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Benzene, Toluene, Xylene Levels and Subjective Complaints in Shoe Workshops

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Abstract

The demand for shoes must be met by the worldwide shoe manufacturing business, but the inhalation dangers associated with its chemical processes—which use benzene, toluene, and xylene (BTX)—raise health issues for workers. Initial surveys showed that most shoe manufacturing workshops do not have adequate ventilation. Most workers often complain of symptoms such as coughing, shortness of breath, and headaches. This study examined the relationships between worker symptoms and chemical levels at shoe factories in Medan, Indonesia, in 2017. This was an observational cross-sectional study. The total population was 72 workers in shoe workshops in the small industrial center area in Medan city. The sample size in this study was 47 people in seven shoe workshops. BTX concentrations were measured in seven workshops. Statistical tests used in this study were chi-square test and Fisher's exact test with a significance level of $p<0.05$. According to the findings, the most common symptoms among employees were coughing (40.4%), dizziness (55.3%), and eye discomfort (55.3% of respondents). The range values were 0.09 ppm to 2.83 ppm, 1.20 ppm to 178.98 ppm, and 0.11 ppm to 50 ppm for benzene, toluene, and xylene, respectively. The two compounds most commonly exposed to levels exceeding the ACGIH (American Conference of Governmental Industrial Hygienists) threshold level value were toluene (55.3%) and benzene (25.5%), according to ambient readings. Of the workshops that were inspected, only two (28.57%) had a functional ventilation system. Exposure to benzene exceeding the quality standard showed a significant association with dizziness ($p = 0.003$) and watery eyes ($p = 0.003$). Meanwhile, exposure to toluene exceeding the permissible limit was significantly associated with dyspnea ($p = 0.005$). Our research showed that over half of the workforce reported subjective complaints and that levels of benzene and toluene exceeded recommendations for occupational exposure.

Introduction

Millions of people around the world receive footwear from the shoe industry, which plays a crucial role in the global economy. However, the manufacturing process in shoe workshops involves the use of various chemicals that can pose health risks to workers (Pattanaik and Kushwaha, 2019). The process of gluing shoes uses glue as the main ingredient in the work. In general, glue or adhesive contains various mixtures that include benzene, toluene, and xylene (BTX), which act as solvents (Maywati, 2012). During the manufacturing of shoes, these materials—known as volatile organic compounds, or VOCs—may be discharged into the atmosphere (Tualeka *et al.*, 2020). It is widely acknowledged that BTX are harmful to human health (Soleimani, 2020). Because of its extreme volatility, breathing is the main way that benzene affects humans (Poli *et al.*, 2022). Occupational exposure is particularly common. According to the International Agency for Research on Cancer (IARC), benzene is recognized as a carcinogen for humans (Zhou *et al.*, 2020). Furthermore, the data indicated that inhalation exposure to benzene in the atmosphere was associated with acute and long-term adverse effects on

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various physiological systems, including the neurological, immunological, respiratory, and reproductive and developmental systems (Cordiano *et al*., 2022).

Like benzene, toluene is a colorless liquid with a distinct, pleasant smell that can be used to determine dangerously high concentrations. Toluene is rapidly absorbed when ingested or inhaled. While healthy skin absorbs toluene slowly, percutaneous absorption can contribute to overall exposure. Systemic effects can occur from ingestion or inhalation. Toluene irritates the respiratory system, eyes, and skin, with inhalation being the most common route of exposure (Maryiantari & Keman, 2020). Toluene poisoning can cause symptoms such as headache, dizziness, ataxia, sleepiness, euphoria, hallucinations, tremors, seizures, and coma in addition to central nervous system effects, ventricular arrhythmias, chemical pneumonitis, respiratory depression, nausea, vomiting, and electrolyte abnormalities (Sousa, 2022). One such cyclic hydrocarbon is xylene, which is recognized as a major pollutant of the environment. Furthermore, it is widely utilized as a solvent in many other industries, including the production of glue, dyes, paint formulation, polishes, and medical technology. The mixture of various xylene isomers may cause transient irritation of the throat, eyes, and nose; over time, this may have deleterious consequences on the neurological system, gastrointestinal tract, and reproductive system. Moreover, the cardiovascular, neurological, pulmonary, and renal systems may suffer negative effects from extended exposure to xylene (Niaz *et al*., 2015).

