

NOAEL Benzene in White Mice as the Basis for Determining the Safe Limit of Benzene Concentration in the Pulogadung Shoe Industry Home in Jakarta

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Abstract

The shoe industry in its operational activities is very dependent on the quality of the material, one of which is glue containing benzene, the industrial workers have a risk of exposure to benzene. The purpose of this study was to determine the safe concentration of benzene in the leather shoe industry in the small industrial village of Pulogadung, Jakarta. This research is descriptive research. The population in this study were shoe workers who worked on the installation of sole 1 and sole 2, which amounted to 16 people. The results of the study were quantitatively analyzed to determine the safe concentration of benzene for workers obtained from data on benzene concentrations in the workplace, worker height, worker weight, rats' weight, worker respiration rate, length of work, worker body surface area, surface area mice body, highest dose of toxin without effect on experimental animals (NOAEL), Km factor in animals (Animal Km), factor Km in workers (Human Km), and safe limit for toxin dose for workers (RfC). The measurement results of the concentration of benzene in the sole 1 section were 0.19 ppm and in the sole 2 part was 0.06 ppm, which means that the concentration of benzene is still below the Threshold Value according to Minister of Manpower Regulation Number 13 of 2011 at 0.5 ppm. Based on the calculations that have been done, the safe limit value is 0.021 ppm. Based on the minimum risk level (MRL), the concentration of benzene every day that can cause acute effects is 0.009 ppm and that can cause chronic effects is 0.003 ppm. From these standards, it can be seen that the concentration of benzene in the leather shoe industry has the potential to have an impact on the health of workers. Control measures are needed to see potential health problems that workers can experience because of the benzene. Recommendations to the leather shoe industry are to periodically monitor benzene levels in the air, conduct health checks on workers, and use personal protective equipment on workers such as masks to reduce levels of inhaled benzene into workers' bodies.

Keywords: Benzene, NOAEL, shoe industry

Introduction

The informal industry sector is an unorganized, irregular, and some legal but not registered sector¹. One type of informal business is the shoe industry. The materials used in making shoes are leather, footwear,

and glue to glue. The increasing number of shoe industries, the more glue is used to produce these shoes. Hazardous substances in glues are volatile organic compounds (benzene, toluene, and xylene) which fall into the category of volatile VOC (Volatile Organic Compound)². Based on the research conducted by the Director General of Indonesian Public Health, stated that the organic solvents in the glue were 70% toluene and more than 1-2% benzene solvents³.

Benzene is a chemical that is dangerous and carcinogenic to humans and is a colorless and volatile liquid. Benzene is widely used in the rubber industry, oil refining, shoe factories, chemical plants and other

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oil-related industries including aged fueling stations (SPBU)⁴.

The glue used in the shoe industry contains benzene which affects benzene exposure in the shoe industry. The permissible levels of benzene exposure according to several world organizations are 1 ppm determined by the National Institute for Occupational Safety and Health⁵ and Occupational Health and Safety Assessment Series⁶ and 0.5 ppm set by the American Conference of Governmental Industrial Hygienists⁷.

Indonesia itself has set a limit exposure in the *benzene* work environment that is set in the Threshold Limit Value (NAB) of *benzene* of 0.5 ppm in accordance with the Minister of Manpower and Transmigration Regulation of the Republic of Indonesia number PER/1/MEN/ X/2011 concerning Factor Threshold Values Physics and Chemistry at Work⁸.

Several health cases related to benzene exposure have been found in several countries. Some cases due to the use of benzene in the shoe industry were in 1946-1956 in the United States there were 107 cases due to the concentration of benzene exposure which exceeded 400 ppm. Of these cases, hemopathy and thrombocytopenia were found⁹. In 1945-1955 there were 125 cases of platelet decline and abnormal liver function due to exposure to benzene which exceeded 400 ppm in the shoe industry. Whereas in 1948, the API (*American Petroleum Institute*) published that benzene is certain to cause leukemia and there is no small tolerance (zero ppm level) to benzene emissions¹⁰.

Determination of safe limits of benzene concentration in the work environment must involve knowledge of worker respiration rate (R), reference concentration (RfC) benzene, duration of work / day (tE), frequency of work each year (fE), duration of work (years) weight (Wb) and the average cancer year (70 years 365 days) and non-cancer (30 years x 365 days)¹¹.

This study aims to determine the level of safe concentration of benzene in different leather shoe industries, namely in the PIK Pulogadung region. The results of this study are expected to be a recommendation for shoe industry entrepreneurs to protect their workers from benzene exposure.

Material and Method

This research is descriptive research. This study

aims to determine the magnitude of the environmental health risks of benzene exposure to workers in the shoe industry in Pulogadung Small Industry Village using an environmental health risk analysis approach. The population in this study were shoe workers who worked on the installation of solee 1 and solee 2, which amounted to 16 people.

