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A case study: Chemical health risk assessment in three footwear small industries in Bogor-Indonesia year 2019★

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ABSTRACT

Objective: This study aimed to analyse the health risks related to the use of chemicals among workers in small footwear factories.

Methods: This was a descriptive case study conducted in three selected small footwear factories located in Ciomas, Bogor, Indonesia. The assessment was conducted using the chemical health risk assessment method by the Department of Safety and Health Malaysia Year 2018.

Results: Results showed that the level of risk of chemicals through inhalation fell on the moderate and high-risk categories, indicating that high exposure could lead to carcinogenic effects. Dermal exposure was categorised as moderate risk, causing such health effects as skin and eye irritation.

Conclusion: Factory X, Y, and Z have been found to have a significant risk of hazardous chemical exposure (i.e., benzene and toluene), specifically at the glueing stations, either from inhalation or dermal contact.

Introduction

Small- and medium-sized enterprises (SMEs) play a significant role in providing jobs and economic growth. According to the World Bank, SMEs contribute up to 60% of the total employment and 40% of gross domestic product (GDP).[1–3] In Indonesia, SMEs contribute 97.16% to job creation and 58.65% to the national GDP.[2] However, despite their economic significance and the number of individuals dependent on them for living, focus on occupational safety and health (OSH) in this sector is poor.[3]

According to the International Labour Organisation (ILO), work-related diseases inflicted a substantial mortality burden in 2008, and there were 2.02 million deaths caused by work-related diseases and 321,000 by work-related accidents.[4,5] The small industry is over-represented in work-related deaths compared to larger enterprises, but under-represented in these organisations' focus on OSH issues. Accidents are 20% more frequent in the small industry than in larger enterprises with more than 100 workers and 40% more frequent than in enterprises with more than 1000 workers.[3,6,7]

OSH implementation barriers in small industries include the following: lack of workforce, financial capacity, technological resources, and establishment of OSH committees.[5,8–10] They also possess a lower capacity to assess and control risks compared with larger enterprises effectively.[11,12]

Footwear manufacturing in Indonesia is one of the industrial sectors that have demonstrated a sustainable growth level and is concentrated mainly in a small cottage industry.[13] Workers in the footwear manufacturing industry are exposed to an extensive range of hazards such as complex mixtures of organic solvents, which may enter their system through inhalation and dermal routes.[13,14]

Todd et al. (2008) found an association between exposure to chemical hazards and adverse health outcomes in footwear manufacturing industries exposure.[14] Some studies conducted in the footwear manufacturing small Industry in Bogor-Indonesia found that the average benzene and toluene levels were over the threshold limit value (TLV).[15–17] The manufacturing process used in the footwear industry uses hazardous chemicals, and the associated risks are poorly managed. OSH risk assessment should be given much more priority in SMEs.[18] Therefore, this study analysed the health risks related to the use of chemicals among workers in this sector.

Methods

The study was a descriptive case study conducted in three selected small footwear factories located in Ciomas, Bogor, Indonesia. The total number of factory X, Y, and Z employees are 13, 12, and 8 workers respectively. Those factories were categorised as small industries according to Indonesian business classification.[19] We selected two workers for each factory samples per factory that we determined to represent exposure to the maximum risk employee(s).

This study used the methodology from 'Assessment of the Health Risks Arising from the Use of Hazardous Chemicals in the Workplace,' by the Department of Occupational Safety and Health (DOSH) in Malaysia.[20] We limited the routes of exposure to inhalation and dermal route. For the inhalation assessment, we conducted personal air sampling using the NIOSH manual of analytical methods 1501.[21] The chemicals concerned in this study were benzene and toluene that its vapor concentrations were measured and then compared with the Indonesian occupational exposure limit (OEL), governed by Regulation of Ministry of Labour Number 5 the Year 2018 (TLV-TWA Benzene: 0.5 ppm; toluene: 20 ppm).[22]

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Table 1
Hazard rating for inhalation exposure.

