Quantitative Risk Assesment of Benzene Exposure in Printing Industry X Surabaya City

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Abstract

Benzene is a compound chemically volatile and lasts a long time in the air and quickly inhaled into the human body. The use of benzene is widely used in various industries, one of which is the printing industry. Benzene produced right in the printing industry are ink, cleaning fluid, and when the machine in operation. Workers exposed to benzene can risk cancer and non-cancer health effects that are harmful to the human body. This study aimed to assess cancer and non-cancer risk of workers in the printing industry X Surabaya City. This research is observational, cross-sectional with the same sample with a total population of 11 workers in the printing industry X Surabaya City. The risk assessment method uses four stages: hazard identification, exposure analysis, dose and response analysis, and risk characterization. This research shows that the average concentration of benzene is 1.0729 mg/m^3 or 0.34 ppm. RQ value > 1 both real-time and lifetime. As many as 63.6% of workers have real-time ECR >10 $^{-4,}$ and 81.8% of workers have ECR lifetime >10^{-4}. This study concludes that workers are in an unsafe condition and have non-carcinogenic and carcinogenic health risks.

Keywords: *benzene, printing, assessor a risk, Risk Quotient, Excess Cancer Risk*

Introduction

Benzene is a compound that has the chemical formula C $_6$ H $_6$. Benzene including organic compounds, volatile or *Volatile Organic Compounds* (VOC). Due to the volatile nature of benzene and lasts a long time in the air, it is quickly inhaled and enters the human body. About 50% of benzene in the air is quickly absorbed through the lungs[4]. Benzene as a vapor can last for hours or even days, depending on the environment, climate, and other pollutants[20].

Benzene is used in a variety of industries, including petroleum, chemical production, and manufacturing. In some countries, it still occurs in shoemaking, painting, printing, and rubber manufacturing[14]. In Indonesia, benzene is still used in the petroleum industry, gas stations (*SPBU*), printing, shoes factory, workshops[17,23,25,27,29]. The use of benzene in printing is proven in[16]research that benzene is released during printing machine operation, depending on the printing speed and temperature

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equipment. Benzene is damaging indoor air quality and adversely affects health workers[16]. Several studies also show that there is a concentration of benzene in the printing industry[3,10,17,22].

Each chemical has its safe value or Threshold Value (NAV). For example, benzene has a NAV of 0.05 ppm, according to Manpower Regulation Number 5 of 2018. Meanwhile, according to NIOSH, benzene has a NAV of 0.1 ppm[4]. Based on the research of[17], shows that there is a concentration of benzene in the X printing press in Semarang City with an average of 0.1322 ppm, which has a NAV above 0.1 ppm according to NIOSH[17]. Based on the research of[3] showed that the benzene concentration in the Printing X Surabaya had a NAV that exceeded 0.5 ppm, and the highest benzene concentration was 15.6418 ppm[3].

Exposure to benzene which humans inhale then distributed throughout the body through the blood. Once distributed, benzene is metabolized to be excreted or will produce harmful substances to the body and cause health problems.

Health disorders caused by benzene could be cancerous or non-cancerous. Based on research by[11] conducted in a newly renovated building in Beijing showed that inhalation exposure to formaldehyde and benzene could result in both cancer and non-cancer risks[11]. The risk of cancer caused by benzene that often occurs is Acute Myeloid Leukemia (AML). Based on the research of[28] showed that exposure to benzene, diesel fuel, metals, insecticides, fertilizers, glues and adhesives, paints and other coatings, as well as inks and pigments, is associated with an increased risk of *Acute Myeloid Leukemia* (AML) (all subtypes combined) and subtypes individuals[28]. For non-cancer health risks in the form of headaches, *fatigue,* and other non-cancer health problems. Based on the research[10] shows that workers in the X printing office in Semarang City experience several health complaints, namely headaches and fatigue[10].

Based on the explanation above, the purpose of this study is to assess the level of cancer and non-cancer risk of workers in the printing industry X Surabaya City.

Method and Material

This research is an observational study. Only observations were made without intervention, and according to time, this study used a cross-sectional research design. This research was conducted in the printing industry X Surabaya City in 2019. The sample in this study is the same as the total population of 11 workers.

Data collection for benzene concentration was using the 1501-2003 gas chromatography method and the High Volume Dust Sampler (HVDS). At the same time, the data collection characteristics of respondents using questionnaires and interviews. Data analysis using risk assessment. There are four stages in the risk assessment, namely hazard identification, exposure analysis, dose and response analysis, and risk characterization.