Despite observing typical health issues such as headaches, dyspnea, and coughing, Research on BTX has focused on various activities. The average concentration (mean ± SD) of benzene, toluene, and xylene at the toll gate was 0.00167 ± 0.000056 mg/m^3, 0.00124 ± 0.000049 mg/m^3, and 0.00147 ± 0.000063 mg/m^3, according to Handoyo and Wispriyono (Wispriyono and Handoyo, 2016). Meanwhile, Ayu could not find a significant association between the amounts of malondialdehyde and toluene (Ayu *et al*., 2020). Budiarti's work on appropriate detoxifying dosages for employees exposed to benzene toxins in the paint industry suggests that more research is required to examine the consequences of benzene exposure (Budiarti *et al*., 2020). Toluene vapor exposure was linked to respiratory problems and other health risks in shoemakers, according to a different Indonesian study. The research findings indicate that toluene is carcinogenic to humans and that small workshops with inadequate safety precautions have a higher chance of exposure(Maryiantari & Keman, 2020). This study's main goals were to assess acute subjective complaints in workers and collect quantitative data on the amounts of BTX chemicals in the ambient settings of shoe workshops.

Method

This study was an observational quantitative study using a cross-sectional design. The population in this study was all shoe manufacturing workers at the research location. Overall, 47 shoemakers (7 workshops) in Medan City were selected for this study by purposive sampling. The sample inclusion criteria in this study were workers who were over 18 years old, had worked for at least 1 year, and were willing to sign a consent form. Meanwhile, the criteria for sample exclusion were having a history of bronchial asthma, pulmonary tuberculosis, type 2 DM, hypertension, and having experienced head trauma. A structured questionnaire was developed and used to assess subjective symptoms (respiratory, neurologic, and eye), including baseline demographics, work environment, and job characteristics. The survey was conducted between July and August 2017. Questionnaires were administered face-to-face after explaining the study with a phone call in advance and obtaining consent by personally visiting the workshop.

A total of 7 ambient air monitoring study sites were selected for the 8-hour working time of the workers. Ambient air samples in the breathing zone of each individual were collected using the NIOSH (National Institute for Occupational Safety and Health) Manual of Analytical Procedures 1501 as a guide, using an active charcoal tube with a flow rate of 100 mL min-1. Gas chromatography with a flame-ionization detector was used to evaluate the target chemicals. Sample tubes were kept at 4°C during transportation to the laboratory and stored in a refrigerator until further analysis. Data analysis was performed using "Statistical Package for Social

Table 1. Baseline Characteristics

Characteristics	n (%)	Mean±SD	Min - Max
Age, years		36.53 ± 13.43	17 – 67
> 40 years	15 (31.9)		
≤ 40 years	32 (68.1)		
Work duration, years		7.11 ± 6.71	1 – 24
> 5 years	19 (40.4)		
≤ 5 years	28 (59.6)		
Average working hours a day, h		10.21 ± 0.98	9 – 12
Smoking history			
Yes	47 (100)		

Source: Primary Data, 2017

Sciences" (SPSS) version 21. Categorical variables were presented in frequency distribution and percentage. Numerical variables were represented as means (standard deviation ± SD) and range (minimum-maximum). Chi-squares and Fisher's exact test were used to analyze categorical variables. For the numerical variables, first, the normality of the data was assessed using Shapiro-Wilk.

