Safe Concentration of Benzene Exposure Based on Safe Human Dose of Workers in The Paint Manufacturing Industry Sidoarjo, East Java, Indonesia

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Abstract

Background: Manufacture of paints using benzene in large quantities in the products they produce. Workers in the paint industry may face an increased risk of high health complications. The purpose of this study was to determine the levels of safe concentration of benzene for workers in the Paint Manufacturing Industry in Sidoarjo East Java, Indonesia. **Methods:** This research was conducted using a cross sectional method. The sample in this study were 24 respondents. The variables that became the data of this study included benzene concentration (C) time of daily exposure (tE), frequency of annual exposure (fE), duration of exposure (Dt), height (cm), weight (kg), age, respiration rate (BR), body surface area, weight of white rat, body surface of white rat, highest dose of toxin without effect on experimental animals (NOAEL), Km factor in animal (Animal Km), Km factor on workers (Human Km), safe limits for toxin doses for workers (SHD), and benzene concentrations in safe air for workers (C is 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 Paint Manufacturing Industry in Sidoarjo East Java, Indonesia. **Results:** Based on the results of measurements carried out, the concentration of benzene in the work environment of the Sidoarjo Paint Industry in the mixing solvent section is 2 ppm and in the packing section is 0.4 ppm, the safe concentration is 0.028 ppm. **Conclusion:** The recommended safe concentration of benzene exposure is 0.028 ppm. The safe concentration value exceeds the set value of 0.009 ppm daily for acute effects and 0.003 ppm daily for chronic effects, so control measures are needed to protect against the adverse effects of benzene on the health of workers. Control recommendations are to provide a good exhaust ventilation system at the paint manufacturing.

Keywords: *Benzene Exposure, Safe Concentration, Paint Manufacturing*

Introduction

The Paint manufacturing industry uses benzene in the products they produce in large quantities. Workers in the paint industry may overcome high health problems. Paint manufacturers usually use three main components in the manufacture of their products consisting of coloring agents, binding agents, and solvents that allow other components to remain in liquid form. Solvents are widely used in industries such as benzene. Using benzene as a solvent agent allows manufacturers to use materials that are cheaper and easier to obtain in their products to make high quality, inexpensive effective products to obtain. Individuals who work in cat-making facilities, either make products or service equipment used to produce products, according to the highest needs of long-term Benzene. Other individuals working in facilities are also at risk because benzene can enter the air during the manufacturing process.

Many industrial sectors use organic solvents. Organic solvents such as benzene can result in damage to the nervous system (central and peripheral), kidney damage, and liver, adverse reproductive effects, such as sperm changes and infertility, skin lesions, and cancer[1,2]. In paint production, solvent vapor is removed during the manufacturing process. If these emissions are left uncontrolled, high concentrations of organic solvents can accumulate in the work area, which endangers the health and safety of workers. Removing volatile organic

solvents into the atmosphere can cause increased tropospheric ozone levels, pollutants that cause negative health effects on the human lung system[3]. Appropriate exhaust ventilation applications are used to remove contaminants produced by operations to maintain a healthy work environment [4].

The Threshold Limit Value (TLV) of benzene chemicals in the workplace is the maximum allowable value is 0.5 ppm and is certainly included as a carcinogenic group in humans *(A1 = Confirmed Human Carcinogen)*[5]. The recommended exposure limit for 8 working hours is 0.1 ppm[6]. In Indonesia, TLV benzene is 0.5 ppm[7]. Whereas based on the Minimum Risk Level (MRL) set for benzene is 0.009 ppm daily can have an acute effect and 0.003 ppm every day has a chronic effect[8]. The aim of this study was to determine the level of safe concentration of benzene for workers in the Paint Manufacturing in Sidoarjo, East Java, Indonesia.

Methods and Materials

This research was conducted in the Paint Manufacturing in Sidoarjo, East Java, Indonesia. This research was conducted using a cross sectional method. The sample in this study were 24 respondents. Data was taken including measuring the concentration of benzene, filling in questionnaires and interviewing workers, while also collecting primary data in experimental animals namely the weight of white rats. Data on the concentration of benzene in the air was obtained by direct measurement using Coconut shell charcoal and analyzed by Gas Chromatography (GC), referring to the NIOSH 1501 method.

The variables in this study include benzene concentration (C) daily exposure time (tE), frequency of annual exposure (fE), duration of exposure (Dt), height (cm), weight (kg), age, rate respiration (BR), body surface area of workers, weight of white mice, body surface area of rats, 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 dosage for workers (SHD), and benzene concentration in safe air for workers (safe consentration).

