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Estimating the safe duration and concentration of benzene exposure in the workplace in the printing industry

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ABSTRACT

Introduction: Increased levels of benzene in the air in the work environment can increase the case of leukemia cancer in workers. In their every activity, printing workers unwittingly breathe benzene vapor from the solvent used in ink. This study aimed to estimate safe concentrations and exposure times when working with benzene exposure in the workplace.
Methods: The type of this study is observational and cross-sectional. The research sample consisted of 25 people who worked in the printing industry.
Results: Benzene measurements in the work environment in the production section range from 1.57-4.88 mg / m3 with an average level of 2.54 mg/m3. The average intake was 0.0243 mg/ kg/day, while the average Risk Quotient (RQ) value was >1 (88%), which means there is a risk of adverse effects due to exposure to benzene vapor. Based on the calculation results, the current conditions with the concentration and characteristics of workers obtained an average safe duration of 3.2 years. For safe concentration, assuming a working life of 25 years and with the characteristics of the workers, the average safe concentration value is 0.2 mg/m3.
Conclusions: The level of risk of benzene exposure will continue to increase as the working period increases. It can be prevented by taking technical and administrative control measures and using personal protective equipment.

Keywords: benzene, concentration, printing, safe duration.
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INTRODUCTION

Printing is a medium for physically printing a file or data, which is still necessary for everyone, even though some people have switched to digital systems. Printing has developed into an industry that expands with rising demand throughout time, leading to the emergence of several new printing businesses, both small and large. In the printing process, whether done by hand or with a machine, the three basic raw materials are paper, ink, and solvents. Health and safety risks are brought on by the printing sector. Inks, glues, and solvents used in the printing business all contain hazardous compounds.[1] The use of solvents can cause health problems, both chronic and acute diseases.[2]

One of the solvents is benzene. The blood-forming organs may develop cancer as a result of prolonged exposure to benzene.[3] The name of this illness is leukemia. Benzene exposure can harm the reproductive organs in women.[4] Benzene exposure in the workplace can affect various indicators of genetic damage.[5] Occupational health complaints in the printing industry, as many as 78.8% of respondents experienced complaints of health problems such as headaches, nausea, shortness of breath, coughing, sneezing, and sore eyes.[6] According to studies, >80% of people who work in the printing business experience eye discomfort, rhinitis, and allergic skin reactions. Chest tightness, vision problems, and dizziness were all rather common, with prevalence rates of 43.1%, 31.0%, and 27.6%, respectively.[7] This study will be examined related to benzene exposure in the work environment which can cause health problems for workers. Based on research conducted by Tualeka (2018), in order to understand how long benzene exposure is associated with either non-carcinogenic or carcinogenic risks in workers exposed to benzene, additional study on risk assessment is required, particularly on the safe limit of benzene concentrations in the workplace.[8]

The study's goals were to ascertain the amount of benzene that workers inhale into their bodies, learn about the substance's risk qualities (RQ), and establish the length and safe level of benzene exposure in the workplace for those who work in the printing sector.

METHODS

This type of research is included in observational, cross-sectional, and descriptive research. The research sample consisted of 25 people. The research variables were the concentration of benzene in the workplace, the length of work per day, the frequency of work each year, the intake of benzene in workers through breathing, the length of

work, the RQ, the duration, and the safe concentration of workers.

The information gathered for the study came from primary sources, including questionnaires on years of service, body weight, age, and length of employment. The safe time for workers to be exposed to benzene was determined by quantitative data analysis utilizing a manual method in this study.

Intake data is calculated using the following equation:

$$I = \frac{C \times R \times te \times fe \times Dt}{Wb \times tavg} \quad \text{.....1}$$

The formula used to calculate safe duration is:

$$Dt = \frac{RfC \times Wb \times t\,avg}{C \times R \times tE \times fe} \quad \text{.....2}$$

The formula used to calculate the safe concentration is:

$$C = \frac{RfC \times Wb \times tavg}{R \times tE \times fe \times Dt} \quad \text{.....3}$$

I : intake (mg/kg/day)
C : risk agent concentration, mg/m^3
R : rate of respiration (m^3/hour)
te : time of exposure/work in a day (hours/day)
fe : frequency of annual exposure (day/year)
Dt : duration of exposure (years)
Wb : weight (kg)
Tavg : average time

To calculate the intake or exposure intake, this study uses several standard exposure factor values for workers based on USEPA, which include respiratory rate (R), time of exposure/length of work in a day (te), frequency of annual exposure (fe) and time. average (tavg), which can be seen in Table 1 as follows.[9]

The reference value of benzene concentration (RfC) in this study uses a reference value of 0.03 mg / m^3.[10] Based on the RfC value, it is then converted into the RfD value with the following equation:

$$RfC\ \left(\frac{mg}{m^3}\right) \times \frac{\frac{20\ m^3}{day}}{70} kg = RfD\left(\frac{mg}{kg}/day\right) \quad \text{.....4}$$

From the above equation, the RfD value is 0.00857 mg/kg/day.