Results and Discussion

Overall, 47 shoemakers from seven different workshops in the city of Medan were chosen. All of the participants were male workers between the ages of 17 and 67, making up the entire study population. The shoemakers who worked there were exposed to solvent vapour while they glued the materials together. Personal protective equipment (PPE) was not used, and there was no local exhaust ventilation in the workshops. According to the available information, the employees consistently performed the same tasks, and the production rate had been quite stable throughout the previous months. The baseline characteristics of shoe workshop workers are displayed in Table 1. The workers were 36.53 years old on average. The work duration and average working hours were 7.11 years and 10.21 hours a day, respectively. All of the subjects (100%) in this study were smokers. One of the main sources of benzene inside is thought to be environmental tobacco smoke (ETS). Emissions from smoking cigarettes can vary from 10 to 130 mg/m3, and each cigarette can produce 20 to 100 μg of benzene. Several studies have demonstrated a link between smoking cigarettes—particularly combustible ones—and higher blood levels of volatile organic compounds (VOCs), such as benzene and toluene (Wu *et al*., 2023; Scherer *et al*., 2022). Smokers are exposed to approximately 1,800 g of benzene per day, while non-smokers only inhale about 50 g. This significant disparity in benzene intake leads to a notable elevation in indoor benzene levels (Vardoulakis *et al*., 2020).

Studies have indicated that indoor tobacco smoking conditions, including secondhand smoke exposure, can have far higher air pollution levels. Among these pollutants are volatile organic compounds (VOCs) like benzene and toluene, as well as nitrogen oxides (NOx) (Savdie *et al*., 2020), (Braun *et al*., 2021), (Vardoulakis *et al*., 2020). These concentrations may be above the guidelines established by the World Health Organization (WHO), resulting in harmful consequences to health, namely affecting the respiratory and cardiovascular systems (Braun *et al*., 2021). Although heat-not-burn tobacco and electronic cigarettes produce fewer emissions compared to traditional cigarettes, their use still contributes to indoor air pollution (Savdie *et al*., 2020).

Table 2 provides a summary of the working conditions seen in shoe workshops. The shoe workshops were between 31.30 °C and 32.30 °C. Air humidity ranged from 63.30% to 69.20%. There were two workshops (28.57%) without adequate ventilation. The evaporation and volatilization of VOCs from materials and products can be accelerated by higher temperatures. This may result in increased indoor VOC concentrations and, thus, a higher risk of worker exposure. At

Table 2. Working Conditions of a Shoe Workshop

Item	n	Mean±SD	Min - Max
Temperature, °C	7	31.85 ± 0.34	31.30 – 32.30
Humidity, %	7	65.78 ± 2	63.30 – 69.20
Air pressure, mmHg	7	748.30 ± 1.44	746 – 750
The size of the workshop room, m^2	7	22.12 ± 7.66	7.5 – 36
Ventilation	7	11.72 ± 3.57	8.21 – 19.83
Adequate ventilation			
Yes	5 (71.43)		
No	2 (28.57)		

Source: Primary Data, 2017

standard room temperature, VOCs readily evaporate or sublimate into the air (Shuai *et al*., 2018). Indoor temperatures were measured between 31,30 °C and 32,30 °C Celsius at 7 study sites. This situation showed how interior temperatures could readily allow VOCs to evaporate and harm employees' health. The vapour pressure of VOCs is influenced by humidity levels, which in turn affect how much of them is released into the atmosphere. At increased humidity levels, some VOCs could become more volatile (Kasemy *et al*., 2019). High humidity can enhance the intake of some VOCs, which could exacerbate neurological and respiratory symptoms. According to reports, VOC emissions increased when the humidity level was raised to 50% (Jung *et al*., 2022). The measured humidity in this study ranged between 63.3% and 69.20%. This suggests a high humidity level at the study site, which will facilitate the evaporation of volatile organic molecules.

