Determination of Safe Level of Benzene Concentration in Mechanics Workshop "X" Tembalang Semarang

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Abstract

Vehicles are used in community in a large number and being repaired in motorbike repair shops. The repaired motorbike at the workshop has the potential to provide benzene exposure to the mechanic, so the mechanic was also at risk of experiencing health problems due to benzene exposure. This study aimed to determine the safe concentration of benzene in Workshop X Tembalang, Semarang. This study was a descriptive research. The population in this study were mechanics at Locations 1 and 2, totally 18 people. The results of this study were quantitatively analyzed to determine the safe concentration of benzene for workers obtained from the benzene concentrations in the workplace, worker height, worker weight, rats weight, worker respiration rate, length of work, worker body surface area, mice body surface area, highest dose of toxin without effect on experimental animals (NOAEL), Km factor in animals (Animal Km), Km factors in workers (Human Km), and safe limit dose for workers (RfC). The measurement of benzene concentration at Location 1 was 0.28 ppm and Location 2 was 0.19 ppm, which means that the benzene concentration was still below the Threshold Value according to Minister of Manpower Regulation Number 13 in 2011 amounting to 0.5 ppm. This research showed that the safe limit value was 0.023 ppm. Based on the minimum risk level, the concentration of benzene everyday that can cause acute effects was 0.009 ppm and that can cause chronic effects was 0.003 ppm. These standards indicate that the concentration of benzene in the workshop has the potential to have a negative impact on the health of workers. Recommendations to workshop owners and mechanics are to periodically monitor benzene levels in the air, use personal protective equipment by all mechanics and if needed the workshop owner can conduct a health check-up for all mechanics.

Keywords : *Benzene, safe level, mechanics workshop*

Introduction

Motorcycles was widely used in community and increased every year in Indonesia. Data from AISI (Asosiasi Industri Sepeda Motor Indonesia) in 2015 stated that motorcycle sales in 2014 reached 7,926,104 million units[1]. The large number of motorbike uses can provide opportunities for motorcycle workshops to provide automotive needs services that include repair and maintenance processes that carried out by workshop mechanical workers[2]. Workshop mechanics often referred to as mechanics or engineers who works to repair, install, or modify the vehicles which in the work process was very high risk of exposure to hazardous chemicals[3].

Benzene was a chemical that was dangerous and carcinogenic for workers which found in fuel oil[4,5]. The limit levels of benzene exposure according to several world organizations are 1 ppm (National Institute for Occupational Safety and Health[6] and Occupational Health and Safety Assessment Series[7)] and 0.5 ppm (the American Conference of Governmental Industrial Hygienists[8]).

In Indonesia, the limit of exposure *benzene* in the work environment was stipulated in the threshold value (NAB) of *benzene* at 0.5 ppm according to the Regulation

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of the Minister of Manpower and Transmigration PER/13/MEN/X/2011 about Factor Threshold Values Physics and Chemistry at Work[9].

Some research show that the concentration of benzene in the air below the normal limit, which still have negative effects such as headaches and tremors[10]. Determination of safe limits of benzene concentration in the work environment involves knowledge of worker breathing rate (BR), reference concentration (RfC), work-hours/day (tE), weight (Wb) and the average cancer year (70 years) and non-cancer (30 years)[11].

This study aims to determine the level of safe concentration of benzene in Bengkel X in Tembalang Semarang so that it can provide recommendations to workshop owners so they can determine safe actions and protect workers from benzene exposure.

Material and Method

This study was a descriptive study that aims to determine the magnitude of the environmental health risk of benzene exposure to workers in Workshop X Tembalang Semarang using an environmental health risk analysis approach. The population in this study was a mechanic totaling 18 people.

The design of the research was to collect initial data, the work process, and the number of workers. Furthermore, collecting primary data was the concentration of benzene in the workplace air, length of work time, and worker weight. Secondary data collection was also carried out on experimental animals, the weight of white mice. The type of data in this study was primary data, obtained through questionnaires and observations as well as measurements of benzene in the air of the workers' workplace.

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

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 work environment in Workshop X Tembalang Semarang.

Findings

1. Characterwastics and Surface Area of Animals Experiments

Toxicity can be interpreted as the ability of poison to cause damage if it enters the body and the location of organs susceptible to it. Toxicity was very diverse for various organism, depending on various factors such as test species, the way piosons enter the body, the frequency and length of exposure, concentration of exposure agents, and the vulnerability of various species to pollutants. In this study, the implementation of a toxicity experimental test in white mice. This study was done considering the human response to toxicity qualitatively was the same as the response of animals, so this fact was the base of extrapolation from animal to human data.