HR	Hazard classification	H-code
5	Acute toxicity category 1 (inhalation)	H330
	Carcinogenicity category 1A	H350, H350i
	Mutagenicity category 1A	H340
	Reproductive toxicity category 1A	H360, H360D, H360F, H360FD, H360Fd, H360Df
	Specific target organ toxicity – single exposure category 1	H370
4	Acute toxicity category 2 (inhalation)	H330
	Carcinogenicity category 1B	H350, H350i
	Mutagenicity category 1B	H340
	Reproductive toxicity category 1B	H360, H360D, H360F, H360FD, H360Fd, H360Df
	Effects on or via lactation	H362
	Specific target organ toxicity – single exposure category 2	H371
	Specific target organ toxicity – repeated exposure category 1	H372
	Respiratory sensitisation category 1	H334
3	Acute toxicity category 3 (inhalation)	H331
	Carcinogenicity category 2	H351
	Mutagenicity category 2	H341
	Reproductive toxicity category 2	H361, H361f, H361d, H361fd
	Specific target organ toxicity – repeated exposure category 2	H373
	Specific target organ toxicity – single exposure category 3 (respiratory tract irritation)	H335
2	Acute toxicity category 4 (inhalation)	H332
	Specific target organ toxicity – single exposure category 3 (narcotic effect)	H336
1	Chemical not otherwise classified	H333

Source: Department of Occupational Safety and Health Malaysia (DOSH) (2018).

Chemical hazard information was obtained from the European Chemicals Agency (ECHA) to determine the hazard rating (HR) for inhalation and hazardous properties for dermal.[23,24] The HR for inhalation is outlined in Table 1. We listed the HR assigned and selected the highest as the HR. The hazardous properties are outlined in Table 2. All the hazard classification of chemicals is following the Globally Harmonized System of Classification and Labelling of Chemicals.[25]

The evaluation for inhalation exposure was conducted quantitatively, while dermal exposure was performed qualitatively. The exposure rating (ER) was determined using the exposure measurement data based on the time-weighted average (TWA) of a typical working day. The ER for inhalation exposure is outlined in Table 3. The qualitative evaluation of dermal exposure was measured by determining the extent of dermal contact (outlined in Table 4) and dermal contact duration, categorised as being above or below 15 min per shift.

The level of risk for inhalation exposure was based on the risk rating (RR) derived from the HR and ER outlined in Table 5, and that of the level of risk for dermal exposure in Table 6.

Table 2
Hazardous properties relevant to dermal exposure.

Hazardous properties	Corresponding hazard classification and H-code
Irritation	• Skin corrosion or irritation category 2 (H315) • Serious eye damage or eye irritation category 2 (H319)
Corrosion	• Skin corrosion or irritation category 1 (H314) • Serious eye damage or eye irritation category 1 (H318)
Sensitisation	• Skin sensitisation category 1 (H317)
Acute toxicity	• Acute toxicity (dermal) category 1 (H310) • Acute toxicity (dermal) category 2 (H310) • Acute toxicity (dermal) category 3 (H311) • Acute toxicity (dermal) category 4 (H312)
Skin-absorption and other properties	• Specific target organ toxicity-single exposure category 1* (H370) • Specific target organ toxicity-single exposure category 2* (H371) • Specific target organ toxicity-repeated exposure category 1* (H372) • Specific target organ toxicity-repeated exposure category 2* (H373) • Carcinogenicity category 1*(H350) • Carcinogenicity category 2*(H351) • Germ cell mutagenicity category 1*(H340) • Germ cell mutagenicity category 2*(H341) • Reproductive toxicity category 1*(H360, H360D, H360F, H360FD, H360Fd, H360Df) • Reproductive toxicity category 2*(H361, H361f, H361d, H361fd)

Source: Department of Occupational Safety and Health Malaysia (DOSH) (2018).

Table 3
Exposure rating determination.

Time-weighted average (TWA)	Exposure rating (ER)
≥PEL	5
≥0.75 PEL but <PEL	4
≥0.5 PEL but <0.75 PEL	3
≥0.1 PEL but <0.5 PEL	2
<0.1 PEL	1

Source: Department of Occupational Safety and Health Malaysia (DOSH) (2018).

Table 4
Extent of dermal contact.

Extent of Contact	Observation/Condition
Small	• Small-area of contact with chemicals capable of skin absorption, skin sensitising or causing damage to the dermal e.g. limited to palm (intact skin) (<2% or 0.04 m^2); • No indication of any skin conditions; intact/normal skin; • No contamination of skin or eyes.
Large	• Contact with chemicals capable of skin absorption, skin sensitising or causing damage to the dermal; • Gross contamination with chemicals capable of skin absorption, skin sensitising or causing damage to the dermal – skin soaked or immersed in chemicals; • Area of contact not only confined to hands but also other parts of body. Skin area >2%; • Follicle rich areas; • Skin dryness or detectable skin conditions

Source: Department of Occupational Safety and Health Malaysia (DOSH) (2018).

