Safe Concentration of Benzene Exposure as Referenee for Determining Threshold Limited Value in Enviromental Working

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Abstract

Background: The aim was to measure the limits of the safe concentration of benzene in the shoe home industry in Romokalisari Surabaya.

Method: The study was pre-experimental study with single group design. Samples taken were 25 workers at shoe home industry in Romokalisari, Surabaya. To determine the safe concentration of benzene for workers obtained data on weight of experimental animal (W animal), body surface of experimental animals (BSA animal), weight of workers (W), height of workers (h), body surface area of workers (BSA), breathing rate of workers (BR), working time (t), concentration benzene, Animal Km, Human Km, NOAEL, and safe human dose (SHD).

Results: The average measurement of benzene concentration was 1.98 ppm (6.34 mg / m^3), which means it was above the threshold value (TLV) at Indonesia. The safe limit value of benzene concentration of 0.0275 ppm also exceeds the stipulated level of 0.009 ppm daily for acute effects and 0.003 ppm daily for chronic effects.

Conclusion: Control efforts are needed so that workers are protected so they are not adversely affected by benzene exposure. The recommendation such as use appropriate personal protective equipment and plant a number of ornamental plants that can absorb and reduce the concentration of benzene.

Keyword: *Benzene concentration, Shoe home industry, Safe concentration, Workers.*

Introduction

Community demand for various necessities of life continues to increase such as the demand for shoes. To meet the increasing demand, the shoe industry must provide sufficient stock to prevent inequality. The use of chemicals can interfere with the health of shoe craftsmen includes the use of glue whose contain of benzene, which have an impact on health if continuously inhaled for a long time[1]. Benzene is a liquid that is colorless, evaporates very quickly in the air, and difficult to dissolve in water[2]. Benzene is a raw material for making plastics, resins, synthetic fibers, dyes, and also a component of crude oil[3]. Pathway of benzene exposure can be through the skin, respiratory tract, mouth continues to the digestive tract[4]. A person who is exposed to high levels of benzene can experience several signs and symptoms, including drowsiness, dizziness, rapid or irregular heartbeat, headaches,

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tremors, confusion, unconsciousness, until death[5]. Benzene can cause a decrease in blood cell production which is a result of a disruption in the spinal cord[6].

The American Conference of Government Industrial Hygienists (ACGIH) and Regulation of Threshold Limit Value at Indonesia set the threshold value of benzene in the workplace that was permitted was 0.5 ppm (1.6 mg/m^3)[7-8]. National Institute for Occupational Health and Safety (NIOSH) set the recommended exposure limit for 8 hours of work at 0.1 ppm (0.32 mg/m^3)[9]. ATSDR set the maximum limit for benzene exposure is 0.009 ppm (0.028 mg/m^3) per day which can have an acute effect and 0.003 ppm (0.009 mg/m^3) per day which can have a chronic effect[2]. The most vulnerable population to the accumulation of benzene exposure is shoe home industry workers (shoe craftmens). This is because workers work every day at that place so continuous exposure can accumulates while give impact to high concentration of benzene in the workers' body.

Previous research on gas station workers revealed the concentration of benzene at gas stations both in the operator and administration area was 0.02 ppm (0.06 mg / m^3), which means it was still below the value threshold (TLV) at Indonesia[10]. However, based on manual calculations the limit of benzene concentration is 0.03 ppm. This value if according to the minimum risk level of ATSDR, exceeds the set limit of 0.009 ppm per day for acute effects and 0.003 ppm per day for chronic effects[2]. Unfortunately, research of risk assesment is still limited especially at Indonesia. Safe concentration guidance also based on foreign source such ACGIH and EPA. However to calculate safe concentation was based by workplace condition and absolutely another workplace have difference conditions such as temperature or humidity. We need an measured standart for this conditions especially in shoe home industry at Indonesia. Based on the background above, the aim of this study was to measure the limits of the safe concentration of benzene at shoe home industry in Romokalisari Surabaya.

