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Analysis of health risk and respiratory complaints on footwear craftsman exposed to Toluene vapour

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Abstract

Background: The primary effect of toluene on the respiratory tract following inhalation is irritation. This study was conducted to analyze the level of health risks and respiratory complaints due to toluene exposure by footwear craftsmen, in order to get scientific reference for Maximum Contaminant Level and working tenure restriction.

Design and Methods: A total of 51 footwear craftsmen from eight factories participated in this study. The toluene concentration in the work environment was measured according to National Institute of Occupational Safety and Health 1501. Moreover, data were collected using an American Thoracic Society standardized questionnaire to assess respiratory health effects. A characterization of risk model was to analyze the toluene exposure risk and suggest improvements.

Results: The results showed toluene levels were over the Threshold Limit Value 20 ppm (138.88 ppm). The most commonly observed respiratory symptoms included coughing by 81.3% and cold by 85.7%, Symptoms of respiratory irritation by 72.7%, higher among workers who were highly exposed to toluene above the median. This is observed from the opportunity value (P-value) of toluene exposure with the characteristics the workers of each variable which was less than 0.05 work station and working tenure. Maximum Contaminant Level of toluene is 4.59 ppm, a safe working tenure restriction for toluene exposure is maximum 25 years.

Conclusions: The recommended risk control measures include ventilation improvements, personal hygiene and protection of workers through periodic physical examinations.

Introduction

Footwear industry has been playing an important role in human culture throughout history and has been reported to be one of the oldest manufacturing activities with mass production recorded to have started in the late 1850s.[1] In Indonesia it is possible to trace the development of the footwear industry to each of the regions in the country because shoes have been informally found to be one of the labor-intensive export commodities absorbing many workers and playing an important role in the economy of low-income people.

Previous research showed almost 70 percent of the workers aged 20-30 years in the shoe industry of Tasikmalaya, West Java Province, Indonesia, experienced respiratory disorders due to the glue fumes inhaled and exposure to dust for a long period.[2] A number of population-based studies found that workers exposed to toluene had a significantly higher prevalence of respiratory symptoms compared to those that were not exposed.[3,4]

oluene has been found to enter the human body mainly through inhalation and, on rare occasions, by ingestion through contaminated food or through the use of cigarettes correlated by bad personal hygiene. This chemical irritates the mucous membranes of the eyes and respiratory tract causing cough, cough with phlegm, shortness of breath/wheezing, and snot before it reaches the major organ and it affects in the body. In high concentrations, toluene has the ability to cause lung lesions which further leads to permanent airway wall damage and obstructive respiratory disease.[5]

Toluene is a volatile aromatic hydrocarbon being sold freely in the market due to its wide use as a solvent in paints, adhesives, and several other manufacturing processes. Human beings are exposed to the chemical repeatedly in the work environment through inhalation and this mostly leads to negative health effects on the nervous system, respiratory system, kidneys, liver, and heart, while systemic contact with its vapor or liquid has the ability to cause irritation or burning. In extreme cases, it can cause permanent damage to the brain.[1,5,6]

Several informal industries in Surabaya, East Java Province, Indonesia, produce imitation footwear on a small-scale using leather and fabric. In general, the process of making the shoes consists of several stages including cutting, sewing, coloring, coating, and gluing. Some of these processes such as cleaning, polishing, and gluing require the use of volatile organic solvents like toluene,

Significance for public health

Toluene levels over the Threshold Limit Value can cause irritative respiratory tract diseases. Therefore, it is recommended that workplaces are separated from domestic activities whenever possible and the workers are protected from unnecessary exposure. This study describes the level of health risks and respiratory complaints due to toluene exposure by footwear craftsmen in footwear industry.

which has been discovered to be toxic to human health. Moreover, the lack of safety regulations in these small enterprises increases the risk of exposure. Therefore, this research focused on investigating the concentration of toluene in the atmosphere of footwear manufacturing.