The RQ is calculated by dividing the non-carcinogenic intake of the risk agent by the RfD or Rfc according to the equation:

$$RQ = \frac{I}{RfC/RfD} \quad \text{.....5}$$

Table 1. Standard exposure factor values for workers based on USEPA 2014.

Parameter	Unit	value
Respiratory rate (R)	m^3/hr	0.83
Exposure time (te)	hours/day	8
Frequency of exposure (fe)	day/year	250
Average time (tavg)	year	70

Table 2. Characteristics of workers in the informal sector printing industry in the city of Surabaya 2020.

Variable	Category	n	%
Age (years)	Teenagers (17-25)	6	24
	Adult (26-45)	16	64
	Elderly (> 46)	3	12
Gender	Male	15	60
	Female	10	40
Working time	≤ 8 hours	25	100
	> 8 hours	0	0
Working period	≤ 10 year	16	64
	> 10 year	9	36

RQ : Risk Quotient
Ink : Intake (mg/kg/day)
RfD / Rfc : reference dose/reference concentration

RQ >1 shows the potential for risk of adverse effects and the necessity for control measures if the value of RQ 1 indicates that there is no danger of harmful effects.[11]

RESULTS

Respondent Characteristics

From the results of this study, the data variables according to the respondents, in Table 2, it can be seen that the age group is mostly 64% in the adult age group. The gender of workers is 60% male. The working period that the respondents have passed while working in the research printing company is 64% less than or equal to 10 years. Working hours in a day 100% of respondents work 8 hours/day.

Measurement of benzene in the work environment in the production department ranges from 0.4914 - 1.5277 ppm or 1.57 - 4.88 mg/m^3 with an average level of 0.7959 ppm or 2.54 mg/m^3. The research data shows the average daily life value, risk, duration and safe concentration in Table 3. It can be concluded that the average intake is 0.0243 mg/kg/day, while the average RQ value is >1, which means there is a risk of adverse effects due to exposure to benzene vapor—based on the calculation results obtained an average safe duration of 3.2 years by current conditions with the concentration and characteristics of workers. For a safe concentration, assuming a working life of 25 years and with the characteristics of the worker, the average safe concentration value is 0.2 mg/m^3.

The determined risk level, or RQ value, is then classified as either risky or not. If the RQ value is more than 1, then there is a health risk that needs to be controlled, and this is how the RQ value is classified. If the RQ number is less than one, there is no health risk. The average RQ findings were >1 (88%), which signifies that the level of benzene contamination in the production section's work area poses a risk to the person's health and falls into the unsafe category (Figure 1).

DISCUSSION

The results of benzene measurement in the work environment area obtained an average result of 0.7959 ppm or 2.54 mg/m^3. Similar research conducted in the printing industry in the city of Semarang found that the average benzene concentration was 0.422 mg / m^3 or 0.13 ppm.[12] Measurements are made at the point where workers carry out their activities. The main source of benzene in the work environment comes from the solvent used to dissolve inks in the printing process. This is also felt by workers who smell chemicals in the work environment. Benzene affects the blood-forming system at low exposure levels. There may not be a safe level of exposure to benzene because

Table 3. **Calculation of the daily average dose of life, risk, duration and safe concentration.**

Respondent	Intake (mg/kg/day)	Risk Quotient (RQ)	Safe Duration (years)	Safe Concentration (mg/m³)
1	0.02027	2.36	3.0	0.235
2	0.01610	1.88	4.3	0.328
3	0.02063	2.41	2.5	0.204
4	0.01245	1.45	2.8	0.241
5	0.03808	4.44	3.4	0.214
6	0.02230	2.60	3.8	0.279
7	0.00508	0.59	3.4	0.318
8	0.01650	1.93	3.1	0.255
9	0.01019	1.19	4.2	0.356
10	0.01000	1.17	3.4	0.300
11	0.02139	2.50	2.8	0.223
12	0.02539	2.96	3.4	0.245
13	0.04584	5.35	2.8	0.178
14	0.00311	0.36	2.8	0.269
15	0.04008	4.68	3.6	0.220
16	0.06301	7.35	2.9	0.158
17	0.02539	2.96	2.7	0.208
18	0.06876	8.02	3.1	0.158
19	0.01800	2.10	2.9	0.234
20	0.02845	3.32	3.0	0.219
21	0.01925	2.25	3.1	0.247
22	0.04552	5.31	3.0	0.187
23	0.01100	1.28	3.9	0.330
24	0.01834	2.14	2.3	0.198
25	0.00300	0.35	2.9	0.279
Min	0.00300	0.35	2.3	0.2
Max	0.06876	8.02	4.3	0.4
Average	0.0243	2.83	3.2	0.2

