Evaluation to Identify Benzene Safe Concentration in Oil and Gas processing Facility in East Java Area Due to Process Fugitive Emission

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Abstract

Benzene is an organic chemical compound with the chemical formula C6H6. The benzene molecule is composed of six carbon atoms joined in a ring with one hydrogen atom attached to each. Acute benzene exposure can cause central nervous system depression. Longterm exposure can result in depression of the blood-forming system and may increase risks associated with anemia and leukemia. The purpose of this research is to identify benzene safe concentration in crude oil processing plant in east java area due to process fugitive emission. Sample is taken from 20 workers include work duration and weight of the worker also crude oil plant air quality monitoring is measured using direct-measure benzene detectors.

In the benzene measurement on the crude oil plant in east java area, 2 spot sample is taken with resulting data 0.96 mg/m3 or 0.30 ppm and 0.86 mg/m3 or 0.27 ppm, and according to final manual calculation for safe benzene concentration with the result 1.12 mg/m3 or 0.35 ppm, all of those number are still below safe concentration limit by refer to minister of man power No.13 / MEN / X / 2011 regulation and The Occupational Exposure Limits (OELs) which have been adopted globally as a company standard which is 0.5 ppm as an eight hour time-weighted average (TWA8) and 1.0 ppm as a Short Term Exposure Limit (STEL) (averaged over fifteen minutes). But according to Minimum Risk Level (MRL) ATSDR 2007, those value already above threshold which is 0,009 ppm daily exposure for acute effect and 0,003 ppm daily exposure for chronic effect, Recommendation to control and reduce fugitive emission which resulting in number of benzene is by reviewing engineering design for equipment causing fugitive emission, and since this company regulation for respirator usage in benzene case are 0.5-5.0 ppm must use Half-face mask with organic vapor cartridge, 5.0-25.0 ppm use Full-face mask with organic vapor cartridge, and Greater than 25 ppm use Self-Contained Breathing Air (SCBA) then need to re asses all area which has an obligation to wear personal protective equipment (Half-full / full mask with organic vapor cartridge or Self contain breathing apparatus) by not only based on benzene level but also considering the exposure duration. .

Keywords: *Benzena, safe concentration, Crude Oil Plant, Fugitive emission, engineering design.*

Introduction

Oil and gas processing facility is place to separate raw oil from water, sediment, and unwanted gas. According *Agency for Toxic Substances and Disease Register* (ATSDR), dangerous chemical substances in the crude oil proprietary is benzene, toluene, xylene, ethylene, TPH (*Total Petroleum Hydrocarbon*), and *Polycyclic Aromatic Hydrocarbon* (PAHs)[1]. From six of them, benzene has the highest carcinogen effect to which can cause high severity harmful effect to the body[2].

Airborne benzene is the most common route of exposure. Even at low doses of airborne benzene (<1 parts per million (ppm)), As a result of inhalation

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exposure, lungs are the major site of benzene metabolism (Arnold et al., 2013)[3]. Worker in here continually exposed by benzene from process fugitive emission which come from process fugitive emission on the oil and gas processing facility[4].

The results of the measurement of benzene at two points in the Oil and Gas processing plant Industry in East Java are 0.96 mg/m3 or 0.30 ppm and 0.86 mg/m3 or 0.27 ppm. These results are still below safe concentration limit according to minister of man power No.13 / MEN / X / 2011 and The Occupational Exposure Limits (OELs) which have been adopted globally as a company standard which is 0.5 ppm as an eight hour time-weighted average (TWA8) and 1.0 ppm as a Short Term Exposure Limit (STEL) (averaged over fifteen minutes)[5]. but workers who are exposed to benzene will still have a carcinogenic effect. A similar study at the Pancoranmas Depok gas station by Abdul rohim (2012), even though benzene concentrations at the site had yields below the safe concentration limit, but workers at the exposed area had a risk of carcinogenic effects at the duration of the lifetime exposure[6].

The authors will measure the limits of the safe concentration of benzene in different areas, namely in the Oil and Gas Industry processing plant in east java region.

Material and Method

This type of research is an observational, cross sectional and descriptive study. The population in this study are all production operators in oil and gas company workers in the East Java region. The sampling technique is the total population, so the sample is 20 workers.

The research variables is benzene concentration in the workplace, worker body weight, worker height, respiration rate of ayworkers, length of day working, body surface area, weight of white mice, body surface of white mice, highest dose of toxin without effect on experimental animals NOAEL), Km factor in animals (Animal Km), factor Km in workers (Human Km), safe dose limit for toxins for workers (SHD), and safe benzene concentration in the air (safe C).

Data analysis in this study was carried out by using quantitative data analysis manually to determine the safe concentration of benzene for oil and gas company workers in the East Java region.