The purpose of this research is to assess the health risks associated with the lungs of workers exposed to toluene vapors in the informal footwear industry of Surabaya in order to provide a scientific reference for prevention and control. The specific focus of this study include source identification and hazard exposure levels assessment, toluene exposure risk analysis, respiratory complaints analysis for exposed workers, understanding the Maximum Contaminant Level (MCL), definition of the limitation of work period or risk management formulation based on anthropometric characteristics, especially body weight, and assessment of the magnitude of risk of exposure in the working population.

Design and Methods

The study was conducted in the informal footwear industry located in Surabaya. The research time consists of two stages. The first phase included the identification of the sources and the assessment of hazard exposure levels, as well as an analysis of the respiratory complaints in toluene exposed workers, followed by suggestions for the improvement. The second phase was conducted to determine the Maximum Contaminant level (MCL) and limitation of work period (risk management formulation) based on anthropometric characteristics (especially body weight)[7] and risk characteristics after the improvements suggested in the first stage. Moreover, 51 workers, including those working in non-glue and glue units, were selected using a total sampling method.

Methods of Identifying Sources and Assessing Occupational Hazard

The identification of sources of contamination and assessments of work environment hazards involved the evaluation of toluene exposure by selecting nine sample points at eight work locations where the gluing process is conducted daily and production is continuous throughout the year. The toluene vapor concentration was determined using the NIOSH 1501 method[8]: air samples were obtained using a pump and passed on charcoal, acting as toluene adsorbents. The sampling process was conducted for 60-120 minutes at an airflow rate of 0.2 L/minute and the vapor was analyzed using the Gas Chromatography instrument at Surabaya Occupational Safety and Health Laboratory. Moreover, the toluene vapor concentration measured was compared to the (Threshold Limit Value) - TWA (Time-Weighted Average) from American Conference of Governmental Industrial Hygienists (ACGIH) 2015, which was 20 ppm.[9]

Methods of Analyzing Respiratory Complaints on Workers Exposed to Toluene

The prevalence of respiratory complaints, history of lung health hazard exposure, smoking and masking habits were measured using a simplified Q-18 questionnaire from the American Thoracic Society, with the questions focusing on the detection of neurological disorders. The questionnaires were merged and simplified to aid the filling process while the data obtained were analyzed for the distribution frequency using SPSS software

Methods of Assessing Health Risk due to Toluene exposure

The data and values measured and referenced in the literature review were processed through risk characterization to determine if the chemical exposure poses risks to the human body or not. The Risk Quotient (RQ) was derived from the calculation of Intake (Ink) by individuals exposed to the reference dose (R*f*C). The value of the intake was calculated by multiplying the concentration (C), respiration rate (R), exposure time (tE), exposure frequency (fE), and duration of exposure in the year (Dt) and the result was further divided by individual body weight (Wb) and average period (tavg).[7] The final result, therefore, showed the characteristics of the risk of toluene exposure to workers, maximum contaminant level, and management formulation based on the risk.

$$Risk\ Quotients/RQ = \frac{Intake\ (Ink)}{R\,f\,C}$$

Description:
RQ = Risk Quotient
Intake of toluene = (C x R x tE x fE x Dt)/(Wb x Tavg) (mg/kg.day)
R*f*C = Reference of Concentration (IRIS US-EPA)
C = toluene concentration (mg/m^3)
R = respiration rate (m^3/hour)
tE = exposure time (hour/day)
fE = average exposure in a year (day/year)
Dt = exposure duration (years)
Wb = weight (kg)
Tavg = average of toluene exposure (non-carcinogen) = 30 years x 365 days / year

Results and Discussions

General Characteristics of Workers

Worker characteristics were obtained from the results of the questionnaire. In order to analyze the relationship between the variables, the Chi-square test was used for gender, work stations, and smoking habits, whereas the Mann Whitney test was used for age, education levels, exposure duration (Table 1). The results showed there was a relationship between the variables of work stations, exposure duration with toluene levels, age with health risks. This is observed from the opportunity value (P= value) of each variable which was less than 0.05.