There were just two poorly ventilated shoe manufacturing locations (28.57%), but 18 people (38.3%) worked there (tables 2 and 6). Higher VOC concentrations in the air can increase the risk of health impacts by causing inadequate ventilation. Chronic respiratory conditions, inflammation, and other symptoms can result from prolonged exposure to high VOC concentrations brought on by inadequate ventilation (Liang *et al*., 2016). Effective ventilation techniques must be put in place to reduce the exposure of workers to volatile organic compounds (VOCs) (Verniers *et al*., 2023), (Vasile *et al*., 2023). This involves efficiently removing and diluting indoor pollutants, while also ensuring a consistent influx of fresh outdoor air. These measures are crucial for maintaining a healthier and safer working environment (Jung & Kim, 2022; Ramasubramanian, 2022). The concentrations of BTX were measured in ambient air at the seven selected workshops in Medan, as seen in Table 3. The concentrations of benzene (ranging from 0.09 ppm to 2.83 ppm), toluene (1,2 ppm to 178,98 ppm), and xylene (0,11 ppm to 50 ppm) were found at all seven selected sites.

Table 4 shows the percentage of workers exposed to toluene above the ACGIH threshold level value (TLV) at 55.3%, while Figure 1 shows the percentage of workers exposed to benzene at 25.5%. No workshop exceeded the TLV for xylene. The TWA (Time Weight Average) for airborne toluene and benzene concentrations was 20 ppm and less than 0.5 ppm, respectively, whereas the level of xylene was below the TLV (100 ppm) (Kuranchie *et al*., 2019). Similar

Table 3. Level of BTX Exposure in Indoor Ambient Work Environment

	n	Mean	SD	Min – Max
Benzene	7	0,90	1,07	0,09 – 2,83
Toluene	7	39,52	52,97	1,2 – 178,98
Xylene	7	7,67	17,90	0,11 – 50

Source: Primary Data, 2017

Table 4. Percentage of Workers' Exposures Higher than TLV

Parameters	n (%)
Benzene	
> 0,5 ppm	12 (25.5)
≤ 0,5 ppm	35 (74.5)
Toluene	
> 20 ppm	26 (55.3)
≤ 20 ppm	21 (44.7)
Xylene	
> 100 ppm	0
≤ 100 ppm	47 (100)

Threshold limit value (TLV) based on the ACGIH criteria for chemical substances
Source: Primary Data, 2017

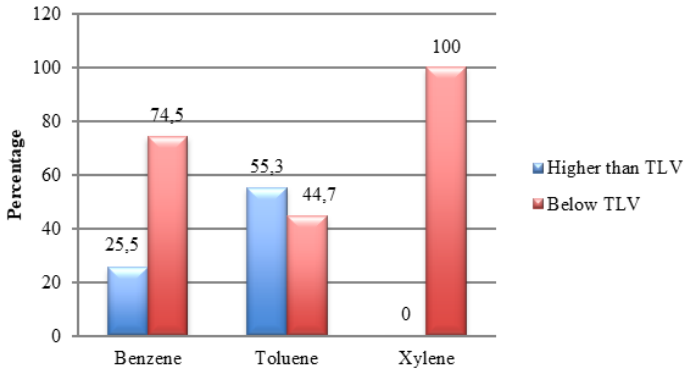

Figure 1. Percentage of Workers' Exposures Higher than TLV

exposure to toluene as observed in our study on tract disorders was also experienced by shoemakers in Mexico, China, and Iran (Azari *et al.*, 2012; González-Yebra *et al.*, 2009; Vermeulen *et al.*, 2004). Toluene and benzene exposure may pose a risk to all shoemakers.

