©2022. Asih dan Tualeka. Published by Universitas Airlangga.
This is an open access article under CC-BY-SA license
Received 19-04-2022, Revised: 19-08-2022, Accepted:01-09-2022, Published:01-12-. 2022

RESEARCH STUDY Open Access

Hubungan Karakteristik Individu, Konsentrasi Benzena dengan Degenerasi DNA Pada Pekerja Pengecatan Mobil di Surabaya

The Relationship of Individual Characteristics, Benzene Concentration with DNA Degeneration in Car Painting Workshop Workers Surabaya

Heningdia Pastika Asih[*1], Abdul Rohim Tualeka[2]

ABSTRAK

Latar Belakang: Bengkel cat mobil merupakan salah satu pekerjaan yang menggunakan cat sebagai bahan kerja utama yang mengandung benzena. Benzena adalah senyawa aromatik cair tidak berwarna yang bersifat karsinogenik bagi manusia. Senyawa ini diklasifikasikan sebagai karsinogen manusia kelompok 1 oleh IARC.
Tujuan: Penelitian ini bertujuan untuk menganalisis hubungan antara karakteristik pekerja dan konsentrasi benzena di tempat kerja dengan degenerasi DNA pekerja di bengkel cat otomotif di Kalijudan, Surabaya.
Metode: Penelitian ini merupakan penelitian observasional dengan desain cross sectional dan pendekatan kuantitatif. Data sekunder dari penelitian sebelumnya dikumpulkan dari 20 responden yang semuanya adalah pekerja cat di bengkel cat mobil. Variabel terikat dalam penelitian ini adalah degenerasi DNA dan variabel bebasnya adalah umur, indeks massa tubuh (IMT), lama bekerja, perilaku merokok, dan konsentrasi benzena. Untuk menganalisis korelasi variabel independen dan dependen, digunakan uji chi-square. Kemudian uji phi dan Cramer's v digunakan untuk menganalisis kekuatan korelasi antara kedua variabel.
Hasil: Pengukuran konsentrasi benzena di tempat kerja menunjukkan konsentrasi rata-rata yang lebih tinggi daripada TLV-TWA. Hasil pemeriksaan laboratorium, 13 dari 20 pekerja menunjukkan degenerasi DNA. Pada saat yang sama, hasil menunjukkan korelasi sedang antara BMI dan degenerasi DNA, dan korelasi yang sangat lemah antara konsentrasi benzena di tempat kerja, karakteristik individu (usia pekerja, tahun kerja, dan perilaku merokok) dan degenerasi DNA.
Kesimpulan: Penelitian ini tidak menemukan hubungan antara karakteristik pekerja dan konsentrasi benzena di tempat kerja dengan degenerasi DNA pada pekerja bengkel cat mobil Surabaya.

Kata kunci: benzene, bengkel pengecatan mobil, DNA, karakteristik individu

ABSTRACT

Background: *A car paint shop is one of the works that use paint as the main working material containing benzene. Benzene is a colorless liquid aromatic compound that is carcinogenic to humans. This compound is classified as a group 1 human carcinogen by the IARC (International Agency for Research on Cancer).*
Objectives: *This study aimed to analyze the correlation between individual characteristics and workplace benzene concentrations with DNA degeneration of workers in an automotive paint shop in Kalijudan, Surabaya.*
Methods: *This study is an observational study with a cross-sectional design and a quantitative approach. Secondary data from the previous study were collected from 20 respondents, all of whom were paint workers in an auto paint shop. The dependent variable in this study is DNA degeneration and the independent variables are age, body mass index (BMI), number of years working, smoking behavior, and benzene concentration. To analyze the correlation of independent and dependent variables, the chi-square test was used. And then the phi test and Cramer's v are used to analyze the strength of the correlation between the two variables.*
Results: *Measurements of benzene concentrations in the workplace showed higher mean concentrations than TLV-TWA. As a result of laboratory tests, 13 out of 20 workers showed DNA degeneration. At the same time, the results showed a moderate correlation between BMI and DNA degeneration, and a very weak correlation between benzene concentration at work, individual characteristics (worker age, years of work, and smoking behavior) and DNA degeneration.*
Conclusions: *This study found no correlation between individual characteristics and workplace benzene concentration with DNA degeneration in Surabaya auto paint shop workers.*