Most of the workers are male because the acceleration of the production process requires speed and energy and the choice of working in the footwear industry was found to be generational with the business being passed on from father to son. However, both male and female workers are at equal risk of being exposed as long as they are directly in contact with the raw materials. Most of the women and children found in the work stations are mainly wives, children or other family members of the owners or workers and their presence is due to the integration of residence into the workplace, which means they are also potentially exposed. It has been reported that toluene has the ability to affect women's reproductive health[5] and the footwear industry has also been recorded by the International Labour Organization (ILO) as one of the worst establishments engaging in the practices of child labor.[2]

Most workers aged between 46-65 years, this is mainly due to the low level of education and the fact that the owner takes an

active part in the production process, especially during the gluing, and since the business is generational, the experience of shoemaking is often related to a person's age. Moreover, the interviews conducted showed a larger percentage of the respondents started their career at a very young age (12 years old). This, therefore, means they have been exposed to hazardous chemicals for a very long period and are at greater risk of health problems.

Another factor observed to be causing an increase in health risks is the inadequate knowledge of the dangers of the substances contained in the adhesives and the reluctance to wear Personal Protective Equipment (PPE), such as nose covering device, in the work environment, because they feel it is uncomfortable and interferes with breathing. Several studies have reported toluene to be highly volatile and this makes it easy to be inhaled through the respiratory tract.[3-5] Moreover, the workers were observed to prefer using fingers to brushes while joining materials to make shoes because it is more practical. However, toluene is also absorbed through the skin[5] and this increases the health risks for the workers. Many of the non-glue workers, predominantly women, are often involved in glue work especially in a situation when lots of production is required in a short time. Besides, the lack of insulation between different units, smoking habits without any restriction policy, eating in a stuffy workspace, and lack of ventilation also contribute to the significant exposure of non-glue workers. Therefore, it is recommended this set of workers is placed outside the working place to reduce the risk of exposure.

More than half of the workers have a working period of more than 5 years, indicating a fairly low turnover rate, and according to the explanation provided by an owner, this is due to the fact that the initial intention of engaging in the footwear industry was to continue the family business. Moreover, a larger percentage of the respondents were graduates of elementary and junior high schools and the interviews conducted also showed they have been exposed to toluene for a long time considering the periods the have worked both in the field and industry.

Concentration of Toluene Exposure

The concentration of toluene in the eight work locations varied from 0.21 ppm – 138.88 ppm with a median value of 4.25 ppm. Moreover, most of the toluene exposure (88.9%) were found to be lower than the 20 ppm TLV-TWA concentration recommended by ACGIH (Table 2).[9] However, the variation in the level of toluene in each work location can be due to the amount of shoe production, type of raw materials used, work methods, inadequate ventilation, and work station either indoor or outdoor.[10,11]

The concentration of toluene was found to be different in each work location due to several factors including the number of shoes produced, the type of raw materials used, and the quantity of adhesive. According to Azari (2012), the amount of glue used affects the concentration of toluene. However, the number of shoes produced is directly proportional to the quantity of glue used.[10] This means the production of a high number of shoe pairs requires the use of more glue which further evaporates into the air to increase its toluene levels. It was observed that there was no air exchange in almost all the work locations due to the closure of the windows, which led to the absence of natural ventilation. The only air available was through the fans placed in front of workers and the entrance to the workstation. Therefore, it is possible the toluene levels of 4.4 and 1.9 found, above the specified threshold value, are caused by inadequate ventilation and air exchange systems at the site.[11] Moreover, there is inadequate space, dirty equipment and raw materials, and hot temperature of 34.1°C at the workstation, all of which makes the exposure to the chemical easy. Most of the respondents also reported they learned to use the glue directly from the original container or in a cut bottle while the remaining product is left in the open state.

The lack of proper storage for waste materials and bad habits of sticking the remains of glue on bottles/glasses are causes of high levels of toluene in the work environment.[12,13] However, another source of the chemical is cigarette smoke and most of the workers were observed to be engaging in this health-deteriorating act while working.

The best method to reduce the level of toluene in the air at the workplace is through the improvement in the ventilation or by placing the glue work in an open space. Other recommended efforts involve the use of activated carbon from candlenut shell waste[14] as well as the ore putting in the room plants such as *Sansevieria sp*., *Anthurium andreanum, Dracena deremensis*, *Tradescantia pallida, Opuntia microdasys*, *Hedera helix*[15,16] due to their ability to reduce toluene exposure.