Method and Materials

The study was pre-experimental study with single group design. Samples taken were 25 workers at shoe home industry in Romokalisari Surabaya. The inclusion criteria in this study were male and female workers who had worked in the Romokalisari shoe home industry for > 10 years and were willing to be used as research respondents. Measurement of benzene concentration in the workplace air were carried out at five spots in this industry. The research technique starts from collecting secondary data related to work processes which include chemicals in the work area and the number of workers involved. Then, collecting primary data in the form of benzene concentrations in the workplace air, length of work, and workers weight. In addition, primary data collection was carried out on experimental animals that is white mice.

Variable of this research were benzene concentration in the workplace, weight of white mice, body surface of white mice, worker body's weight, worker height, respiration rate of workers, length of day working, body surface area of workers, highest dose of toxin without experimental animal effects (No Observed Adverse Effect Level/NOAEL), Km factor in animals (Animal Km), Km factor in workers (Human Km), safe dose limit of toxins for workers (Safe Human Dose/SHD), and safe concentration of benzene in the air for workers (Safe Concentration).

Data of benzene concentrations in the air in the workplace were obtained using Coconut Shell Charcoal and analyzed by Gas Chromatography (GC) according to the NIOSH 1501 method. While, other variables were obtained by doing indepth interviews with workers, and counting manually. Data analysis in this study was carried out by using quantitative data analysis manually to determine the safe concentration of benzene for workers at shoe home industry in Romokalisari Surabaya.

Results

Characteristics and Body Surface Area (BSA) of Experimental Animal (White Mice)

In general, the human response to toxicity is qualitatively similar to the response of animals so that it becomes the basis of extrapolation from animal to human data. In Table 1 shows that characteristics of experimental animal is white mices' weight with average W (kg) is 0,1407 and average BSA is 0,02418.

Based on weigth of white mices, then the body surface area of white mice can be calculated using the formula below[11-13]:

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Based on weigth of white mices, then the body surface area of white mice can be calculated using the formula below[11-13]:

$$Animal\ BSA = 0.09\ x\ W^{0'67}$$

Explanation:

BSA : Body Surface Area (m^2)

W : Weight (kg)

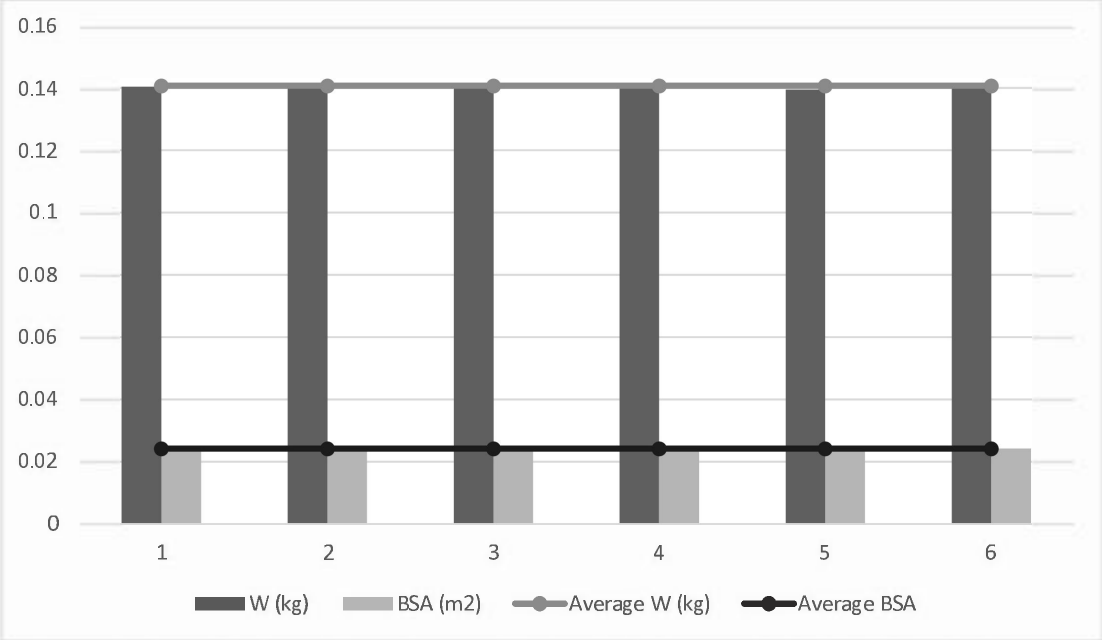

Figure 1. Distribution of Experimental Animal's Characteristics (White Mice)