The design of the research is to collect initial data related to work processes (chemicals in the area) and the number of workers. Furthermore, collecting primary data is the concentration of benzene in the workplace air, length of work time, and worker weight. In addition, secondary data collection was also carried out on experimental animals, namely the weight of white mice. The type of data in this study is primary data, obtained through questionnaires and observations as well as measurements of benzene in the air of the respondent's workplace.

The variables in this study were benzene concentration in the workplace, worker height, worker body weight, rats' weight, worker respiration rate, length of work, body surface area, surface area of the rat body, highest dose of toxin without effect on experimental animals (NOAEL), Km factor in animals (Animal Km), Km factor in workers (Human Km), safe limit of toxin dose for workers (RfC), and benzene concentration in safe air for workers (Safe C).

Data analysis in this study was carried out by using quantitative data analysis manually to determine the safe concentration of benzene for workers in the pulogadung leather shoes factory working environment.

FINDINGS

1. Characteristics of Experimental Animals and Surface Area of Animals Experiments (White Mice)

Toxicity can be interpreted as the ability of poisons (molecules) to cause damage if it enters the body and the location of organs susceptible to it. In this study, the implementation of a toxicity test using experimental animals namely white rats. This is done considering the human response to toxicity qualitatively is the same as the response of animals, so this fact is the basis of extrapolation from animal to human data.

Table 1. Characteristics of Experimental Animals (White Mice)

Experimental Animals (White Mice)	W (kg)	BSA (m2)
1	0.1405	0.024165
2	0.1405	0.024165
3	0.1410	0.024223
4	0.1410	0.024223
5	0.1395	0.024050
6	0.1415	0.024165

Based on these data, it can be calculated the body surface area of white mice with

$$\text{Animal BSA} = 0.09 \cdot W^{0.67}$$

Description:

BSA : Body Surface Area (m²)

W : Weight (kg)

2. Characteristics of Workers, Worker’s Body Surface Area, and Worker’s Respiratory Rate

In this study, worker characteristics include weight and duration working time. The sample in this study were 16 respondents, namely workers in the pulogadung leather shoe factory.

Based on data on worker weight and height of workers, the body surface area and the rate of respiration of workers can be calculated using the following formula.

$$\text{BSA}_{\text{human}} = \sqrt{\frac{W \cdot h}{3600}}$$

Specification:

BSA: Body surface area (m²)

W : Weight (kg)

h : Height (cm)

B. Respiratory rate of worker

$$\text{BR} = \frac{5.3 \cdot (\ln W) - 6.9}{24}$$

Description:

BR : Breathing rate (m³/ h)

W : Weight (kg)

Table 2: Characteristics of Workers

Workers	W (kg)	H (cm)	BSA (m2)	BR (m3/ hour)	t (hour / day)
1	40	159	1.33	0.52	8
2	63	159	1.67	0.63	8
3	55	159	1.55	0.6	8
4	47	159	1.44	0.56	8
5	62	159	1.65	0.62	8
6	55	159	1.55	0.6	8
7	46	159	1.42	0.56	8
8	54	159	1.54	0.6	8
9	46	159	1.42	0.56	8
10	66	159	1.70	0.64	8
11	61	159	1.64	0.62	8
12	40	159	1.33	0.52	8
13	61	159	1.64	0.62	8
14	56	159	1.57	0.6	8
15	55	159	1.55	0.6	8
16	53	159	1.52	0.59	8
Average	53.75	159	1.53	0.59	8

From the calculation of the body surface area and the respiratory rate of workers, it is known that the average body surface area of workers is 1.53 m² and the average respiration rate of workers is 0.59 m³/ hour.

3. Benzene Concentration

The measurement results of benzene concentration at two points in the leather shoes industry showed that the measurement results in the sole 1 section were 0.63 mg / m³ (0.19 ppm) and in the sole 2 section 0.29 mg / m³ (0.06 ppm)

Table 3. Benzene Concentration

Location of Measurement	benzene concentration (ppm)
Solee 1	0.19
Solee 2	0.06

Measurement results done, it is known that the concentration of benzene in the working environment of pulogadung leather shoes in sole 1 part is 0.19 ppm and in sole 2 parts 0.06 ppm. Based on the Minister of Manpower and Transmigration Regulation No. 13 of 2011 concerning the threshold value of physical factors and chemical factors in the workplace for concentrations of Benzene of 0.5 ppm so that the concentration of benzene in the shoe industry, the concentration of Benzene is below the NAB. However, the concentration of benzene is above the Minimum Risk Level (MRL), the level of benzene inhalation exposure set by ATSDR, ie for acute exposure (≤14 days) = 0.009 ppm, moderate exposure (15-364 days) = 0.006 ppm, and exposure chronic (≥365 days) = 0.003 ppm.