Table 1. Characteristics of workers, Chi-square and Mann Whitney analysis test results of toluene exposure and health risks (RQ)

Indicator	Category n	Category %	Mean/ Median	Range	Toluene p-value	RQ p-value
Gender						
Male	34	66.7			1.000	0.803
Female	17	33.3				
Work stations						
Indoor	3	37.5			0.000	0.003
Outdoor	5	62.5				
Smoking habits						
No	11	32.4			0.921	0.728
Yes	23	67.6				
Age						
Young (≤ 35 year)	11	21.6	43.2	21 - 62	0.943	0.002
Adult (> 36 year)	40	78.4	(mean)			
Education levels						
Junior high school education	34	66.7			0.151	0.084
Senior high school education	17	33.3				
Duration (years)						
≤ 5 year	7	13.7	14.0	1 - 35	0.029	0.082
> 5 year	44	86.3	(Median)			

Analysis of Respiratory Complaints in Exposed Workers

A chi-square test was conducted to determine the relationship between the dependent variables of respiratory complaints and the independent variable, toluene exposure and a P-value<0.05 was discovered as shown in Table 3. This means there was a significant relationship between toluene exposure and cough, cough with phlegm, colds, and respiratory tract disorders. Furthermore, education was considered to affect respiratory complaints as evidenced with the P-value <0.05 observed for cough and wheezing.

The concentration of toluene in the majority of exposed workers was found to be less than TLV-TWA 20 ppm and most complaints were made by indoor workers. The room was observed to have low roofs with improvised ventilation and this made it easy for the toluene vapor to circulate indoors and to be inhaled by workers.[11] Moreover, they were found not to be using Personal Protective Equipment (PPE) and are bare-chested while working and this makes the chemical stuck on their skin.

There was no relationship established between the gender and respiratory complaints and this was associated with the fact the production is conducted in one room without insulation which easily exposes everybody. Moreover, education was found to be affecting respiratory complaints as evidenced by the complaints of cough and wheezing by the workers.

Maximum Contaminant Level and Limitation of Work Period

The results showed 10 of the workers had an unsafe health risk level with RQ ≥ 1 after they have been exposed to toluene as shown in Table 2. Moreover, the Maximum Contaminant Level (MCL) for the toluene exposure with non-carcinogenic effects was found to be 4.59 ppm, a safe working tenure restriction for toluene exposure is maximum 25 years.

Conclusions

The recommended risk control measures include ventilation improvements, personal hygiene and protection of workers through periodic physical examinations.

Table 2. Toluene levels and risk characteristics.

Work Station	Toluene level (ppm)	Risk characteristics			
		RQ < 1		RQ ≥ 1	
		n	%	n	%
AM	4.41	5	71.4	2	28.6
Sr	11.26	5	83.3	1	16.7
H.N	0.21	6	100.0	0	0.0
SD (1) SD (2)	0.97 0.68	8	100.0	0	0.0
Kh	0.88	7	100.0	0	0.0
7Mn	138.88	2	50.0	2	50.0
8M.H	10.76	3	28.6	5	71.4
9Wh	4.25	6	100.0	0	0.0
Mean	19.14	0.79			
Median	4.25	0.21			
Minimum	0.21	0.02			
Maximum	138.88	10.99			
Std. deviation	45.10	1.94			

Table 3. Chi-square analysis test results between Toluene exposure and respiratory complaints.

Symptom	Category	Toluene exposure at work station				P-value
		Outdoor		Indoor		
		n	%	n	%	
Cough	No	18	51.4	17	48.6	0.028
	Yes	3	18.8	13	81.3	
Cough with phlegm	No	21	45.7	25	54.3	0.049
	Yes	0	0.0	5	100.0	
Wheezing	No	17	48.6	18	51.4	0.112
	Yes	4	25.0	12	75.0	
Sneezing	No	17	47.2	19	52.8	0.174
	Yes	4	26.7	11	73.3	
Colds	No	19	51.4	18	48.6	0.016
	Yes	2	14.2	12	85.6	
Symptoms of respiratory irritation	No	12	66.7	6	33.3	0.006
	Yes	9	27.3	24	72.7	

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