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Safe Concentration of Benzene Exposure in Work Environment at Motor Workshop

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Abstract

Benzene is a colorless liquid that can evaporate rapidly in air and slightly dissolved in water. Exposure of benzene to the body has a very adverse impact on health. The aims of this research were to know benzene risk characteristic or RQ, and safe concentration of benzene exposure in a workshop environment. This research was observational, cross-sectional design with a population of 7 workers of the motor industry in Surabaya. The benzene exposure in the workplace was measured by Gas Chromatography-Flame Ionization Detector (GC-FID). Data analysis was done by using quantitative data. Maximum benzene intake received by workers was 0.1837 mg/kg/day. RQ on average workers more than 1 (> 1), with the highest RQ of 22.673. The highest safe concentration of workers was 3.9 mg/m^3 and the lowest safe concentration was 0.4 mg/m^3. The concentration of benzene exposure in the motor industry showed was above the threshold limit. According to the regulation of Manpower and Transmigration Ministry No 13 the year 2011, RQ for benzene showed a high-risk impact for workers, the smallest safe concentration for the worker was 0.4 mg/m^3.

Keywords: benzene, motor workshop, RQ, safe concentration

1. Introduction

Recently, globalization is an era that moves in the scope of the world because it increases industrial activity, transportation, and trade. In 2012, the number of motor vehicles (land transportation) in Indonesia was about 94.373.324 units (Central Bureau of Statistics, 2012). Fuel Oil (BBM) is one of the main energy sources in transportation usage. Premium, Pertamax, and Solar are the most widely used types of fuel oil. The Ministry of Energy and Mineral Resources recorded fuel consumption in Indonesia reached about 46 million kiloliters (Gasoline, Solar, and Kerosene) (Ministry of Finance, 2014). The growth in the number of motor vehicles is driving the increasing use of fuel oil (Hasan, Mahlia, & Nur, 2012). This change also resulted in increased labor requirements. Changes to the sector must be balanced with the improvement of the occupational health of workers.

According to the National Environment Committee (KNLH), the use of this fuel oil has an adverse impact on the environment and health. Not just emissions of gas resulted from disposal of motor vehicles, but also direct exposure to fuel oil vapors may have negative health effects (Priangkoso, 2010). The harmful effects of gasoline mostly come from the elements of metal (lead) and chemicals contained therein, in particular, the BTEX (benzene, ethylbenzene, toluene, and xylene) compounds, which are present in small quantities. Inlet point of exposure to fuel oil fumes most commonly occurring through the nose or inhalation/inhalation (Rahman et al., 2008). Benzene is a colorless liquid that can evaporate rapidly in air and slightly dissolved in water (Agency for Toxic Substances and Disease Registry, 2007). Benzene can be found in air, water, and soil which can come from industrial and natural sources. Most benzene can be inhaled in the air by people in about 60 parts of benzene per million parts of water (ppm) (Agency for Toxic Substances and Disease Registry, 2007). Exposure to benzene and carbon

monoxide from fuel oil can cause adverse effects on the blood system, respiratory function and thyroid function (Sahb, 2011). Narcosis as a headache, dizziness, drowsiness, confusion, tremors, and loss of consciousness is a result of acute exposure to benzene. In addition, can also cause eye irritation and skin. As for the effects of chronic exposure to benzene is can cause cancer (World Health Organization, 2010). Inhaled benzene can cause death (Agency for Toxic Substances and Disease Registry, 2007). Various polymer sensing materials have been developed which aim to monitor the level of benzene in the air due to high benzene toxicity (Spinelle, Gerboles, Kok, Persijn, & Sauerwald, 2017).

Risk assessment research on Indonesia still limited especially on the standard safe concentration of benzene in a high-risk population. So, the aim of this research is to know the risk characteristics or Risk Quotient (RQ) of benzene on the workers and to know the safe concentration of benzene exposure in a workshop environment.

2. Method

2.1 Research Design

This research design is the cross-sectional and descriptive approach.

2.2 Population and Sample

The study participants were workers from the workshop (n = 7) of AHASS CV Win Motor Surabaya. Their age ranged from 20 years to 37 years. New workers were excluded.

2.3 Variables

The research variables were the concentration of benzene exposure in the workplace, the rate of respiration of the worker, the length of work per day, the frequency of work each year, the worker's weight, the benzene intake of the worker, the working period, the Risk Quotient (RQ), and the safe concentration on the worker.