Table 5 shows that dizziness and watery eyes (55.3%), cough (40.4%), sore eyes (29.8%), and ataxia (25.5%) were the top five subjective symptoms in the current study. These were associated with symptoms from illnesses of the respiratory tract, eyes, and central nervous system. Volatile substances like benzene and toluene that are inhaled into the body have an impact on the respiratory tract and central nervous system. Additionally irritating to sensitive tissues, such as the eyes, are these chemicals. A sore throat (33.3%), runny nose (31.3%), issued phlegm (18.8%), shortness of breath (14.6%), snorting nose (6.3%), quick weariness or tightness during exertion (39.6%), and cough (50%), according to Hajrah *et al.*, were the most common symptoms (19). Meanwhile, coughing and colds were the most prevalent respiratory symptoms among employees of footwear craftsmen exposed to toluene vapour, according to Maryantari *et al.* (2020b).

As seen in Table 6, the analysis showed that benzene significantly affected dizziness and watery eyes. Meanwhile, toluene also has a significant association with dyspnea. But the proportion of workers exposed below TLV was higher than that of others who had been exposed to toluene above TLV. So, it can be concluded that toluene was not associated with dyspnea.

Exposure to benzene can cause dizziness and other neurological symptoms because of its detrimental effects on the central nervous system (Bao, 2022; Kasemy *et al.*, 2019; Tongsantia *et al.*, 2021; Werder *et al.*, 2019). Solvents and the

Table 5 Subjective Symptoms Among Shoe Workshop Workers

Subjective Symptoms	n = 47
Dizziness	26 (55,3)
Ataxia	12 (25,5)
Headache	9 (19,1)
Cough	19 (40,4)
Dyspnea	6 (12,8)
Watery eye	26 (55,3)
Sore eye	14 (29,8)

Source: Primary Data, 2017

Table 6 Association between Benzene, Toluene Exposures, and Subjective Symptoms of Shoe Workshop Workers

		% of Workers' Exposures Higher than TLV	% of Workers' Exposures Below TLV	p
Benzene	Dizziness	91.7	57.7	0.003[a]
	Ataxia	25	25.7	1.000[b]
	Headache	16.7	20	1.000[b]
	Cough	58.3	34.3	0.182[b]
	Dyspnea	0	17.1	0.315[b]
	Watery eye	91.7	42.9	0.003[a]
	Sore eye	16.7	34.3	0.302[b]
Toluene	Dizziness	57.7	52.4	0.716[a]
	Ataxia	19.2	33.3	0.270[a]
	Headache	7.7	33.3	0.058[b]
	Cough	42.3	38.1	0.770[a]
	Dyspnea	0	28.6	0.005[b]
	Watery eye	65.4	42.9	0.122[a]
	Sore eye	23.1	38.1	0.263[a]

[a]Chi Square, [b] Fischer's Exact
Source: Primary Data, 2017

volatile organic chemical benzene are easily evaporable into the atmosphere. It can enter the bloodstream through inhalation and travel to various parts of the body, including the brain and neurological system (Bao, 2022; Kasemy *et al*., 2019; Polyong and Thetkathuek, 2022; Tongsantia *et al*., 2021; Werder *et al*., 2019). Exposure to benzene can result in watery and painful eyes because of its irritating qualities and effects on the eye's mucous membranes. When benzene, a volatile organic substance, comes into contact with the eyes, it can cause a variety of eye-related symptoms. It can be released into the air as a vapour. Because of its potent irritating properties, benzene can irritate the eyes when it comes into contact with their soft tissues (CDC, 2019). Numerous symptoms, such as redness, stinging, burning, and watery eyes, might result from this inflammation. In addition to increasing sensitivity to light (photophobia), exposure to benzene may also result in eye irritation and soreness (ATSDR, 2015). The mucous membranes lining the respiratory system and airways are known to be irritated when exposed to benzene (Alford and Kumar, 2021). These soft tissues can become inflamed and irritated when exposed to benzene fumes (Cordiano *et al*., 2022).

Coughing is the body's normal response to an irritant in the airways, and it can be brought on by this irritation. Hajrah *et al*. (2020) found the most common symptom was a cough in 48 informal workers (50%) at a shoe workshop in Bogor, Indonesia.