B. Characteristics of Workers (Body Surface Area and Breathing Rate)

Based on data on body weight and height of workers, the body surface area and the respiratory rate of workers can be calculated using the following formula[11]:

1. Body Surface Area of Workers

$$BSA = \sqrt{\frac{W\ x\ h}{3600}}$$

Explanation:

BSA : Body Surface Area (m^2)

W : Weight (kg)

h : Height (cm)

2. Breathing Rate of Workers

$$BR = \frac{53 x \ln W - 69}{24}$$

Explanation:

BR: Breathing Rate (m^3/hour)

W : Weight (kg)

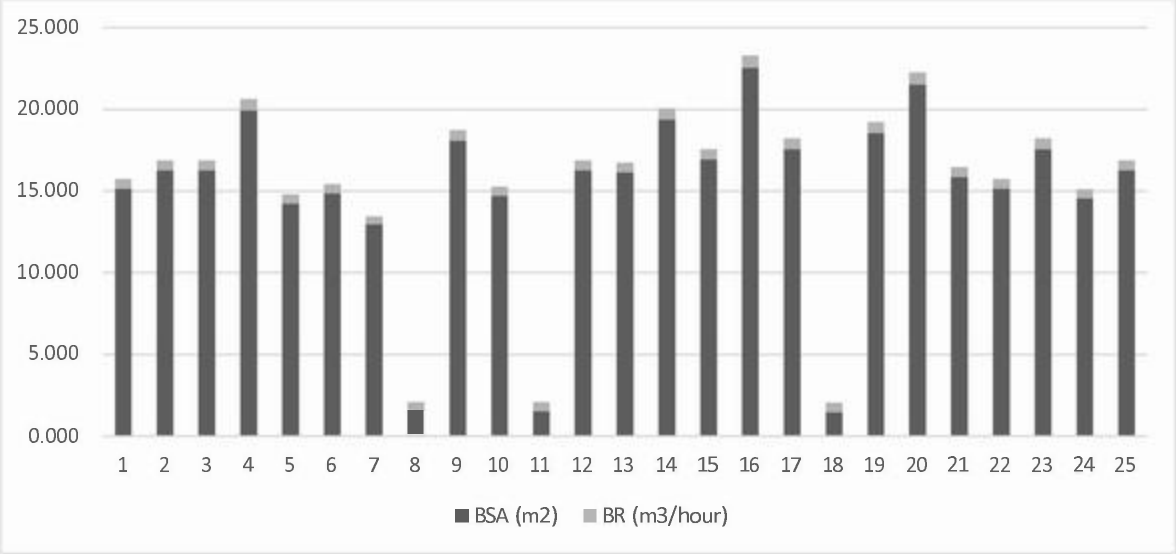

Figure 2. Distribution of Workers' Characteristics (Body Surface and Breathing Rate)

In Table 2, calculation analysis of body surface area and breathing rate of workers shows that the average of workers' body surface area is 1.6655 m^2 and the average of workers' breathing rate is 0.6229 m^3/hour.

C. Benzene Concentration

Table 1. Distribution of Benzene Concentration in The Shoe Home Industry Romokalisari Surabaya

Sample	Results of Measurement		TLV	
	ppm	mg/m^3	ppm	mg/m^3
1st Spot	0.012	0.04	0.5	1.6
2nd Spot	0.018	0.06	0.5	1.6
3rd Spot	0.35	1.12	0.5	1.6
4th Spot	0.40	1.27	0.5	1.6
5th Spot	2.33	7.44	0.5	1.6

Based on the measurement results, benzene concentration tat three spots of this shoe home industry have benzene concentration above the threshold value (TLV). The average of benzene concentration at shoe home industry is 0.622 ppm (1.99 mg/m^3). However, the concentration of benzene in this shoe home industry are above the minimum risk level (MRL) set by ATSDR i.e. acute exposure (≤14 days) = 0.009 ppm, moderate exposure (15-365 days) = 0.006 ppm, and chronic exposure (≥365 days)= 0.003 ppm.