Intake calculation who obtained from the following formula:

$$I = \frac{C \times R \times tE \times fE \times DtC \times R \times tE \times fE \times Dt}{W_b \times t_{avg} \qquad W_b \times t_{avg}}$$

Where:

C = Concentration (mg/m^3)

R = Respiratory Rate (m^3/hour)

tE= Daily Exposure Time (hour/day)

fE=Annual Exposure Frequency (days/year)

Dt=Exposure Duration (real-time or lifetime)

W_b = Body Weight (kg)

t_{avg}= Average Time Period, 30 years x 365 days/ year (non-carcinogenic) or 70 years x 365 days/year (carcinogenic)

The difference between real-time and lifetime is the duration of exposure (Dt). For real-time is the actual time achieved during work, while lifetime is an estimated 30 years.

There are two results from risk characterization, namely, non-carcinogenic risk (RQ) and carcinogenic

risk (ECR).

To determine the RQ (Risk Quotient) the formula is:

$$RQ = \frac{I_{nc}}{RfD \text{ atau } RfC}$$

Where:

I_{nc} = Intake Non-Carsinogenic (mg/kg/day)

RfD or RfC = Reference Dose (mg/kg/day)

After obtaining the RQ value, assumed that the RQ value 1 indicates a safe condition that allows no risk of non-carcinogenic health effects. While RQ > 1 indicates an unsafe condition that enables non-carcinogenic health effects, risk control or management is needed.

Meanwhile, to determine the carcinogenic risk, the ECR (Excess Cancer Risk) calculation is carried out with the formula:

$$ECR = I_c \times CSFI_c \times CSF$$

Where:

I_c = Carcinogenic Intake (mg/kg/day)

CSF = Reference Dose (mg/kg-day)

If the ECR 10^{-4}, then the exposure concentration is safe, and there is no risk of carcinogenic health effects. If the ECR>10^{-4}, then the exposure concentration is not safe for the body and can cause carcinogenic health effects.

Finding

This study resulted in the concentration of benzene at each measurement point in table 1

Table 1. Distribution of Benzene Concentration in Printing Industry X Surabaya City 2019

Measuring Point	Benzene Concentration (mg/m3)	Total	
		f	%
Point 1	0,5056	5	45,4
Point 2	0,1320	3	27,3
Point 3	2,9593	3	27,3
Total		11	100
Mean	1,0729		

In table 1, know that the highest concentration of benzene in the production section was 2.9593 mg/m^3 or 0.93 ppm, and as many as three workers (27.3%) of benzene were exposed. On the other hand, the lowest concentration was 0.1320 mg/m^3 or 0.04 ppm, and as many as three workers (27.3%) of benzene were exposed. The workers who were most benzene exposed were at point 1 as many as five people (45.5%) with a concentration of 0.5056 mg/m^3 or 0.16 ppm. In comparison, the average concentration of benzene in the printing industry X Surabaya City is 1.0729 mg/m^3 or 0.34 ppm.

Table 2. Distribution of Workers Weight in Surabaya City Printing Industry X 2019

Body Weight (kg)	Frequency (person)	Percentage (%)
≤ 54	2	18,2
55-64	3	27,3
65-74	4	36,4
>74	2	18,2
Total	11	100

The distribution of body weight showed that the highest percentage was in the 65-74 kg group, which was 36.4%. While the lowest rate in the two weight groups, 54 and > 74, is 18.2%. The average body weight of workers in the printing industry X Surabaya City is 64.2 kg, which means that the worker's weight is less than the US-EPA standard, 70 kg for adults.

Table 3. Distribution of Activity Pattern in Printing Industry X Surabaya City Workers 2019

Activity Pattern	N	Min.	Max.	Mean	Std Deviation
Daily Exposure Time (hour/day)	11	8	9	8,09	0,302
Annual Exposure Frequency (days/year)	11	260	260	260,00	0,000
Exposure Duration (year)	11	2	20	10,09	5,522

Based on table 3, know that the average exposure time is 8.09 hours/day, with the longest time being 9 hours/day. Meanwhile, the average duration of exposure is 10.09 days/year, with the most prolonged period being 20 days/year. Therefore, for the intermediate frequency of exposure, which is the same as 260 days/year, there is no variation.