2.4 Measurements

Primary data was obtained by filling in questionnaires about the experience of exposure to benzene, duration of exposure, age, and years of service. Data on height and weight of respondents was collected by observation on passive participation. The benzene exposure in the workplace was measured by Gas Chromatography-Flame Ionization Detector (GC-FID) and helped by experts from the technical implementation unit of occupational safety and health (UPTK3) East Java Province. The work period of the respondent was categorized into 2; working period less than 6 months and working period more than or equal to 6 months. The frequency of respondent's working period was obtained from the questionnaire. Safe concentration was calculated by the formula of intake and RQ. The formula used to determine the intake of benzene toxin in the body is (Rohim, 2014):

$$\text{Intake of benzene} = \frac{\text{CxRxtExfExDt}}{\text{Wb x tavg}}$$

Description:

C = benzene concentration (mg/m^3)

R = respiration rate (m^3/h)

tE = exposure time (hour/day)

fE = average exposure in a year (day/year)

Dt = exposure duration (years)

Wb = weight (kg)

Tavg = average of benzene exposure (non-carcinogen)

= 30 years x 365 days / year

It is known that the exposure concentration (C) is 8.063 mg/m^3, the exposure frequency (Fe) is 288 days/year, the average time period (tavg) is 365 days and the reference dose (RfC) for benzene is 0.03 mg/kg/day.

Meanwhile, the formula used to find out the RQ is (Rohim, 2014):

$$\text{RQ} = \frac{Intake}{RfC}$$

The risk characteristics are intended to determine whether a toxin exposure has a risk or not to the human body. Risk quotient (RQ) is the result of a comparison between the intake value and the reference dose of a Reference of

Concentrate (RfC) exposure. RQ was derived from the calculation of intake (I) received by an exposed individual with a reference dose (RfC). Intake was obtained by calculating the multiplication of the concentration of risk agent (C), inhalation rate (R), exposure time (tE), exposure frequency (fE), duration of exposure in the year (Dt). Then, the result was divided by multiplying the individual body weight (Wb) and the average time period (tavg). RfC is the reference concentration, which is the value of non-carcinogenic quantitative toxicity as an estimate of daily exposure dose that has no adverse health effects with the lifetime duration of exposure (Sahb, 2011).

Lastly, the formula used to calculate the C safe is (Rohim, 2014):

$$\text{C Safe} = \frac{\text{RfCxWb x tavg}}{\text{CxRxtExfE}}$$

2.5 Analysis

Data analysis was conducted analysis manually to determine the safe concentration of benzene exposure to workers.

3. Results

3.1 Concentration of Benzene

Measurements of benzene levels were performed at the study sites in the repair section (workshop). Based on Table 1, the result of measurement of benzene level in the repair section (workshop) is 8,601 mg/m^3.

3.2 Characteristics of Respondents

Table 1. Length of work, weight of workers and occupational exposure per day

No.	Caracteristics		Frequency	Percentage (%)	Total
1.	Length of Work (Month)	< 6	3	43.00	7 (100%)
		≥6	4	57.00	
2.	Weight (Kg)	30-40	1	14.30	7 (100%)
		41-50	0	0	
		51-60	4	57.00	
		61-70	1	14.30	
		71-80	1	14.30	
3.	Long Exposure (Hour)	4 – 8	7	100.00	7 (100%)
		> 8 -12	0	0	

Based on Table 2, the working period of 57.00% workers was more than or equal to 6 months. It can be seen that the weight of workers was mostly at the 51-60 kg group with 4 respondents (57 %). The highest weight was 75 kg and the lowest weight was 38 kg, and table 2 that shows the distribution of working hours per working day, it is known that the category of long exposure was the most in the category of 4–8 hours a day as many as 7 respondents (100%).

3.3 Respiration Rate

Based on the calculation of respiration rate on workers, it is known that the highest rate of respiration of workers was 15.9827 m^3/hour, while the lowest rate of respiration of workers was 12.3792 m^3/hour. Average respiration rate of workers was 14.3275 m^3/hour.

3.4 Intake of Benzene. Risk Quotient (RQ) and Safe Concentration

Table 2. Intake of RQ and C Safe

Sample	Intake of benzene (mg/kg/day)	RQ benzene	Safe concentration on workers (mg/m^3)
1	0.1837	22.673	0.4
2	0.1290	16.490	0.5
3	0.0527	8.245	1.0
4	0.1155	14.428	0.6
5	0.1594	3.940	0.4
6	0.0262	31.518	3.0
7	0.0149	2.626	3.9

3.4.1 Intake of Benzene

Based on the calculation of respiration rate on workers, it is known that the highest rate of respiration of workers was 15.9827 m^3/hour, while the lowest rate of respiration of workers was 12.3792 m^3/hour. Average respiration rate of workers was14.3275 m^3/hour. The maximum intake received by the worker is 0.1837 mg/ kg/day as follow as Table 2.