D. Animal Km and Human Km

Determining the safe limits of toxin doses for workers begins with the calculation of Animal Km and Human Km[11].

1. Animal Km

$$Animal\ Km = \frac{W\ animal}{BSA\ animal}$$

Explanation:

Animal Km : Km Factors in Animal

W : Weight of Experimental Animal (White Mice) (kg)

BSA : Body Surface Area of Experimental Animal (White Mice) (m2)

The results of Animal Km calculations in Table 4, show that the average of Animal Km in experimental animals is white mice of 5.81.

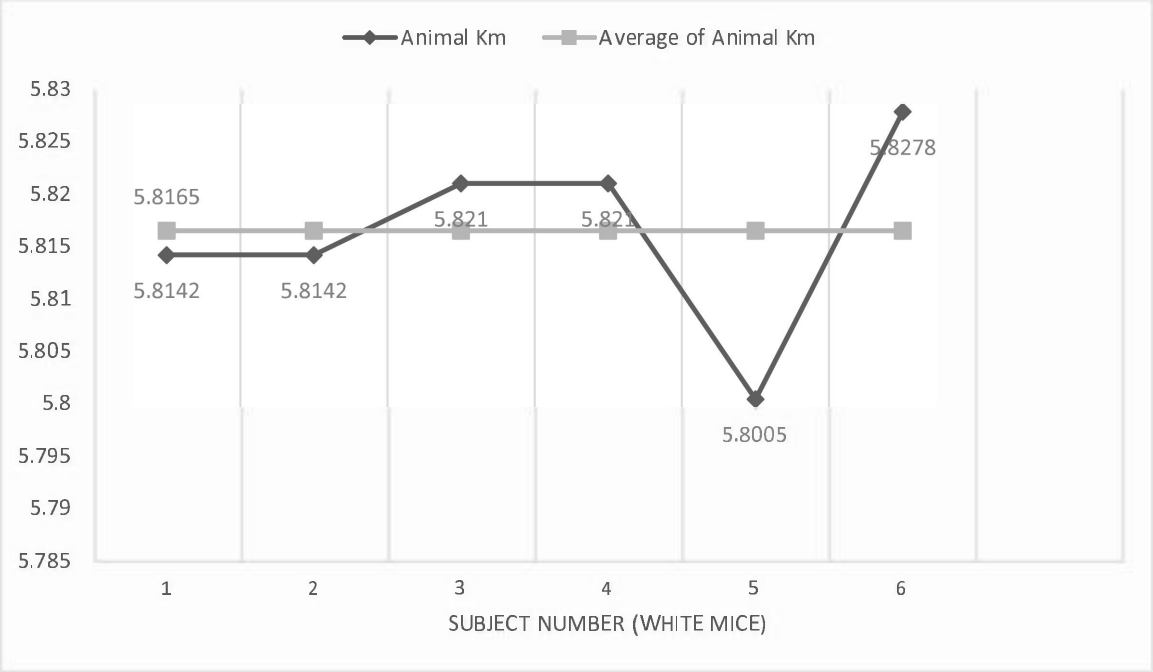

Figure 3. Calculation of Animal Km in Experimental Animal (White Mice)

2. HumanKm

$$Human\ K\ m = \frac{W\ human}{BSA\ human}$$

Explanation:

Human Km : Km Factors in Human (Worker)

W : Weight of Worker (kg)

BSA : Body Surface Area of Worker(m^2)

The results of Human Km calculations in Table 5, show that the average of Human Km in gas station workers of 36.172.