An examination of the correlation between risk variables and workers' subjective complaints in shoe factories is presented in Table 7. The age of the workers exposed to BTX was the sole factor that affected subjective symptoms, such as headache, dizziness, ataxia, cough, dyspnea, and watery and painful eyes. These employees were discovered to be older than 40. Subjective complaints did not significantly correlate with the other parameters. After analyzing the variables that could affect subjective symptoms, such as age, years of employment, the amount of benzene and toluene in the workplace (parts per million), and the ventilation system's sufficiency, it was discovered that the only variable that affected the acute subjective symptoms—dizziness, ataxia, headache, cough, dyspnea, watery eyes, and sore eyes—was the workers' age. According to this study, people over 40 who were exposed to toluene and benzene ran the risk of experiencing subjective symptoms. This could result from the interaction between age and solvent exposure (Kiesswetter *et al*., 2000). People over 40 who were exposed to xylene and toluene in two paint facilities in Eastern Thailand were shown to be at risk of acquiring psychosomatic symptoms. Psychosomatic symptoms (headache, lethargy, loss of libido, unexplained perspiration, dyspnea, tiredness, palpitations, nausea, vomiting, and appetite loss) were influenced by the age of the workers exposed to xylene and toluene. It was shown that the adjusted odds ratio (aOR) for these symptoms in people over 40 who had been exposed to xylene was 9.5 (95% CI 13.2-68.8). For this symptom category, there was an OR of 8.3 (95% CI 1.2-58.5) for individuals who had been exposed to toluene (Thetkathuek *et al*., 2015). The current study's findings indicate that workers over 40 years of age are more susceptible to these conditions, and safety officials should focus their attention on their well-being.

Table 7. The Risk Factors of The Subjective Symptoms

Risk Factors	Subjective Symptoms		p
	+ (n=34)	(n=13)	
Age			
> 40 years	14 (93.3)	1 (6.7)	0.037[a]
≤ 40 years	20 (62.5)	12 (37.5)	
Work duration			
> 5 years	14 (73.7)	5 (26.3)	0.865[b]
≤ 5 years	20 (71.4)	8 (28.6)	
Adequate ventilation			
No	11 (61.1)	7 (38.9)	0.199[a]
Yes	23 (79.3)	6 (20.7)	
Benzene, n (%)			
> 0,5 ppm	11 (91.7)	1 (8.3)	0.136[b]
≤ 0,5 ppm	23 (65.7)	12 (34.3)	
Toluene, n (%)			
> 20 ppm	19 (73.1)	7 (26.9)	0.900[b]
≤ 20 ppm	15 (71.4)	6 (28.6)	

[a]Fisher's Exact, [b]Chi Square
Source: Primary Data, 2017

Conclusion

We found that benzene and toluene levels were over the threshold level. Smoking habits in the working area are also believed to increase the level of benzene in the workshop environment. Moreover, the temperature and relative humidity of all workshops affected the subjective symptoms. The most prevalent symptoms among workers were eye discomfort (55.3% of respondents), dizziness (55.3%), and coughing (40.4%). The concentration ranges for xylene, toluene, and benzene were 0.11 ppm to 50 ppm, 1.20 ppm to 178.98 ppm, and 0.09 ppm to 2.83 ppm, respectively. Benzene (25.5%) and toluene (55.3%) were the two components most frequently found at levels exceeding the ACGIH (American Conference of Governmental Industrial Hygienists) threshold limit values, based on ambient readings. Of the assessed workshops, only two (28.57%) had a functioning ventilation system. A significant correlation was found between dizziness ($p = 0.003$) and watery eyes ($p = 0.003$) when exposure to benzene exceeded the quality level. Dyspnea, however, was significantly linked to exposure to toluene beyond the allowable limit ($p = 0.005$). Only the worker in the age group over 40 years has subjective symptoms. Therefore, our results suggested that workers should use a cartridge mask to protect their health. Moreover, local exhaust ventilation should be installed to provide a sufficient ventilation system.

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