3.4.2 Risk Quotient (RQ)

Based on the calculation data of risk characteristics in Table 5, it can be seen that the RQ on average workers was more than 1 (>1), with the highest RQ of 22.673.

3.4.3 Safe Concentration.

Based on the calculation data in Table 5, the highest safe concentration for workers at 3.9 mg/m^3, and the lowest safe duration is 0.4 mg/m^3.

4. Discussion

4.1 Concentrations of Benzene Exposure

Measurement of benzene levels of AHASS CV Win Motor Workshop was done at 1 point according to the workplace of the workers. Based on the results of measurement of benzene levels, the concentration of benzene exposure was measured to be 2.5319 ppm or 8.601 mg/m^3. This is in line with research conducted in painting workshops showing benzene concentrations exceeding the threshold value (Syafar & Wahab, 2015). In line with the research conducted in Ciomas Bogor at point 9 with the type of glue activity beyond the threshold limit value of 2.1074 ppm or 6.7326 mg / m^3 (Hajrah, Kusumayati, & Hermawati, 2018). In line with the research conducted in Pertamina RU IV Cilacap on the shelter D, KR space, 3 observation desk, 4 observation table, R & D analysis table and the administration room showed the concentration of benzene> 0,05, but the result of the research was different with the result of measurement in part observation table 1 and observation table 2 that is benzene concentration <0,05 (Kartikasari, Nurjazuli, & Rahardjo, 2016).

Based on the regulation of Manpower and Transmigration Ministry No 13 the year 2011 on the Threshold Value of Physical Factor and Chemical Factor in the workplace, it states that benzene level is 0.5 ppm (Ministry of Manpower and Transmigration Republic of Indonesia, 2011). Other than that, this means that the benzene measurements in AHASS CV Motor Workshop were far above the normal threshold value.

Absorption of benzene by the lungs is very fast (DECOS, 2014). Benzene can cause narcosis such as a headache, dizziness, drowsiness, confusion, tremors and loss of consciousness and can cause eye and skin irritation. As for the effects of chronic exposure to benzene is can cause cancer (World Health Organization, 2010).

Benzene contained in gasoline can also affect blood hemoglobin levels. Exposure to benzene through inhalation with certain levels can cause damage to human blood cells. Benzene specifically affects the spinal cord (tissue that produces blood cells) that can cause aplastic anemia, acute bleeding, and immune cell damage. This is evident from the complaints of workers on the respiratory tract and the eyes. We recommended for a worker to use PPE (Personal Protective Equipment) such as a mask to reduce the risk of inhaled benzene or eat of full nutrition foods such as salmon, cow liver to improve immunity against benzene (Rohim, 2014).

4.2 Risk Quotient (RQ) of Benzene

The calculated risk level or RQ value was then categorized into: "there is no risk" and "there are risks." RQ categorization is obtained if the value of RQ is more than 1, then there is a health risk and must be controlled. If the RQ score is less than one, then there is no health risk. The results of the RQ on the workers shows that all had valued more than 1 (RQ >1), which means that the level of contamination of benzene in the work area of AHASS CV Win Motor Workshop is still included in the health risk category and must be controlled (Rohim, 2014). This study is in line with research conducted by Hajrah et al in the informal footwear industry showing a score of RQ > 1 (Hajrah et al., 2018). In addition, according to the research conducted by Kartikasi et al, from 51 respondents, the RQ> 1 (Kartikasari et al., 2016). In line with the research conducted in Tambak Oso by Fahrudhi, 60% of respondents had RQ values > 1 (Fahrudhi, 2017). In line with the research conducted by Hasyim et al, 65% of respondents (13 of respondents) had RQ values > 1 (Hasyim, Tualeka, & Widajati, 2017).

The RQ value of each worker is different because the intake or intake received by each worker is different. This is influenced by the inhalation rate (R) obtained from the equation y = 5.3Ln (x) -6.9; where x is the worker's weight. In addition to the rate of inhalation, it is also affected by exposure time, exposure duration and worker's weight.

Short exposure to benzene (5-10 minutes) with high exposure to benzene in the air (10,000-20,000 ppm) can cause death, whereas with low benzene levels (700-3000 ppm) can cause drowsiness, rapid beating heartbeat, tremors, headache, dizziness, until unconscious (Agency for Toxic Substances and Disease Registry, 2007). Acute exposure to benzene with high concentrations can occur immediately in the nervous system, skin, digestive system and respiratory system. Neurological effects are the first effects that appear in the central nervous system, namely the benzene anesthetic reaction by stimulating excitation followed by depression and if exposed continuously there will be a death due to respiratory failure (Bakta, 2003).

