAGE HABITS, AND SMOKING HABITS ON SUBJECTIVE COMPLAINTS

The results of the analysis of the effects of airborne lead (Pb), age, work tenure, PPE usage habits, and smoking habits on subjective complaints among gas station operators are shown in the following TABLE 6:

1) THE EFFECT OF AIR Pb ON SUBJECTIVE COMPLAINTS OF GAS STATION OPERATORS

Based on TABLE 6, it is shown that the air Pb measurement results still meet the NAB, so that the air Pb data is homogeneous, which means that air Pb has no effect on the subjective complaints of gas station operators

TABLE 6
Chi-Square Test Results of the Effect of Pb on Subjective Complaints

No	Air Pb	Subjective Complaints				Total	
		No Complaint		Complaint Present			
		n	%	n	%	n	%
1	Meets NAB	11	39	17	61	28	100

2) THE EFFECT OF AGE ON SUBJECTIVE COMPLAINTS OF GAS STATION OPERATORS

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TABLE 7
Chi-Square Test Results on the Effect of Age on Subjective Complaints

No	Age	Subjective Complaints				Total		*p - value*
		No Complaint		Complaint Present				
		n	%	n	%	n	%	
1	≤30 year	9	47	10	53	19	100	0,249
2	>30 year	2	22	7	78	9	100	> 0,05

Based on TABLE 7 above, it can be seen that subjective complaints are more commonly experienced by gas station operators over 30 years old (78%) compared to those 30 years old or younger (53%). The p-value from the statistical test is 0.249 > 0.05, indicating that H0 is accepted. This means that age does not have a significant effect on the subjective complaints of gas station operators.

3) THE EFFECT OF WORKING PERIOD ON SUBJECTIVE COMPLAINTS OF GAS STATION OPERATORS

Based on TABLE 8, it is shown that subjective complaints are more commonly experienced by gas station operators with a work tenure of over 2 years (93%) compared to those with a work tenure of 2 years or less (23%). The p-value from the statistical test is 0.001 ≤ 0.05, resulting in the rejection of H0, which means that work tenure has a significant effect on the subjective complaints of the operators at Pertamina Gas Station 54.601.127 in Surabaya.

TABLE 8
Chi-Square Test Results on the Effect of Work Period on Subjective Complaints

No	Working Period	Subjective Complaints				Total		*p - value*
		No Complaint		Complaint Present				
		n	%	n	%	n	%	
1	≤ 2 years	10	77	3	23	13	100	0,001 ≤ 0,05
2	> 2 years	1	7	14	93	15	100	

4) THE EFFECT OF USING PRE ON SUBJECTIVE COMPLAINTS OF GAS STATION OPERATORS

TABLE 9
Chi-Square Test Results on the Effect of PPE Use on Subjective Complaints

No	Using PPE	Subjective Complaints				Total		*p- value*
		No Complaint		Complaint Present				
		n	%	n	%	n	%	
1	Not Using PPE	2	13	13	87	15	100	0,008 ≤ 0,05
2	Using PPE	9	69	4	31	13	100	

Based on TABLE 9, it is shown that subjective complaints are more commonly experienced by gas station operators who do not use PPE (87%) compared to those who do use PPE (31%). The p-value from the statistical test is 0.008 ≤ 0.05, resulting in the rejection of H0. This means that the use of PPE has a significant effect on the subjective complaints of gas station operators

TABLE 10
Chi-Square Test Results of the Effect of Smoking Habits on Subjective Complaints

No	Smoking Habitss	Subjective Complaints				Total		*p - value*
		No Complaint		Complaint Present				
		n	%	n	%	n	%	
1	Non-Smoker	6	37	10	63	16	100	1,000 > 0,05
2	Smoker	5	42	7	58	12	100	

5) THE EFFECT OF SMOKING HABITS ON SUBJECTIVE COMPLAINTS OF GAS STATION OPERATORS

Based on TABLE 10, it is shown that subjective complaints are experienced by 63% of gas station operators who do not smoke compared to 58% of those who do smoke. The p-value from the statistical test is 1.000 > 0.05, leading to the acceptance of H0. This means that smoking habits do not have a significant effect on the subjective complaints of gas station operators.