Based on the data of white rat body weight, the body surface of the white mouse can be calculated using the following formula:

BSA Animal=0,09 $W^{0,67}$

Description:

BSA : Body Surface Area (m^2)

W : Body Weight (kg)

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

The surface area of the worker's body:

$BSA = \sqrt{W}.h/3600$

Description:

BSA : Body Surface Area (m2)

W : Body Weight (kg)

h : Height (cm)

Respiratory rate of workers

BR=5,3ln W−6,9 / 24

Description:

BR : Breathing Rate (m^3/jam)

W : Body Weight (kg)

Determination of safe limits of toxic doses for workers begins first by calculating Animal Km and Human Km.

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)

Human Km:

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

Description:

Human Km : Km factor in humans / workers

W : Worker weight

BSA : Body Surface Area of worker

One of the objectives of research activities in the field of toxicology is to be able to evaluate the safety of a substance. To determine the safe limit of the concentration of a chemical begins with a toxicity test determining the highest dose without causing effects on experimental animals or *No Observed Adverse Effect Level (NOAEL)*.

The safe limit of dosage of toxins for workers or Safe Human Dose (SHD) is found to begin by using the following formula:

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

Description:

SHD : Safe Human Dose (mg/kg)

Animal Km : Km factor in animals

Human Km : Km factor in humans / workers

Determining the safe limit of benzene concentration in the work environment uses the following formula:

$$\text{Safe Concentration} = \frac{(SHD)(W)}{(\delta)(BR)(t)} mg/m3$$

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

$$\text{Safe Concentration} = \frac{\#\ mg/m3x\ 24{,}5\ ppm}{(MW)}$$

Description:

Safe Concentration : toxic concentration in safe air for workers (mg/m^3)

SHD : Safe Human Dose (mg/kg)

W : Body Weight (kg)

δ : % of substances absorbed by the lungs

BR : Human respiratory rate (m3/jam)

t : Working time (hour)

MW : Molecular Weight

FINDINGS

Distribution of Characteristics of Workers

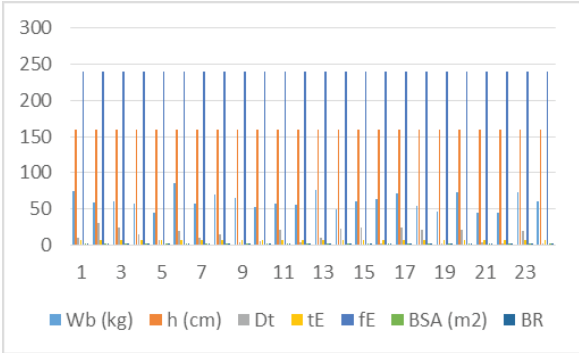

Figure 1. Distribution of Characteristics of Workers

Figure 1. Obtained average weight data (W) of respondents is 60.71 kg, the average height (H) of respondents is 159 cm, the average length of work (Dt) of respondents is 13 years. The duration of working a day (tE) is 7 hours, the number of workdays in a year (fE) is 240. The results of the analysis of calculation of body surface area and worker respiratory rate according to table 2 show that the average body surface area of workers (BSA) is 1,63 m^2 and the average respiration rate of workers (BR) is 0.62 m^3 / hour.

Distribution of benzene concentration in the workplace

Tabel 1. Distribution of benzene concentration in the workplace

Location	C (ppm)
Mixing Solvent	2 ppm
Packing	0,4 ppm

Tabel 1. Based on the results of the measurements made, the concentration of benzene in the work environment of the Paint Manufacturing Industry in Sidoarjo at the mixing solvent section is 2 ppm and in the packing section is 0.4 ppm.

Animal Km

Tabel 2. Calculation Results of Animal Km (White Rat)

ANIMAL KM			
Object (White Rats)	**W (kg)**	**BSA (m2)**	**Animal KM = W/BSA**
1	0,1405	0,024165	5,814194082
2	0,1405	0,024165	5,814194082
3	0,141	0,024223	5,820914007
4	0,141	0,024223	5,82091401
5	0,1395	0,024050	5,80041580
6	0,1415	0,024165	5,855576247
Total	0,7025	0,120826	29,07063198
Average	0,141	0,02	5,81

Table 2. The results of the Animal Km calculation are shown in table 2, with Animal Km averages of 5.81.

Human Km

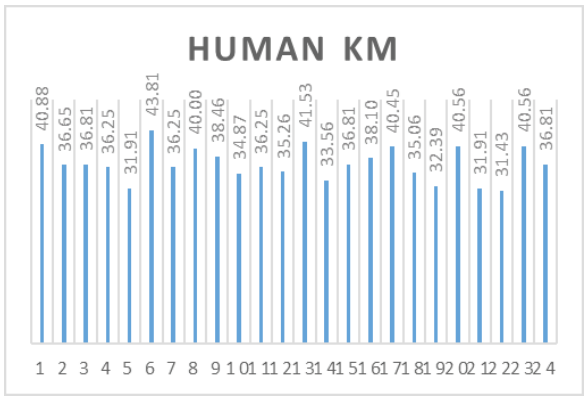

Figure 2. Results of Human KM Calculation on Workers

Figure 2. The results of the Human Km calculation are shown in table 2, with a Human Km average of 36.94.