Keywords: *benzene, car painting shop, DNA, individual characteristics*

*Koresponden:
heningdia.pastika.asih-2018@fkm.unair.ac.id
Heningdia Pastika Asih
Department of Occupational Health and Safety, Faculty of Public Health, Universitas Airlangga Campus C Mulyorejo, Surabaya 60115 East Java, Indonesia

INTRODUCTION

The use of chemicals in daily human activities cannot be avoided, including in work activities. Starting from foodstuffs, beverages, motor vehicles, to basic production materials involved in daily work, they contain a composition of chemicals. Certain chemicals, if they enter the workers' bodies at levels that exceed the recommendations, can be a source of health problems for workers. Based on the Regulation of the Minister of Manpower of the Republic of Indonesia number 5 of 2018 concerning Occupational Safety and Health in the Work Environment, chemicals involved in the work process need to be considered for the level and time of exposure to the workers concerned (Minister of Manpower Regulation, 2018).

The presence of chemicals in the workplace needs to be controlled so as not to cause health problems for workers. Chemicals that enter the body can enter the bloodstream and can cause damage to certain body organs to damage to biomolecules in the body (International Labour Organization (ILO), 2015). Workers can be exposed to chemicals in the workplace through the respiratory system, skin contact, and digestion, where the three exposure pathways can potentially cause occupational diseases. According to the ILO (*International Labor Organization*) (2018), 2.78 million workers died every year due to work accidents and occupational diseases. Of these deaths, 2.4 million (86.3%) were caused by workers experiencing work-related illnesses, and 380,000 (13.7%) were caused by workers experiencing work accidents (International Labor Organization (ILO), 2018).

More than 190,000 workers in various professions in the United States experience occupational diseases due to exposure to chemicals and 50,000 of them died. Occupational diseases caused by exposure to chemicals in the workplace are chronic exposures or require a long time because acute chemical exposure is a very dangerous event and violates the regulations that have been set regarding the permissible concentrations. Therefore, those diagnosed with occupational disease**s** caused by certain chemicals report that workers have been exposed to certain chemicals for extended periods at low levels. Occupational diseases caused by exposure to chemicals include cancer, neurological disease, liver, kidney, lung, and reproductive disorders (Occupational Safety and Health Administration (OSHA), 2020). Based on the Indonesian Ministry of Health (2014), it is estimated that 2.3 million workers die every year due to accidents and occupational diseases. More than 160 million workers suffer from occupational diseases and 313 million workers experience non-fatal accidents per year. Of these cases, 2.3 million are fatality cases. around 651,279 of them are caused by hazardous chemicals (Indonesian Ministry of Health, 2014).

One of the jobs that involve the use of chemicals in daily activities is car painting. Paint shops in Indonesia are divided into two categories, namely paint shops belonging to official brands of cars sold on the Indonesian market and auto paint shops belonging to individuals (private sector), some are in the informal industry. Workers in the informal industry often do not pay attention to safety and health during work activities such as not using proper personal protective equipment (Darwis, D., Mubarak, M. and Anita, 2018).

The paint used is a composition of chemical dyes, solvents, and adhesives, each of which has the potential to cause health problems for workers if it enters the worker's body. Organic solvent chemicals or *Volatile Organic Compounds* (VOC) which are widely used in paints include the aromatic hydrocarbons benzene, toluene, and xylene. Based on research by (Eka, H. and Mukono, 2017), in addition to solvents in paints, dyes or pigments in paints containing lead can affect the increase in blood pressure of workers exposed to these substances during work. Another study conducted by Darwis et al. (2018) stated that there was a phenol content that exceeded the normal limit (20 mg/L) in the urine of car painting workers due to exposure to benzene contained in the paint material used.