IV. DISCUSSION

A. AIRBORNE LEAD (PB) EXPOSURE AND ITS ASSOCIATION WITH SUBJECTIVE COMPLAINTS

The results of this study demonstrated that airborne lead (Pb) concentrations at the gas station sites were substantially below the threshold limit value (TLV) of 0.05 mg/m³ as stipulated by the Indonesian Ministry of Manpower [5]. The average concentration recorded was 0.00043725 mg/m³, indicating that the environmental burden of Pb at the measurement points was minimal. Consequently, statistical analysis showed no significant correlation between ambient Pb levels and the subjective health complaints reported by gas station operators. These results are consistent with previous findings where air Pb concentrations below occupational safety limits were found to pose minimal immediate health risks [41]. Nurwahida [18] similarly concluded that airborne lead exposure in school environments with Pb levels under 0.01 mg/m³ had no measurable health impact on children. On the contrary, studies conducted in higher exposure zones, such as roadside vendors or industrial zones, showed significant health associations due to elevated lead levels [13], [42]. The variation in outcomes may stem from differences in environmental context, measurement duration, or individual susceptibility. However, it is important to recognize that even low-level chronic exposure can lead to bioaccumulation over time, potentially resulting in systemic effects, especially in populations with prolonged exposure duration [43]. Furthermore, the limited scope of air sampling conducted over only two days may not capture diurnal or seasonal fluctuations in pollutant concentrations. Biological monitoring, such as blood Pb levels, would be necessary to verify the internal exposure and its health implications [44]. In light of these findings, while current Pb levels at the studied stations appear to meet regulatory safety standards, long-term surveillance and incorporation of biomarker analysis are recommended to ensure comprehensive worker protection [45].

B. INDIVIDUAL CHARACTERISTICS AND THEIR INFLUENCE ON SUBJECTIVE COMPLAINTS

1) AGE

Although biological susceptibility to pollutants may increase with age due to declining organ function and reduced detoxification capacity, this study found no statistically significant relationship between age and subjective complaints (p = 0.249). While operators over

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the age of 30 exhibited slightly higher complaint rates (78%), this was not sufficient to be considered statistically meaningful. These findings align with research by Laia et al. [20] and Gusti et al. [21], both of whom reported no significant association between age and fatigue in gas station operators. Nonetheless, age remains an essential demographic factor in occupational health risk assessments, especially when evaluating cumulative exposure effects and resilience to occupational stress [46].

2) WORK TENURE

Work duration exhibited a statistically significant relationship with the prevalence of subjective complaints ($p = 0.001$). Operators with over two years of experience were significantly more likely to report symptoms such as fatigue and headaches. These findings are consistent with earlier studies indicating that longer occupational exposure increases the likelihood of adverse health effects [25], [26]. Repeated exposure to vehicle emissions, even at low concentrations, may lead to chronic stress on physiological systems, particularly when protective measures are not consistently used. Furthermore, extended periods of routine, repetitive work may contribute to physical and mental fatigue [22], [47].

3) PERSONAL PROTECTIVE EQUIPMENT (PPE) USAGE

The data indicated a significant association between PPE usage particularly face masks and the occurrence of subjective complaints ($p = 0.008$). Operators who used PPE regularly reported substantially fewer symptoms than those who did not. This confirms findings by Andriani et al. [29] and Ida et al. [28], both of whom identified PPE usage as a significant protective factor in reducing occupational health complaints. The N95 respirator is particularly effective in filtering fine particles, including airborne heavy metals such as lead. Despite this, the study revealed that only 46% of respondents regularly used PPE. Barriers to consistent use may include discomfort, lack of training, or insufficient enforcement by management. It is recommended that gas station operators receive targeted health education, training on the importance of PPE, and that PPE availability and policy enforcement be improved at the organizational level [48].

4) SMOKING HABITS

No significant relationship was observed between smoking and subjective complaints ($p = 1.000$). This is in line with research by MJ [32], which reported no association between smoking and hypertension among gas station operators. While smoking has been linked to increased blood Pb levels and other health risks in the general population, its specific role in modulating subjective symptoms in this context appears minimal. Nevertheless, it is advisable to discourage smoking in such environments due to the potential synergistic effects of tobacco smoke and environmental contaminants, and because of the explosion risk associated with open flames near fuel dispensers [31].