The following are characterwastic data of experimental animals.

Table 1. Characterwastics of Animal Experiments

Animal Experiments	W (kg)	BSA (m^2)
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 :

Animal BSA = $0.09 \times W^{0.67}$

Description:

BSA : Body Surface Area (m^2)

W : Weight (kg)

2. Characterwastics, Body Surface Area, and Respiratory Rate of The Workers

In this study, worker characteristics include weight and duration work-time. The sample in this study were 18 mechanic in Workshop X Tembalang Semarang.

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

A. The Workers' Surface Area

$$\text{BSA Human} = \sqrt{\frac{W\,h}{3600}}$$

Description:
BSA: Body surface area (m^2)
W : Weight (kg)
h : Height (cm)

B. Workers' Respiratory Rate

$$BR = \frac{5{,}3(\ln W) - 6{,}9}{24}$$

Description:
BR : Breathing rate (m^3/h)
W : Weight (kg)

Table 2. Characterwastics, Respiratory Rate and Work Time of Workers

Worker	W (kg)	H (cm)	BSA (m2)	BR (m3/ hour)	t (hour / day)
1	50	160	1.49	0.57	8
2	52	160	1.52	0.58	8
3	47	160	1.44	0, 56	8
4	68	160	1.73	0.64	8
5	60	160	1.63	0.61	8
6	74	160	1.81	0.66	8
7	50	160	1.49	0.57	8
8	59	160	1.61	0, 61	8
9	67	160	1.72	0.64	8
10	69	160	1.75	0.64	8
11	51	160	1.50	0.58	8
12	45	160	1.41	0.55	8
13	46	160	1.42	0, 55	8
14	60	160	1.63	0.61	8
15	80	160	1.88	0.67	8
16	47	160	1.44	0.56	8
17	59	160	1.61	0.61	8
18	70	160	1.76	0, 65	8
Average	58.56	160	1.60	0.60	8

Based on Table 2, it was known that the highest body weight of workers in the Workshop X Tembalang Semarang was 74 kg, while the lowest weight was 45 kg. The length of work in a day was all 8 hours and height uses the average value of Indonesian adult male height which was 160 cm.

From the calculation of the body surface area and the respiratory rate of workers it was known that the average body surface area (BSA) of workers was 1.60 m^2 and the average respiration rate of workers was 0.60 m^3/hour.

3. Benzene Concentration

The measurement of benzene concentration at two points in Workshop X showed that the measurement results at location 1 were 0.28 ppm and at location 2 was 0.19 ppm.

Table 3. Benzene Concentration

Location	Benzene Concentration (ppm)
Location 1	0.28
Location 2	0.19

The results of measurements, it was known that benzene concentration in Workshop X Tembalang Semarang Location 1 was 0.28 ppm and Location 2 was 0.19 ppm. Based on the Minister of Manpower and Transmigration Regulation Number 13 in 2011 concerning the threshold value of physical factors and chemical factors in the workplace for a concentration of Benzene of 0.5 ppm so that the concentration of benzene in this workplace was still below the NAB. However, the concentration of benzene was above the Minimum risk Level (MRL), the level of benzene inhalation exposure determined by ATSDR, for acute exposure (≤14 days) = 0.009 ppm, moderate exposure (15-364 days) = 0.006 ppm, and chronic exposure (≥365 days) = 0.003 ppm.

4. Animal Km and Human Km

A. Animal Km

$$AnimalKm = \frac{WAnimal}{BSAAnimal}$$

Description:

Animal Km : Km factor in animal

W : Animal body weight

BSA :Body Surface Area of

experimental animal

Table 4. Animal Calculation Results Km on Animal Experiments

Animal Experiments (White Mice)	**Animal Km**
1	5,81420952
2	5,81420952
3	5,82102947
4	5,82102947
5	5,80052067
6	5,81420952
Rata-rata	5,81

The Animal Km calculation shown in table 4. Average Animal Km in animal experiments white rats were 5.81.

B. Human Km

$$HumanKm = \frac{WHuman}{BSAHuman}$$

Description:

Human Km: Km factor in Worker

W : Worker weight

BSA Body Surface Area worker

Table 5. Human Km Calculation for Workers in Workshop X

Pekerja	Human KM
1	33,54
2	34,20
3	32,51
4	39,11
5	36,74
6	40,80
7	33,54
8	36,43
9	38,82
10	39,40
11	33,87
12	31,81
13	32,17
14	36,74
15	42,42
16	32,51
17	36,43
18	39,68
Rata-rata	36,15

The Human Km calculation shown in table 5. Average of Human Km workers at Workshop X Tembalang Semarang was 36,15.