Benzene is the basis of aromatic compounds that are carcinogenic to humans in the form of a colorless liquid. These compounds are grouped in *Group* 1 of carcinogenic substances to humans (International Agency for Research on Cancer (IARC), 2018). The toxic nature of benzene can cause aplastic anemia, which is anemia caused by damage to the bone marrow, so it cannot produce new blood cells (Timbrell, 2009). Individual worker factors can influence the poisoning response to the chemical benzene. These factors include the age of workers, BMI, years of service, and smoking behavior. Age can affect a person's level of vulnerability to disease (Agency for Toxic Substance and Disease Registry (ATSDR), 2007a). Someone over the age of 45 years tends to experience a decrease in the physiological function of organs that can affect a person's metabolic rate and excretory ability (Darwis, D., Mubarak, M. and Anita, 2018). BMI can reflect a person's nutritional status which

can affect health status and the more fat content in the body, the higher the absorption of fat-soluble toxic substances (Darwis, D., Mubarak, M. and Anita, 2018). Workers who have worked in car painting workshops for years and are exposed to benzene for a long time (> 5 years of work) will have a higher risk of problems than workers who are new (≤ 5 years of work) in that place (Kusgiyanto, 2017). And cigarette smoke is one source of exposure to benzene through inhalation or breathing. An active smoker every day will inhale cigarette smoke that contains benzene. A person who smokes as many as 32 cigarettes per day, will inhale as much as 1.8 mg of benzene per day (Agency for Toxic Substance and Disease Registry (ATSDR), 2015). Based on research by Salem, et al., 2018 smoking habits can significantly affect the level of DNA damage in gas station workers in Africa. The DNA repair process is also delayed due to smoking habits (Salem, E., El-garawani, I. dan Allam, 2018).

Control of benzene exposure in workers can be carried out by referring to applicable international regulations and national regulations. The national regulation that regulates the requirements of the industrial work environment in Indonesia is the Regulation of the Minister of Health of the Republic of Indonesia number 70 of 2016 concerning Standards and Requirements for the Health of the Industrial Work Environment. Based on this regulation, there is a final Threshold Value for the type of exposure to physical and chemical factors in the workplace. Exposure to benzene with certain concentrations for a certain period can cause various health problems (Minister of Health Regulation, 2016). These health problems can arise acutely or chronically depending on the concentration and time of exposure. One of the health problems that can occur in the human body is DNA degeneration or damage to DNA.

DNA degeneration is a condition in which DNA malfunctions or is impaired failing to control cell reproduction which often leads to cancer (uncontrolled cell division) and/or vice versa, DNA damage causes unwanted cell reproduction death (Manahan, 2003). Malfunctions or disturbances in DNA can occur in all or part of the DNA structure, such as in the double helix strand, in the nitrogen base arrangement, or in other parts of DNA that can give rise to inappropriate genetic information, such as mutations to cancer (Zhao. *et al*., 2012). DNA degeneration occurs when there is oxidative stress from interactions and reactions between natural molecules in the body and toxic substances such as reactive benzene metabolites.

Several types of benzene metabolites can be spread in tissues in the body. The main storage of benzene metabolites in the body is the liver, bone marrow, and fat tissue (Tualeka. *et al*., 2020). Benzene undergoes metabolic processes in the *liver* of humans. Benzene metabolism occurs in two phases with the help of the CYP2E1 enzyme to oxidize benzene, and if the oxidation product can bind to the glutathione (GSH) enzyme, which is one of the antioxidants in the body, it will be directly excreted from the body through urine in the form of sPMA (*s-phenylmercapturic acid*). However, if the oxidation of benzene with CYP2E1 produces reactive metabolites such as benzene oxide, phenol, hydroquinone, catechol, and benzene quinone and reacts to form bonds with DNA, DNA degeneration occurs (Tualeka. *et al*., 2020). The binding of toxic substances with DNA will form DNA adducts and can be excreted through urine as a biomarker as a marker of oxidative stress in the body (Li. *et al*., 2019).

The concentration of benzene with DNA degeneration in workers is in line with previous research in the shoe industry in Osowilangun, Surabaya, where benzene was the main solvent. Of the 25 workers exposed to benzene below and above the NAV, 15 of them were found to have DNA degeneration (Tualeka. *et al*., 2020). Another study was conducted on gas station workers in Shebin El Kom City, Menoufia Province, Egypt. The results of this study showed that there was a relationship between DNA breakdown and exposure to benzene (Salem, E., El-garawani, I. dan Allam, 2018).

From the description above, it can be seen that the work process in a car painting workshop that uses chemicals can be harmful to the health of workers. Therefore, this study aimed to determine the relationship between individual characteristics and benzene concentration with DNA degeneration of car painting workshop workers in Kalijudan, Surabaya.