C. STUDY LIMITATIONS AND PRACTICAL IMPLICATIONS

This study utilized a cross-sectional design, which inherently limits the ability to establish causal relationships between exposure to airborne lead (Pb) and the reported health outcomes. One of the methodological limitations lies in the air sampling process, which was conducted over a relatively short period of only two days, potentially restricting the representativeness of environmental exposure levels across different timeframes. Additionally, the data on subjective health complaints were obtained through self-reported measures, which may be susceptible to recall bias or response bias, as participants' perceptions and reporting accuracy could vary. Another notable limitation is the absence of biological verification, such as the measurement of blood lead levels, which would have provided a more direct and objective assessment of internal exposure. The lack of such biological data reduces the study's ability to fully evaluate the physiological burden of lead among workers, thereby constraining the depth of exposure–response analysis. Despite these limitations, the findings hold practical implications. Interventions aimed at enhancing PPE usage and monitoring operator tenure are recommended. Policies should also include regular medical checkups and air quality assessments. Future research should incorporate longitudinal data collection and biological sampling to better understand cumulative exposure and its health effects [44]. Additionally, integrating ergonomic assessments and psychosocial evaluations may provide a more holistic picture of occupational well-being among petrol station operators in high-traffic urban areas.

V. CONCLUSION

This study aimed to assess the influence of airborne lead (Pb) concentrations and individual characteristics including age, work tenure, use of personal protective equipment (PPE), and smoking habits on the subjective health complaints of petrol station operators in Surabaya. Utilizing a cross-sectional analytical observational design with 28 randomly selected respondents, this research revealed several key findings. Air Pb levels measured across two points averaged 0.00043725 mg/m³, well below the maximum permissible threshold of 0.05 mg/m³ set by national occupational health standards. Despite this, 61% of respondents (17 individuals) reported experiencing subjective health complaints, with fatigue (61%) and headaches (57%) being the most prevalent symptoms. Statistical analysis using the chi-square test indicated that neither air Pb concentration, age ($p = 0.249$), nor smoking habits ($p = 1.000$) significantly affected the occurrence of subjective complaints. In contrast, two individual factors showed statistically significant associations: length of service ($p = 0.001$), with 93% of respondents with >2 years of experience reporting complaints, and PPE usage ($p = 0.008$), where 87% of non-users reported symptoms compared to only 31% among users. These findings underscore the critical role of preventive behaviors particularly PPE compliance and work duration management in mitigating occupational health risks, even

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when environmental exposures are within regulatory limits. Given the limitations of this study, including a relatively small sample size, a short duration of air sampling, and the absence of biological exposure markers such as blood lead levels, future research should incorporate longitudinal data and biomonitoring to strengthen causal inference. Moreover, expanding the investigation to include psychosocial factors, ergonomic risks, and a broader geographic area could yield a more comprehensive understanding of occupational health burdens in petrol station environments. Institutional recommendations include enforcing PPE protocols, promoting regular health screenings every six months, and encouraging workplace health education programs to enhance self-awareness and compliance with occupational safety standards.

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DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Salsabila Ro'iqoh contributed to conceptualization, data collection, and manuscript drafting. Rusmiati supervised the study, contributed to methodology design, data analysis, and critical revision of the manuscript. Winarko assisted with statistical analysis, interpretation of findings, and data visualization. Khambali supported in validation, project administration, and technical editing. Seow Ta Wee contributed to literature review, academic consultation, and final manuscript proofreading. All authors have read and approved the final version of the manuscript.

DECLARATIONS

ETHICAL APPROVAL

This study was conducted in accordance with ethical guidelines and approved by the Ethics Committee of the Politeknik Kesehatan Kemenkes Surabaya. Written informed consent was obtained from all participants prior to data collection.

CONSENT FOR PUBLICATION PARTICIPANTS.

Consent for publication was given by all participants

COMPETING INTERESTS

The authors declare no competing interests.

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