Table 4. RQ (Risk Quotient) Real-time and Lifetime Surabaya City Printing Industry X 2019

Respondent	RQRealtime	RQ Lifetime
1	237,356	474,7114
2	63,1498	94,7246
3	195,308	585,9252
4	13,3743	26,7486
5	37,8899	94,7246
6	85,1794	511,0765
7	11,6436	87,3268
8	6,9054	23,0180
9	5,54687	27,7343

Table 4. RQ (Risk Quotient) Real-time and Lifetime Surabaya City Printing Industry X 2019

Respondent	RQRealtime	RQ Lifetime
10	58,5976	878,9633
11	29,9133	69,0306

Table 4 shows that all 11 workers have an RQ value > one both real-time and lifetime, which indicates their condition is not safe and has a risk of non-carcinogenic health effects.

Table 5. ECR (Excess Cancer Risk) Real-time and Lifetimein Printing Industry X Surabaya City Workers 2019

Respondent	ECR*Realtime*	ECR *Lifetime*
1	0,00092	0,00184
2	0,00025	0,00037
3	0,00076	0,00228
4	0,00005	0,00010
5	0,00015	0,00037
6	0,00033	0,00199
7	0,00005	0,00034
8	0,00003	0,00009
9	0,00002	0,00011
10	0,00023	0,00342
11	0,00012	0,00027

Table 6. Distribution of Excess Cancer Risk (ECR) Printing Industry X Surabaya City Workers 2019

No.	ECR	f	%
Real-time			
1	Safe ($\leq 10^{-4}$)	4	36,4
2	Unsafe ($>10^{-4}$)	7	63,6
Total		11	100
Life-time			
1	Safe ($\leq 10^{-4}$)	2	18,2
2	Unsafe ($>10^{-4}$)	9	81,8
Total		11	100

Based on table 6, from the ECR real-time calculation of benzene exposure, seven workers (63.6%) were in an unsafe condition and at risk of having carcinogenic health effects. While the results of the calculation of the ECR lifetime of benzene exposure were more extraordinary, as many as nine workers (81.8%) in unsafe conditions and at risk of having carcinogenic health effects

Discussion

Benzene in the printing industry X Surabaya arises from chemicals containing benzene in the production process. Based on the research of[26], benzene in the printing industry is produced by solvent cleaners[26]. Chemicals are containing benzene, one of which is printing equipment, in addition to solvents, thinners, cleaners, inks, and anti-rust oils[7].

The concentration of benzene in the printing industry X Surabaya City is divided into an average value of 1.0729 mg/m^3 or 0.34 ppm. The average value of benzene concentration in the printing industry X Surabaya City, by Ministry of Manpower 5 of 2018, shows that it is still below the Threshold Value (NAV) for benzene chemicals, which is 0.5 ppm. However, one point with a concentration exceeding the Threshold Limit Value (TLV) of 0.5 ppm equals 2.9593 mg / m ^{3} or 0.93 ppm. The results are in line with research by[10] that the average concentration of benzene in the printing industry X Semarang was under NAB is equal to 0.4226 mg / m ^{3} or 0.1323 ppm. There is one sample that exceeded NAB, i.e., 0.553 ppm. In addition, the research by[22] showed that 64% of workers in the printing industry in Medan who were exposed to benzene concentrations were below the NAV and 36% above the NAV.

The daily exposure time shows the number of hours worked in a day that the worker has. The highest working hours of workers in the printing industry X Surabaya City is 9 hours/day. While the duration of exposure shows how long workers are exposed to benzene in years. The workers in the printing industry X Surabaya longest worked for 20 years and most recently worked for two years. The duration of exposure affects the effect of benzene on the body, which can interfere with workers' health this is in line with research by[2], who showed that long-term or long-term exposure to benzene could cause dermatological effects that can increase skin diseases, besides that blood disorders and liver disorders are also caused by long-term benzene exposure[2].

The RfD or RfC value or reference dose represents the daily exposure level in the human population, which is unlikely to have an adverse effect. RfD and RfC are that the RfD is for chronic exposure by mouth, while RfC is for chronic exposure through inhalation. Each chemical has a different RfD and RfC. The RfC of benzene in this study was 0.00031 mg/kg/day.

To get to know the value of RQ or non-carcinogenic risk characteristics, it is necessary to value *Intake* Non-carcinogenic (I_{nc}) and the value of the RfC, then dividing the value I_{nc} RfC. From the calculation results in table 4. Real-time and lifetime Risk Quotient (RQ), which has a value of more than one (RQ> 1) which means unsafe conditions that allow the risk of non-carcinogenic health effects for workers in the printing industry X Surabaya City. This is in line with research by[21] conducted at the printing and photocopying center of the city of Ardabil, Iran, that the *hazard quotient* (HQ) of benzene in indoor air with *an inkjet printer* is > 1, which indicates that the risk of non-hazardous The carcinogenicity associated with benzene exposure is enormous. Non-carcinogenic risks are health disorders that attack the human body but do not cause cancer. Such as cardiovascular risk, headaches, fatigue, and others. The results of research conducted by[1] showed that there was a relationship between benzene exposure and cardiovascular risk[1]. In addition, the study by[6] showed that benzene exposure was associated with fatigue at work[6].