4. Animal Km and Human Km

A. Animal Km

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

Description:

Animal Km : Km factor in animals

W : Experimental animal weight (white mouse)

BSA : Body Surface Area of experimental animals (White mice)

Table 4. Results of Calculation of Animal Km in Experimental Animals (White Mice)

Experimental Animals (White Mice)	Animal Km
1	5,81420952
2	5,81420952
3	5,82102947
4	5,82102947
5	5.80052067
6	5.81420952
average	5.81

Km Animal calculation results are shown in table 4. average Animal Km in animal experiments white rats were 5.81.

B. Human Human Km

$$Km = \frac{W\ human}{BSA\ human}$$

Description:

Human Km: Km factor in human/worker

W : worker weight

BSA : Body Surface Area worker

Table 5. Human Km Calculation Results for Leather Shoe Industry Workers

Workers	HumanKM
1	30.07
2	37.8
3	35.5
4	32.6
5	37.6
6	35.5
7	32.4
8	35.06
9	32.4
10	38.8
11	37.2
12	30.07
13	37.2
14	35.7
15	35.5
16	34.9
Average	34,9

The calculation results of *Human Km* are shown in table 5. Average Human Km for Leather Shoe Industry workers which is 34.9.

5. NOAEL

NOAEL is the highest dose of a substance in statistical or biological chronic or subchronic toxicity studies that do not show detrimental effects on test animals. Toxicology testing can be used to calculate No Observed Adverse Effect Level (NOAEL) and is

useful for clinical trials. To determine the safe limit of concentration of a chemical begins with the toxicity test *No Observed Adverse Effect Level (NOAEL)*.

Swaen (2010) states that benzene NOAEL is 3.0 mg / m³ or equivalent to 0.022 mg / kg.

$$NOAEL\ benzene = \frac{3 \times 0,00013 \times 8}{0,1405} = 0,022\ mg / kg$$

6. Safe Human Dose

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

Description:

- RfC : Safe human dose (mg / kg)
- Animal Km : Km factor in animals
- Human Km : Km factor in humans

Based on these equations, the calculation of RfC obtained is

$$RfC = 0.022 \frac{5.81}{34.9} = 0.003\ mg / kg$$

7. Limit of Safe Level of Benzene Concentration

Determination of safe limits of benzene concentration in the work environment of the leather shoes industry uses the following formula (William, 1985; Soemirat, 2003; Davis, 1991).

$$C\ safe = \frac{(SHD)(W)}{(\delta)(BR)(t)}\ mg / m^3$$

To convert units of mg / m³ to ppm the following formula is used.

$$C\ safe = \frac{\#\ mg / m^3}{(MW)} \times 24.5\ ppm$$

Description:

- Safe C : concentration of toxin in the air is safe for workers (mg / m³)
- RfC : Safe Human Dose (mg / kg)
- W : Weight (kg)
- δ : % of substances absorbed by the lung
- BR : Human respiratory rate (m³/ hour)
- t : Duration of working time (hours)
- MW : Molecular Weight / Molecular Weight

Based on the above equation, the calculation results of the concentration of safe concentration of benzene in The Leather Shoes Industry is |

$$C\ safe = \frac{(0.003)(53.75)}{(50\%)(0.59)(8)} = 0.068\ mg / m^3$$

$$C\ safe = \frac{0.068 \times 24.45}{78.11} = 0.021\ ppm$$

The results of the calculation of the concentration of safe levels of benzene in the air for workers above can be used to predict the concentration of toxins in the air a safe work environment for workers and to be compared with NAB that has been set by various good institutions by Kemenakertrans, National Standardization Agency, ACGIH, NIOSH, and OSHA.

Benzene in the shoe industry must be identified to determine the level of exposure that can cause effects on shoe workers. What can be done to reduce benzene exposure to workers is to use PPE regularly such as masks, especially during the bonding process. Another approach is taken by eating foods rich in detoxification enzymes, especially GSH which is usually found in most vegetables such as asparagus, spinach, broccoli, garlic, kale, and onions¹².

Conclusion

The results of the measurement of benzene concentration in the Leather Shoes Industry in Pulogadung Small Industrial Village, Jakarta in the sole 1 section are 0.19 ppm and in the sole 2 part is 0.06 ppm. Based on the Minister of Manpower and Transmigration Regulation Number 13 of 2011, the threshold value of benzene is 0.5 ppm. From the results of measurements in this study when compared with the threshold value then it is still below the set threshold value.

Based on the minimum risk level (MRL) of ATSDR 2007, the concentration of benzene every day that can cause acute effects is 0.009 ppm and that can cause chronic effects is 0.003 ppm. From these standards, it can be seen that the concentration of benzene in the leather shoe industry has the potential to have an impact on the health of workers.

Control measures are needed to see potential health problems that workers can experience because of the benzene. Recommendations to the leather shoe industry are to periodically monitor benzene levels in the air, conduct health checks on workers, and use personal protective equipment on workers such as masks to reduce levels of inhaled benzene into workers' bodies.

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Ethical Clearance: The study was approved by the Institutional Ethical Board of Faculty of Public Health, Airlangga University.

All subjects were fully informed about the procedures and objectives of this study each subject prior to the study signed an informed consent form.

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