5. NOAEL

NOAEL was 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 was 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 was 3.0 mg/m^3 (0.022 mg/kg).

$$NOAEL\ benzene = \frac{3\ x\ 0,00013\ x\ 8}{0,1405}$$

$$= 0,022\ mg\ /\ kg$$

6. Safe Human Dose

$$RfC = NOAEL \frac{AnimalKm}{HumanKm}$$

Description:

RfC: Safe human dose (m g/kg)

Animal Km : Km factor in animals

Human Km : Factor Km in Human

Based on these equations, the calculation of RfC obtained was :

$$Rfc = 0{,}022 \frac{5{,}81}{36{,}15}$$

= 0.003 mg / kg

7. Safe Limit of Benzene Concentration

Determination of safe limits of benzene concentration in Workshop X Tembalang Semarang uses formulas (William, 1985; Soemirat, 2003; Davwas, 1991) the following:

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

to convert units of mg/m^3 to ppm :

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

Description:

C safe : safe concentration in the air for workers (mg/m^3)

RfC: Safe Human Dose (mg/kg)

W : Weight (kg)

δ :% of substances absorbed by the lung

BR : Human respiratory rate (m^3/hour)

t : Duration of working time (hours)

MW : Molecular Weight

Based on the above equation, the calculation results of the concentration of safe concentration of benzene in Workshop X was:

$$Caman = \frac{(0{,}003)(58{,}56)}{(50\%)(0{,}60)(8)}$$

= 0.073 mg / m^3

$$Caman = \frac{0{,}073x24{,}45}{78{,}11}$$

= 0.023 ppm

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 the NAB established by various institutions either by Indonesian statute, National Standardization Agency, ACGIH, NIOSH and OSHA.

Discussion

Benzene in a motorbike repair shop environment needs to be identified to determine the level of exposure that can cause a negative effect to the mechanics. This study measured 2 locations which were considered to have the most exposure to benzene from exhaust gases from motorcycles, Locations 1 and 2 in Workshop X Tembalang Semarang. The results of the measurement of benzene concentrations in these two locations differ because of several things such as the number of repaired motors and the levels of benzene produced by vehicles' combustion. The more the number of motors was repaired, the higher the exhaust gas from the exhaust of the motor, the higher the concentration of benzene in that location.

Exposure time was the total work time per day. From the research conducted, it was known that the mechanic's working hours in the motorcycle workshop are 8 hours per day. This result was in accordance with normal working hours according to Labor Law No. 13 in 2003 which states normally, the length of work permitted to each worker was no more than 8 hours/day.

The concentration of benzene exposure in Tembalang X Workshop Semarang was influenced by several factors, but one of the most influential was the condition of the air at the work site (benzene concentration in the air). From the results of the calculation of the safe concentration of benzene, the value of safe C was 0.073 mg/m^3 or 0.023 ppm.

What can be done to reduce exposure to benzene in workers was the installation of exhaust fans, the use of PPE such as masks, especially during the process of repairing the motorbike. Another approach was taken by eating foods rich in detoxification enzymes, especially GSH which was usually found in most vegetables such as asparagus, spinach, broccoli, garlic, and onions[5].

Prevention of benzene exposure requires an active role from both mechanics and workshop owners. It can be done to reduce levels of benzene exposure in the work environment was by installing an exhaust fan as a vent in the workspace. Ventilation was the process of providing clean outdoor air which was naturally exchanged with indoor air. The main function of ventilation as an exchange of outside air with the room, this was also intended to control the air temperature so that it wasn't hot and stuffy so that it increases the intake of benzene exposure. According to Minister of Health Regulation RI 1077/MENKES/PER/2011 concerning guidelines for air sanitation in a well ventilated room was to meet the criteria for extensive ventilation >10% of the floor area at the workplace[12].

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

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

Conclusion

The results of measuring the concentration of benzene in Workshop X in Location 1 was 0.28 ppm and Location 2 was 0.19 ppm. Based on Minister of Manpower and Transmigration Regulation Number 13 in 2011, the threshold value of benzene was 0.5 ppm. From the results of measurements in this study when compared with the threshold value then it was 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 was 0.009 ppm and that can cause chronic effects was 0.003 ppm. From these standards, it can be seen that the concentration of benzene in this workplace has the potential to have a negative impact on the health of mechanics.

Control measures are needed to minimize the risk of health problems that can be experienced by workers due to benzene exposure. The recommendation given to Semarang Tembalang X Workshop was to periodically monitor benzene levels in the air, use personal protective equipment properly by mechanics and if necessary a health check-up can be done at Workshop X Tembalang Semarang.

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