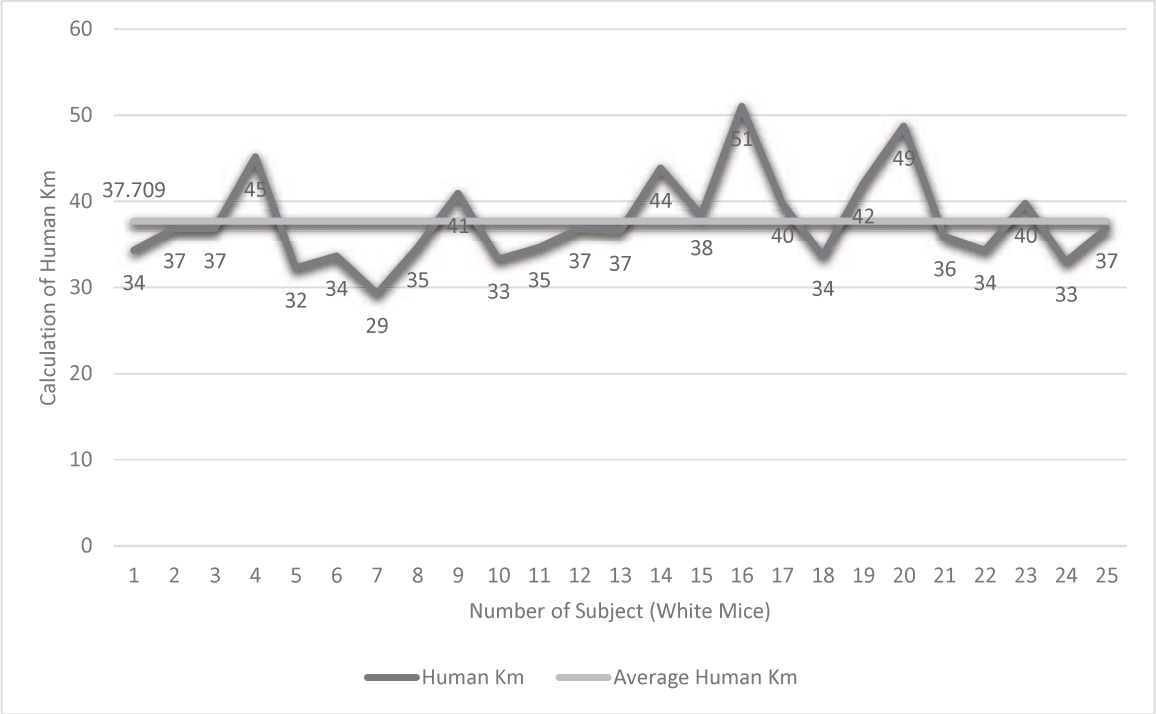

Figure 4. Calculation Results of Human Km in Shoe Home Industry Workers

E. NOAEL

To determine the safe limit of the concentration of a chemical begins with the toxicity test determining the highest dose without causing effects on experimental animals or No Observed Adverse Effect Level (NOAEL). Based on the other research shows that NOAEL of benzene is 3.0 mg/m^3 or equal to 0.022 mg/kg that obtained from that calculation of formula below[14]:

$$\text{NOAEL benzene (mg/m}^3\text{)} = \frac{3 \times 0.00013 \times 8}{0.1407}$$

$$= 0.022 \text{ mg/kg}$$

F. Safe Human Dose (SHD)

The safe limit of dosage of toxins for workers or Safe Human Dose (SHD) begins using the following formula from Shaw et al[15]:

$$SHD = NOAEL \frac{Animal\ Km}{Human\ Km}$$

Explanation:

SHD : Safe Human Dose (mg/kg)

Animal Km : Km Factors in Animal

Human Km : Km Factors in Human (Workers)

Based on formula above, so the calculation results of SHD that obtained from NOAEL, the average of Animal Km, and the average of Human Km is:

$$SHD = 0.022 \text{ mg/kg} \times \frac{5.8165}{37.709}$$

$$= 0.0033 \text{ mg/kg}$$

G. Safe Limit of Benzene Concentration

Determining the safe limits of benzene concentrations in the work environment (gas stations) use the following William formula (1985)[11]:

$$Safe\ Concentration = \frac{SHD\,x\,W}{\delta\ x\ BR\ x\ t}\left(\frac{mg}{m3}\right)$$

To convert mg/m^3 to ppm use the following formula:

$$Safe\ Concentration = \frac{mg/m3}{MW}\ x\ 24.5\ ppm$$

Explanation:

Safe concentration : Concentration of toxin in safe air for workers

SHD : Safe Human Dose (mg/kg)

W : Weight (kg)

δ : % of substances absorbed by the lungs

BR : Breatihing Rate (m^3/hour)

t : Working time

MW : Molecular weight

Based on the formula above, the calculation results of safe concentration of benzene at shoe home industy Romokalisari Surabaya obtained from the SHD value, average body weight, percentage of absorption of substances by the lungs, average respiratory rate, and average length of work time are:

$$\text{Safe Concentration (mg/m}^3\text{)} = \frac{0.0033 \times 63.96}{50\% \times 0.6229 \times 8}$$

$$= 0.0847 \text{ mg/m3}$$

$$\text{Safe Concentration (ppm)} = \frac{0.0847 \text{ mg/m3} \times 24.5 \text{ ppm}}{78.11}$$

$$= 0.0265 \text{ ppm}$$

Discussion

In measurements carried out at five spots, at shoe home industry in Romokalisari Surabaya, there were several potential sources of benzene exposure. WHO warned that every 1 µg/m^3 of benzene exposure would add 4-8 cases of leukemia per one million population over the lifetime. US-EPA, IARC, and the US health department concluded that benzene is a carcinogen in humans[16]. EPA classifies benzene in category A (carcinogen in humans) while IARC classifies benzene in group 1 (carcinogenic in humans)[16]. In addition, workers rarely use personal protective equipment such as masks and gloves or other tools for gluing. Workers usually take the glue directly by hand and attach it to the shoe. The environmental conditions of the workplace are also very hot with a strong smell of steam. Most workers carry out the process of producing shoes with bare-chested and smoking. Workers also eat and sleep in the same place as when they work. The highest benzene exposure concentration was 2.33 ppm (7.44 mg/m^3), while the lowest benzene exposure concentration was 0.012 ppm (0.04 mg/m^3).

Compared with the threshold value stipulated by ATSDR and regulation of chemicals TLV at Indonesia, threshold value determined by ACGIH, NIOSH, and OSHA at 0.5 ppm, 0.1 ppm and 1 ppm. The average of benzene concentration in the working environment of the shoe home industry in Romokalisari Surabaya greater than what has been set by NIOSH. When compared with the threshold value of benzene based on SE 1/MENAKER/1997, all spots at this shoe home industry two are still below the threshold value of 10.02 ppm (32 mg / m^3). Whereas IRIS stipulates that the permissible concentration of benzene is 0.00094 ppm (0.003 mg / m^3), so that the concentration of benzene at shoe home industry in Romokalisari is greater than the threshold value set by IRIS[6]. The safe limit for benzene concentration was 0.0265 ppm (0.0847 mg/m^3) and it also exceeds ATSDR MRL. Although there is limited reference of safe concentration in same conditions (shoe home Industry), this result could be pioneer for standart safe concentration of benzene at Indonesia especially in shoe home industry or other workplace exposured by benzene.

OHSAS 18001 provides specific control guidelines for OHS hazards through elimination, substitution, technical, administrative and personal protective equipment approaches[17]. The approach of elimination and substitution in shoe home industry Romokalisari Surabaya is quite difficult, although it is from non-permanent source, but lack of monitoring and has become the habit of workers. For the technical approach, this is also quite difficult, because there are no official regulations that regulate workers when producing shoes. And for the personal protective equipment approaches is quite difficult too, because there is no appeal from supervisor for workers to use personal protective equipment and lack of monitoring.

Conclusion

The measurement results of the average concentration of benzene at the shoe home industry in Romokalisari Surabaya was 0.622 ppm (1.99 mg/m^3) whose above TLV at Indonesia. The safe limit for benzene concentration was 0.0265 ppm (0.0847 mg/m^3) and it exceeds ATSDR MRL. So, benzene concentration in shoe home industry Romokalisari Surabaya has the potential to provide health effects for workers such as drowsiness, dizziness, and for the long term can caused of cancer. Control management is needed so that workers are protected from the adverse effects of benzene. Control recommendation can be made by using personal protective equipment and reducing even ignoring smoking when the shoe production process so it is required supervision to monitor.

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