Findings

A. *Characteristics of Try Animals and the Surface Area of Try Animals (White Mice).*

According to Saridewi and Tualeka, the implementation of a toxicity test using experimental animals which is white rats[6]. In general, the human response to toxicity is qualitatively similar to the response of animals, so this fact forms the basis of extrapolation from animal to human data.

In table 1, the characteristics of experimental animals in the form of white rat body weight are displayed on below table.

Table 1. Distribution of Characteristics of Animals

Research (White Mice).

Animal research (White Mice)	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 the data of white rat body weight, the body surface of the white mouse can be calculated using the following formula[7].

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

Explanation:

BSA : Body Surface Area (m^2)

W : Weight (kg)

B. Worker Characteristics, Worker's Body Surface Area and Worker's Respiratory Rate.

Table 2. Workers characteristics distribution, Worker's Respiratory Rate and Length of Working Time in oil processing companies in East Java region.

Workers	W (kg)	H (cm)	BSA (m2)	BR (m3/ hours)	t (hours)
1	65	159	1,69	0,63	12
2	60	159	1,63	0,62	12
3	63	159	1,67	0,63	12
4	97	159	2,07	0,72	12
5	90	159	1,99	0,71	12
6	73	159	1,80	0,66	12
7	67	159	1,72	0,64	12
8	60	159	1,63	0,62	12
9	70	159	1,76	0,65	12
10	79	159	1,87	0,68	12
11	77	159	1,84	0,67	12
12	69	159	1,75	0,65	12
13	65	159	1,69	0,63	12
14	66	159	1,71	0,64	12
15	70	159	1,76	0,65	12
16	90	159	1,99	0,71	12
17	85	159	1,94	0,69	12
18	76	159	1,83	0,67	12
19	66	159	1,71	0,64	12
20	93	159	2,03	0,71	12
Average	74,05	159	1,80	0,66	12

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

1. Worker Body Surface Area

$= \sqrt{W \cdot h/3600}$

Explanation:

BSA : *Body surface area* (m^2)

W : *Weight* (kg)

h : *Height* (cm)

2. Workers Breathing Rate.

$= 5{,}3 \ln - 6{,}9 / 24$

Explanation:

BR : *Breathing rate* (m^3/jam)

W : *Weight* (kg)

Table 2 shows that the average body surface area of workers is 1.80 m2 and the average respiration rate of workers is 0.66 m3 / hour.

B. *Benzena Concentration.*

The measurement results of the concentration of benzene at two points in the Oil and Gas processing plant Industry in East Java are 1.44 mg / m3 or 0.45 ppm and 1.18 mg / m3.

Tabel 3. Distribution of Benzene Concentration in oil and gas processing plant in east Java region.

Measuring Location	Benzene Concentration (ppm)
Point 1	0.45
Point 2	0.37

Those benzene concentration is still below the threshold limit value of 0.5 ppm in accordance with the provisions of the Minister of Manpower Regulation No.13 / MEN / X / 2011 concerning Occupational Safety and Health at the Work Environment. However, the concentration of benzene is above the Minimum Risk Level (MRL), the level of benzene inhalation exposure determined by ATSDR which is for acute exposure (≤14 days)= 0.009 ppm, moderate exposure (15-364 days)= 0.006 ppm, and chronic exposure (≥365 days) [8]

C. *Animal Km dan Human Km*

The first step to determine safe dosage of toxin for workers is by calculating Animal Km and Human Km.

1. *Animal Km*

$$Animal\ Km = \frac{W\ animal}{BSA\ animal}$$

Keterangan :
Animal Km : Animal Km Factor.
W : Weight of research animal (White Mice).
BSA : Body Surface Area (White Mice).

The results of the Animal Km calculation are shown in table 4. The average Animal Km in the experimental animal is white rats which are 5.81.

Tabel 4. Result of Animal Km for Research animal (white mice).

Animal research (White Mice)	*Animal Km*
1	5,81420952
2	5,81420952
3	5,82102947
4	5,82102947
5	5,80052067
6	5,81420952
Average	5,81

Source: [6]

The results of the Human Km calculation are shown in table 5. Based on Table 5, the average Human Km in the oil and gas company environment in East Java is 36.70.

2. *HumanKm*

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

Explanation:
Human Km: Human Km factor.
W : Weight of workers.
BSA : Workers Body Surface Area.

Table 5. Calculation result of Human Km in oil and gas operators in east java region.