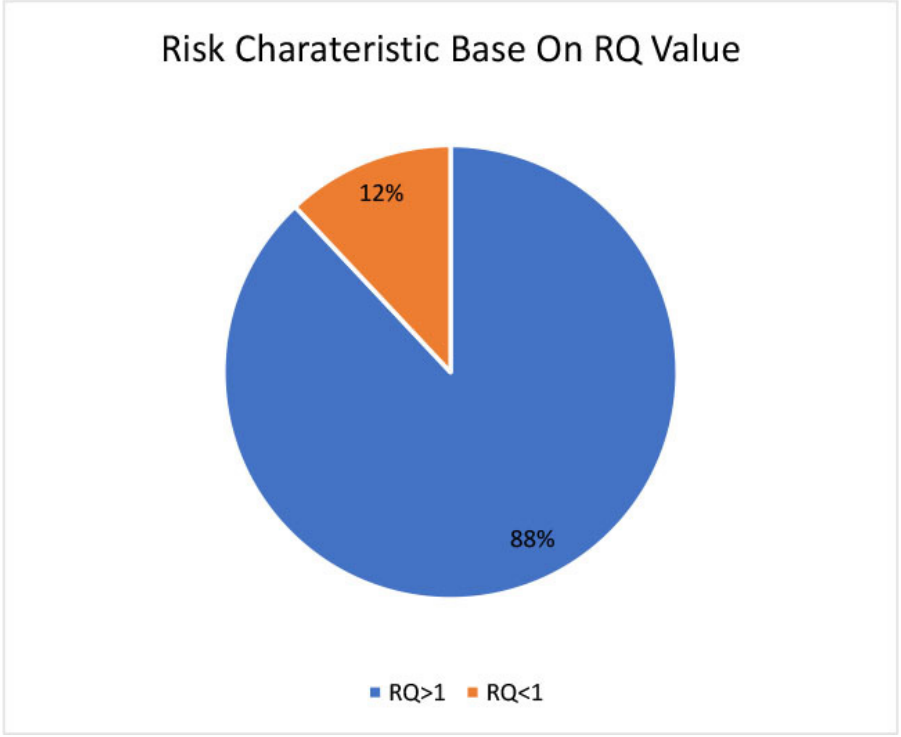

Figure 1. RQ value

all exposures have a linear and additive risk.[13]

The duration of exposure referred to here is the length of time the respondent works in the production section according to the respondent's information in units of years, while the daily exposure time is the length of time the respondent works in the workplace to breathe air in a period of one, namely 8 hours/day. The research results showed that the highest length of exposure was 8 years, with the number of hours worked every day being 8 hours. This means the respondent who worked the longest in the production department was 7 hours daily for 8.8 years. The high duration of exposure to workers can result in high health risks. This risk can occur due to the accumulation of benzene exposure that enters the body through inhalation, increasing over time.[14] The RQ value for each worker is different because the intake or intake received by each worker is different. This is influenced by the rate of

inhalation, time of exposure, duration of exposure and bodyweight of the worker.[15]

The duration of exposure is the amount of time the worker is exposed to the accumulated years or years of service during the exposure to benzene vapor. Meanwhile, concentration is the value of a pollutant obtained from work environment measurements. Based on the analysis of exposure to duration and safe concentration values, an approach can be made through calculations based on current data, both worker characteristics and levels of contaminant concentrations in the work environment. The calculation of safe duration obtained an average safe duration of 3.2 years, which means that with the characteristics of workers and the current benzene concentration, workers do not get risks due to exposure to benzene. The safe working period is 3.2 years. If the worker is going to work for more than 3.2 years, some control measures must be made, either technically, administratively or using personal protective equipment.[16]

Based on the data on the characteristics of the respondents, the safe concentration is the average safe concentration of 0.2 mg/m^3. The result of this calculation assumes that with the characteristics of workers today, benzene concentration in the work environment must be controlled at a concentration of 0.2 mg/m^3 so that workers can work with relatively acceptable risks for the next 25 years.[17] The limitation of this study is that the sample size is small. Further research is needed to increase the number of respondents. Also, the location of this study is limited. Therefore, multicentre research in the future could be considered.

CONCLUSIONS

Measurement of the benzene concentration in the work environment obtained an average concentration of 0.79 ppm, and when compared with the threshold value of bats, it has been exceeded, namely 0.5 ppm. Risk characteristics 88% of workers risk experiencing health problems due to benzene exposure. The average safe duration was 3.2 years, and the safe concentration was 0.06 ppm or 0.2 mg/m^3. Therefore, workers must continue using appropriate personal protective equipment to reduce risks and occupational diseases.

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ETHICAL CONSIDERATIONS

This research has been declared ethically feasible by the research committee of Universitas Nahdlatul Ulama Surabaya, with ethical clearance reference number 147/EC/KEPK/UNUSA/2020.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

All authors contributed equally in conducting research and writing manuscripts.

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