No Observed Adverse Effect Level (NOAEL)

Benzene NOAEL is 3.0 mg / m3 or equivalent to 0.022 mg / kg obtained from the calculation of the formula as follows[9]:

$$\text{NOAEL penerapan } \left(\frac{mg}{mg}\right) = \frac{0,1402}{3 \times 0,00013 \times 8} = 0,022mg/kg$$

Safe Human Dose

Based on the formula from Shaw et al., The calculation of SHD obtained from the NOAEL value, the average animal Km, and the average human Km is 0.003 mg / kg based on the calculation below:

$$SHD = 0,022mg/kg\,\frac{5,81}{36,94} = 0,003mg/kg$$

Safe Concentration of Benzene

Calculation of safe concentration of benzene in the Paint Manufacturing industry in Sidoarjo is 0.028 ppm obtained from the calculation below:

$$\text{Safe Concentration } \left(\frac{mg}{m3}\right) = \frac{0,003 \times 60,71}{(50\%)(0,6)(7)} = 0,088mg/m3$$

$$\text{Safe Concentration (ppm)} = \frac{0,088\frac{mg}{m3} \times 24,45}{78,11} = 0,028\,ppm$$

Discussion

Concentrations of Benzene Exposure

Based on the results of the measurements made, the concentration of benzene in the work environment of the Paint Manufacturing Industry in Sidoarjo at the mixing solvent section is 2 ppm and in the packing section is 0.4 ppm. The benzene concentration in the mixing solvent section is above the Threshold Value (NAB) while the benzene concentration in the packing section is below the Threshold Value (NAB) of 0.5 ppm[7]. However, the concentration of benzene is above the Minimum Risk Level (MRL), the level of exposure to benzene inhalation is determined namely for acute exposure (≤14 days) = 0.009 ppm, moderate exposure (15-364 days) = 0.006 ppm, and chronic exposure (≥365 days) = 0.003 ppm[8].

Safe Concentration to Workers

Research shows that safe concentration for workers in the Sidoarjo paint industry is 0.028 ppm. Benzene is carcinogenic in humans and concentrated air benzene is associated with excessive lifetime risk resulting in leukemia[10]. The minimum risk level of benzene at a concentration of 0.009 ppm has been reduced for the duration of exposure to acute inhalation (14 days or less), the minimum risk level of 0.006 ppm benzene concentration has been lowered for medium duration inhalation exposure (15-364 days) and minimum risk level of benzene 0.003 ppm reduced for chronic duration inhalation exposure (364 days or more)[8].

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 enters the bloodstream[8]. With high concentrations of benzene in short exposures in the range of hundreds of ppm can cause confusion, tremor, headaches, and unconsciousness. While continuous exposure to low concentrations can cause blood-related diseases such as excessive bleeding, anemia, and decreased immune response. In addition, benzene can also cause acute blood cancer or myeloid anemia because it is carcinogenic[11]. This research can contribute as one of the studies on the topic of risk assessment which is still limited in Indonesia, especially focusing on the standard benzene concentration in the paint manufacturing industry. This research is also limited in a number of sampling, requiring improvements in method design (not only cross-sectional but also in case-control, cohort design or experiments), and further research is needed to recognize the risk assessment of benzene in the paint industry. Control recommendations are to provide a good exhaust ventilation system at the paint manufacturing plant, consume CYP2E1 enzymes contained in beef liver which serve to reduce the level of benzene in the body, use of appropriate Personal Protective Equipment[12].

Conclusion

Workers in the Mixing Solvent section at the Indonesian Paint Industry in Sidoarjo showed benzene exposure concentrations of 2 ppm, which was above the threshold value of 0.5 ppm according to the Minister of Manpower and Transmigration Regulation No. 13 of 2011, included in the health risk category. Unsafe concentration for workers. The recommended safe concentration of benzene exposure is 0.028 ppm. The safe concentration value if according to the Minimum Risk Level (MRL) exceeds that which is set at 0.009 ppm daily for acute effects and 0.003 ppm daily for chronic effects, so that control efforts are needed to be protected from the adverse effects of benzene on the health of workers. Control recommendations are to provide a good exhaust ventilation system in the paint manufacturing industry.

Conflicts of Interest : All authors have no conflict interest to declare.

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

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