Table 5
Level of risk for inhalation exposure.

Level of risk	RR value
Low risk	1–4
Moderate risk	5–12
High risk	15–24

Source: Department of Occupational Safety and Health Malaysia (DOSH) (2018).

Table 6
Risk matrix for dermal exposure.

Hazardous properties	Relevant H-code	Duration/extent of skin contact			
		Short-term (<15 m)		Long-term (≥15 m)	
		Small area	Large area	Small area	Large area
Irritation	H315	L	M1	M1	M2
	H319	M1		M2	
Corrosion	H314	M1	H1	H1	H2
	H318	H1		H2	
Sensitisation	H317	L	M1	M1	H1
Acute toxicity	H312	M1	M1	M2	H1
	H311	M1	M1	M1	H1
	H310	H1	H1	H1	H2
Combination effect*	H310 with H314	H1	H1	H1	H2
Skin absorption and other properties**	H351	M1	M1	M2	H1
	H350	H1	H1	H1	H2
	H341	M1	M1	M2	H1
	H340	H1	H1	H1	H2
	H361, H2361f, H361d, H361fd	M1	M1	M2	H1
	H360, H360F, H360D, H360FD, H360Fd, H360fD	H1	H1	H1	H2
	H370	H1	H1	H1	H2
	H371	M1	M2	M2	H1
	H372	M1	M1	M2	H1
	H373	L	M1	M2	M2

L: low risk; M: moderate risk; H: high risk.
* For chemicals classified both as acute toxicity (dermal) category 1 or 2 and skin corrosion or irritation category 1 (1A/1B/1C).
** If indicate as skin absorption or effect is due to dermal exposure.

Table 7
Determination of the HR and hazardous properties.

Route of exposure	Parameter	Classification	H-code	HR/hazardous properties
Inhalation	Benzene	Carcinogenicity 1A	H350	5
		STOT RE* 1	H372	4
		Mutagenicity 1B	H340	4
	Toluene	STOT RE* 2	H373	3
		Reproductive Toxicity 2	H361d	3
		STOT SE** 3	H336	2
Dermal	Benzene	Eye irritant 2	H319	Irritation
		Skin irritant 2	H315	Irritation
	Toluene	Skin irritant 2	H315	Irritation

* STOT RE: Specific target organ toxicity – repeated exposure.
** STOT SE: Specific target organ toxicity – single exposure.

Result

Three factories were selected, namely factory X, Y, and Z. Most of the workers was male, ranging from 18 to over 60 years of age and have worked in their respective factories for more than a year. Most of them have worked in the industry throughout their careers and demonstrate a limited educational achievement level.

In the process of hazard identification, walkthrough surveys, and discussions with employees and employers were conducted. In general, footwear manufacturing involves four processes: preparation, stitching, assembling, and finishing. The stitching and assembling process had the most significant risk of occupational chemical exposure. According to the safety data sheet and data from previous studies, the organic solvents that were used for diluting the adhesives in Ciomas footwear small industry contained benzene and toluene.[16,17,26]

The glue application method increased the likelihood of solvent exposure via inhalation and dermal absorption to the glueing stations' workers. Since the adhesives need to be heated for curing the glue, the solvent evaporation is accelerated. We also found that the potential of organic vapor exposure was exacerbated by poor ventilation. Wall exhaust fans were used to assist with airflow but were ineffective. Personal protective equipment (PPE) was not provided, and almost all workers applied glue with their bare hands; only a few used a brush or spatula. Taking all these factors into account confirmed that the glueing stations' workers are exposed to hazardous chemical solvents via both respiratory and dermal routes. In order to assess health risks associated with chemical exposure, the HR and the ER of benzene and toluene were determined. The results for the HR determination are shown in Table 7.

Table 8 shows the TWA value and the ER from the measurement results of benzene and toluene exposure of the six sampled workers.

Table 9 and Table 10 show the results of our CHRA for benzene and toluene.

Discussion

Footwear factories in the sub-district of Ciomas are home-based industries. Previous studies found benzene and toluene are parts of the adhesives and solvents' ingredients in Ciomas footwear factories, at about 1.34–1.52% for benzene and 73.72–76.79% for toluene.[16] In this study, we found that health risks caused by benzene exposure at the glueing stations of factory X and Z were categorised as high risks, while those at factory Y were found to

Table 8
Exposure rating results.