Workers	Human KM
1	38,36271775
2	36,85770701
3	37,76791091
4	46,86391378
5	45,14128763
6	40,65501431
7	38,94844197
8	36,85770701
9	39,81087364
10	42,29278006
11	41,75399653
12	39,52548736
13	38,36271775
14	38,65668924
15	39,81087364
16	45,14128763
17	43,86944611
18	41,48198063
19	38,65668924
20	45,88747517
Average	40,84

D. NOAEL

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

There was a research from Swaen et.al (2010) revealed that benzene NOAEL is 3,0 mg/m^3 (0.94 ppm) or equivalent with 0,022 mg/kg which come from below calculation.[9]

$$NOAEL\ benzene = \frac{3\ x\ 0{,}00013\ x\ 12}{0{,}1405}$$

E. $= 0{,}022$ mg/kg

F. Safe Human Dose

$$SHD = NOAEL \frac{W\ human}{human\ km}$$

According to above formula then from the SHD calculation which come from NOAEL value, average from animal KM and human KM are:

$$SHD = 0{,}022 \frac{74.05}{4\ ,84} = 0{,}0398\ mg/kg$$

G. Benzene safe concentration limit.

Below formula (William, 1985)[10] is used to determine benzene safe concentration limit in process area of oil and gas processing plant in east java region.

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

And to convert unit of mg/m^3 to be ppm can use below formula.

$$C\ aman = \frac{\#mg/m^3}{(MW)}\ x\ 24{,}5\ ppm$$

Explanation:
C Safe : safe toxin concentration in the air for worker (mg/m^3).
SHD : Safe Human Dose (mg/kg).
W : Weight (kg).
δ : % absorbed substances in lungs.
BR : Human breathing rate (m^3/jam)
t : Working time duration (jam).
MW : Molecular Weight.

The results of calculating the benzene safe concentration in the oil and gas process area in east java region are obtained from the SHD value, the average body weight, the percentage of absorbed substances, the average workers breathing rate and the average working time duration are:

$$C\ aman = \frac{(0{,}0398)\ (74{,}05)}{(50\%)\ (0{,}66)\ (12)}$$

$= 0{,}729$ mg/m^3

$$C\ aman = \frac{0{,}729\ x\ 24{,}45}{78{,}11}$$

$= 0{,}35$ ppm

Discussion

The risks of benzene are caused by the increasing accumulation of benzene exposure in the body through inhalation. It is also in line with the research of Maryiantari et al (2016), enter the duration exposure workers with a high level of exposure has adverse effects against the risk of developing health problems[11].

In this study involving 20 outside operators who work on the detected benzene area. Under normal condition, outside operators will stay on the benzene exposed area for doing routine job, but there will be potential higher benzene exposure where the activity in abnormal state (equipment failure, equipment under preparation for maintenance, pigging pipeline, or other breaking containment job).

OHSAS 18001 (2007) provides specific control guidelines for Occupational Health and Safety Hazards through elimination, substitution, technical, administrative and personal protective equipment approaches. The approach of elimination and substitution at oil and gas processing plant in east java will require big project means will demand high cost. For the technical approach can be done by making sure the preventive maintenance to minimize equipment failure, and continue re assessing area which producing harm benzene value and providing personal benzene detector to increase awareness when time to use benzene respirator protection as a personal protective equipment approach.[12]

Conclusion

In the benzene measurement on the crude oil plant in east java area, 2 spot sample is taken with resulting data 0.96 mg/m3 or 0.30 ppm and 0.86 mg/m3 or 0.27 ppm, those number are still below safe concentration limit according to minister of man power number No.13 / MEN / X / 2011 and The Occupational Exposure Limits (OELs) which have been adopted globally as a company standard which is 0.5 ppm as an eight hour time-weighted average (TWA8) and 1.0 ppm as a Short Term Exposure Limit (STEL) (averaged over fifteen minutes), and also according to final manual calculation for safe benzene concentration with the result 1.12 mg/m3 or 0.35 ppm, but according to Minimum Risk Level (MRL) ATSDR 2007, all of those value already above threshold which is 0,009 ppm daily exposure for acute effect and 0,003 ppm daily exposure for chronic effect, then control action needed to protect workers from benzene harm effect to worker occupational health, Recommendation is reviewing engineering design for equipment causing fugitive emission (review type of gasket on flanges, change to double seal on the pumps or compressors, and re-routing hazardous gas vent), and since this company regulation for respirator usage in benzene case are 0.5-5.0 ppm must use Half-face mask with organic vapor cartridge, 5.0-25.0 ppm use Full-face mask with organic vapor cartridge, and Greater than 25 ppm use Self-Contained Breathing Air (SCBA) then need to re asses all area which has an obligation to wear personal protective equipment (Half-full / full mask with organic vapor cartridge or Self contain breathing apparatus) by not only based on benzene level but also considering the exposure duration[4].

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