4.3 Safe Concentration to Workers

The research shows the highest safe concentration for workers at 3.9 mg/m^3, and the lowest safe concentration is 0.4 mg/m^3. So, it can be concluded that safe concentration to workers in this study is an exposure of 0.4 mg/ m^3. Benzene is carcinogenic in humans and concentrations of airborne benzene associated with an excess lifetime risk of leukemia of 10^{-4}, 10^{-5} and 10^{-6} are 17, 1.7 and 0.17 μg/m^3, respectively (World Health Organization, 2010).

Secure Dt is more associated with a safe duration in working a day and a year (years) at work. Determination of safe Dt is important in work as it relates to workers'safety. Determination of Dt safe in work is related to work rotation or transfer of worker to work elsewhere safer in the aspect of the chemical work environment.

Based on the results of the study, it can be seen that the safe duration for workers to work is the highest at 11 years and the lowest at 1 year. The meaning of Dt safe of 11 years or 1 year is with the condition of environmental quality as it happened in the AHASS CV Workshop parts, so the workers can safely work for 1 to 11 years depending on the intake received.

According to ATSDR (2007), a minimum risk level of benzene at a concentration of 0.009 ppm has been derived for acute-duration of inhalation exposure (14 days or less), a minimum risk level of benzene concentration 0.006 ppm has been derived for intermediate-duration inhalation exposure (15–364 days) and a minimum risk level of benzene concentration 0.003 ppm has been derived for chronic-duration inhalation exposure (364 days or more) (Agency for Toxic Substances and Disease Registry, 2007).

Benzene levels with acute exposure in humans with a duration of 1 day 5 - 10 minutes with exposure to 20,000 ppm can cause death, for a duration of 1–21 days with 2.5–8 hours/day with an exposure of 60 M ppm can cause system disruption respiration such as mucous, membrane irritation and dyspnea), disorders of the hematological system such as leukopenia, anemia, thrombocytopenia, MCV elevation, and dermal system disorders, ie skin irritation. Benzene exposure at a duration of 30 minutes with benzene concentrations of 300 ppm can cause drowsiness, dizziness, and headaches while exposure to 1–21 days for 2.5–8 hours/day with benzene concentration of 60 M ppm can cause dizziness, nausea, headache, peculiar or strong odor, chemical taste, and fatigue. Exposure to benzene for a duration of 4 months - 1 year with benzene concentration of 150 ppm can cause pancytopenia and 210 ppm can cause pancytopenia, hypocellular to the hypercellular bone marrow. Exposure to 1-year duration with a concentration of 40 ppm can cause a decrease in WBC counts in the first 4 months. Exposure with a duration of 3.5 months to 19 years with a concentration of 29 ppm can cause aplastic anemia. Exposure with a duration of 4 months to 1 year with a concentration of 210 ppm can cause pancytopenia, hypoplastic to the hyperplastic bone marrow and enlarged spleen while the duration of exposure of 1 year with a concentration of 40 ppm can cause decreased lymphocytes. Benzene exposure at a duration of 3.5 months to 19 years with benzene concentrations of 29 ppm can cause CEL and human lymphocytic leukemia (Agency for Toxic Substances and Disease Registry,

2007).

Benzene can enter the body through the digestive tract, lungs or skin (EPA). When exposed to high levels of benzene, about half of the benzene inhaled passes through the lining of the lungs and into the bloodstream (Agency for Toxic Substances and Disease Registry, 2007). With a high concentration of benzene in a short exposure with a range of hundreds of ppm can cause confusion, tremor, headaches, and unconsciousness. While continuous exposure with low concentrations can cause blood-related diseases such as excessive bleeding, anemia, and a decrease in the body's immune response. In addition, benzene can also cause acute blood cancer or myeloid anemia because it is carcinogenic (Cenonus Energy Health & Safety, 2015). This study could contribute as one of the research on risk assessment topics which still limited in Indonesia especially focus on the standard of benzene concentration at motor workshop place. The study also limited in a number of sampling, require improvement in method design (not just cross-sectional but also in case-control, cohort or experiment design), and further research is required to acknowledge benzene risk assessment in the motor workshop.

5. Conclusion

Majority worker at AHASS CV Win Motor Workshop shows concentration of benzene exposure still under the Threshold Limit Value (TLV) according to the regulation of Manpower and Transmigration Ministry No 13 the year 2011 that measured the concentration of the three points and the average measurements. RQ score shows more than 1 (RQ >1), which means that the level of contamination of benzene in the work area of AHASS CV Win Motor Workshop is still included in the health risk category. The safe concentration for workers in Motor Workshop was 0,4 mg/m^3. The longest safe duration for workers was 11 years.

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Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

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