CSF (*Carcinogenic Slope Factor*) is the risk value obtained by the average lifetime amount of one mg/kg/day of chemical carcinogens and specific contaminants. The CSF benzene value in this study was 0.029 mg/kg/day.

To get the value of ECR and determine the characteristics of the required value of carcinogenic risk *Intake* carcinogenic (I_c) and the value of CSF,

then dividing the value I_c by the CSF. *Realtime* ECR of benzene exposure of 7 workers in unsafe conditions and at risk of carcinogenic health effects. At the same time, the results of the calculation of the ECR *lifetime of* benzene exposure are more significant, namely as many as nine workers in unsafe conditions and at risk of having carcinogenic health effects. Most of the workers in the printing industry X Surabaya City are at risk of having carcinogenic health effects. This is in line with research[10] which showed that the average ECR benzene *real-time* at 0.00028 to 0.0012 and *lifetime* of 0.001 to 0.0043, then the value of the ECR> 1 which means that workers in the industry X printing Semarang is at risk of having cancer health effects. Benzene is a chemical that has carcinogenic properties that can cause cancer. It is proven that benzene is included in the A-1 category, which is carcinogenic to humans[12]. Benzene causes Acute Myeloid Leukemia (AML) which is a malignant disease (cancer) that attacks the blood system and bone marrow[19]. This is evidenced in a study[15] which showed that the concentration of benzene in the ambient air of Tehran, Iran, can increase the risk of AML, especially in the southern and central areas of Tehran, Iran. Benzene exposure can increase the AML. There are men between the ages of 30 and 40. In addition to AML, benzene also can cause *non-Hodgkin lymphoma* (NHL), *Chronic Lymphocytic Leukemia* (CLL), and *Multiple Myeloma* (MM), which is also cancer. *Non-Hodgkin Lymphoma* develops in the lymphatic system (lymph), which is part of the human immune system[18]. According to[5] , there was an increased risk of *Non-Hodgkin Lymphoma* in Chinese women exposed to benzene in Shanghai[5]. While *Chronic Lymphocytic Leukemia* (CLL) is a type of cancer which is a small lymphocyte in the bone marrow and peripheral tissues that will overgrow with medium-sized (immature) tumor cells slowly but with accumulation[13]and *Multiple Myeloma* (MM) is cancer in which the cell immunoglobulin production pl asthma long-lived, and the end of the differentiation pathway for B cell neoplasm[9]. This is by research on[8] showed that exposure to benzene is associated with the risk of *Chronic Lymphocytic Leukemia* (CLL) and *Multiple Myeloma* (MM)[8]. In addition to attacking the blood system, benzene can also cause colon cancer, according to Talibov *et al.* (2018), which shows a relationship between benzene exposure at work and an increased risk of colon cancer. Exposure to benzene can cause cancer, especially in the proximal colon, but women can also be at risk of developing cancer rectal[24].

Smoking habits in workers can increase the risk of carcinogenic and non-carcinogenic health effects due to benzene exposure. The smoking habit of workers exacerbates the work environment that has been exposed to benzene. This is important to prevent to minimize the risk of health effects due to benzene on workers. In addition, the use of PPE (Personal Protective Equipment) that workers rarely use, such as gloves and masks, increases the risk of workers being exposed to carcinogenic and non-carcinogenic health effects. Therefore, it is essential to educate workers to maintain health, especially not smoking and using PPE and exercising every day, and consuming nutritious food.

Conclusion

Benzene concentration in the printing industry X Surabaya City is still below the Threshold Limit Value (NAV) with an average concentration of benzene which is 1.0729 mg/m^3 or 0.34 ppm.Realtime and lifetime RQ values (in the next 30 years) exceed one, which means workers risk non-carcinogenic health effects.For real-time ECR calculation, 63.6% of workers have ECR > 10^{-4}. Meanwhile, the calculation result of ECR lifetime is 81.8% ECR > 10^{-4}. Both mean that workers are in unsafe conditions and are at risk of having carcinogenic health effects.

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