Factory	Worker	TWA Benzene (ppm)	ER Benzene	TWA Toluene (ppm)	ER Toluene
X	1	0.64	5	16.00	4
	2	1.04	5	27.47	5
Y	3	0.05	2	31.14	5
	4	0.07	2	21.89	5
Z	5	0.32	3	55.67	5
	6	0.27	3	56.63	5

Table 9
CHRA for benzene and toluene exposure through inhalation.

Parameter	HR	ER						RR					
		SME X		SME Y		SME Z		SME X		SME Y		SME Z	
		1	2	3	4	5	6	1	2	3	4	5	6
Benzene	5	5	5	2	2	3	3	25	25	10	10	15	15
Toluene	3	4	5	5	5	5	5	12	15	15	15	15	15

Table 10
CHRA for benzene and toluene exposure through dermal.

Parameter	Classification	Hazardous properties	Exposure		RR	Level of risk
			Duration	Area skin contact		
Benzene	Eye irritant 2 – H319	Irritation	Long term	Small	M2	Moderate
	Skin irritant 2 - H315	Irritation	Long term	Small	M1	Moderate
Toluene	Skin irritant 2 - H315	Irritation	Long term	Small	M1	Moderate

be moderate. Those risks were partially due to benzene's high HR (HR = 5) because benzene is confirmed as a carcinogen.[16,23,25,27,28] Another factor was the ER of benzene, which were 5 and 3 at factory X and Z, respectively, above the OEL. However, the concentration of benzene at factory Y was lower than in factory X and Z (ER = 2). Long-term (≥1 year) exposure to benzene can harm the bone marrow, resulting in anaemia and excessive bleeding.[27]

On the other hand, toluene is less hazardous than benzene, with lower toxicity (HR = 4). Prolonged exposure to toluene can lead to central nervous system damage, sexual function, fertility impairment, and aspiration toxicity.[24,29,30] Due to the high exposure level of toluene at the glueing stations of factory X, Y, and Z (ER = 4–5), it is categorised as high risk.

Even though factory X, Y, and Z utilise hazardous chemicals in their work processes, we found no separation between hazardous and non-hazardous areas. Therefore, health risks caused by benzene and toluene exposure may also develop to other groups of workers in that factory. Furthermore, there was also a lack of ventilation, OSH awareness, and even PPE. Analogous with our findings, Pastorino et al. (2004) found that small enterprises' environmental conditions are usually unsatisfactory and caused by the lack of available rooms, safety ranges, fixed pathways, and lighting. Small enterprises generally do not pay much attention to the working conditions at the design stage. Therefore risk controls may be little to none, mostly limited to PPE only.[16] Todd et al. (2008) reported that the prevalence of symptoms after being hired was much higher than the prevalence of symptoms before being hired for workers in footwear industries. This result implies that there is an association between exposure to chemical hazards and adverse health outcomes.[14]

For dermal exposure assessment, according to the Agency for Toxic Substances and Disease Registry (ATSDR), dermal effects, including skin and eye irritation, can occur after benzene exposure. Dermal contact with toluene can cause skin damage because it can remove lipids from the skin. Workers exposed to solvent mixtures, in which toluene is the main component, have been found to have skin problems on their hands. Moreover, eye irritation in humans can occur after exposure to toluene vapor in the workplace.[29]

Chemical exposure can also come from the hand application of glues to the footwear and equipment pieces as they are assembled.[14] Almost all workers in the footwear manufacturing SMEs apply glue with the palms of their bare hands. According to the workers' interviews, using their hands instead of a brush or spatula was more effective. However, they also admitted that their palms would feel hot when performing the glueing process and sometimes peel off after finishing the process.

Conclusion

Factory X, Y, and Z have a significant risk of hazardous chemical exposure (i.e., benzene and toluene), specifically at the glueing stations. The existing control measures at those factories are poorly managed. We found that the health risks from chemical exposure through inhalation are more significant than those from dermal exposure. The level of risk of chemical exposure through inhalation fell under the moderate and high-risk categories. Long-term exposure to benzene may cause cancer and harmful effects on the bone marrow. While, through the dermal route fell under moderate risk, leading to skin and eye irritation.

No effective control measures were found in the workshops. Therefore, we recommend that OSH control measures should be established. Chemical exposure through inhalation can be minimised through proper ventilation, providing workspace separation, and PPE, such as masks. Gloves should be provided to minimise the dermal exposure they would receive. Workers should also be given proper OSH awareness regarding their overall work process.

Conflicts of interest

The authors declare no conflict of interest.

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