METHOD

This study was an observational study with a cross-sectional design and a quantitative approach. This study aimed to analyze the correlation between individual characteristics and workplace benzene concentrations with DNA degeneration of workers in an automotive paint shop in Kalijudan, Surabaya. The study was conducted in October 2019 at a car painting workshop in Surabaya with a total of 20 workers which is the total number of workshop workers who are active in the painting area. There were 2 variables used in this study, namely the independent variable and the dependent variable. The independent variables in this study were the individual characteristics of the workers (age, BMI, years of service, and smoking behavior) and the concentration of benzene in the workplace. Meanwhile, the dependent variable in this study was DNA degeneration. Data was collected in several ways, including questionnaires, measuring benzene concentrations, and taking the workers' blood samples.

In previous studies, researchers did not examine the individual characteristics and the DNA was seen

based on total genomic DNA fragmentation, micronucleus test and cell viability test. Questionnaires were used to see the characteristics of workers consisting of age, weight, and height which were processed into body mass index, years of service, and smoking behavior. Measurement of benzene concentration using a charcoal tool was analyzed using gas chromatography by the NIOSH 1501 procedure which was carried out at 20 points where workers usually did their work. Measurements were carried out by the Technical Implementation Unit for Occupational Safety and Health. While the DNA degeneration examination was carried out by taking a sample of the worker's blood. Blood samples were taken by the *Institute of Tropical Disease* (ITD) laboratory team, Airlangga University. The method used in the examination of DNA degeneration was acrylamide electrophoresis with silver staining and using the RT-PCR (*Real-Time Polymerase Chain Reaction*) method. Statistical tests performed to analyze the relationship between independent and dependent variables were the chi-square test and phi correlation test and Cramer's v correlation test to analyze the strength of the relationship between two variables. This research had been approved by the Ethics Board for the Dental Institute of Airlangga University with ethics certificate number 605/HRECCFODM/IX/2019.

RESULT AND DISCUSSION

Individual Characteristics of Car Painting Workshop Workers

The number of respondents in this study was 20 male workers with an age range of 16-58 years. Although all workers were male, the characteristics of each worker were different. Table 1 shows the characteristics of workers in a car painting workshop in Surabaya which consists of age, BMI, years of service, and smoking behavior. The results of Table 1 show that most workers had an age of 45 years (75%) and a service period of > 5 years (55%). In addition, table 1 shows that 16 workers (80%) mostly had a normal BMI and each of 2 workers (10%) were thin and *overweight*. as Also, 16 workers (80%) had smoking behavior.

Table 1. Characteristics of Car Painting Workshop Workers in Surabaya 2019

No.	Characteristics of Respondents Workers	Total	Percentage (%)
1.	**Age**		
	a. ≤ 45 years	15	75
	b. > 45 years	5	25
2.	**BMI**		
	a. Underweight	2	10
	b. Normal	16	80
	c. Overweight	2	10
	d. Obesity	0	0
3.	**Working Period**		
	a. ≤ 5 years	9	45
	b. > 5 years	11	55
4.	**Smoking Behavior**		
	a. Smoking	16	80
	b. No smoking	4	20

The characteristics of workers can play a role in the absorption of toxic substances that enter the body. The age of the worker can affect a person's level of vulnerability to disease (Agency for Toxic Substance and Disease Registry (ATSDR), 2007a). Painting workers at the Kalijudan car painting workshop, Surabaya had a minimum age of 16 years, maximum age of 63 years, and the average age of workers was 36.5 years when data collection was carried out in 2019. Someone over 45 years of age tends to experience a decrease in physiological function organs that can affect a person's metabolic rate and excretory ability (Darwis, D., Mubarak, M. and Anita, 2018)

Body mass index (BMI) can also play a role in the absorption of toxic substances. BMI is the quotient of body weight (kg) by the square of height (m). The results of the BMI calculation were categorized into four, namely thin with a value of < 18.5, normal with a value of 18.5 – 25,0, overweight with a value of > 25.0, and obese with a value of > 27.0 (Ministry of Health RI, 2020). There were 2 workers in the car painting workshop in Kalijudan, Surabaya, who were in the thin BMI category, 15 workers were in the normal BMI category, 3 workers were in the overweight BMI category, and no workers were in the obese BMI category. BMI can reflect a person's nutritional status which can affect health status and the more fat content in the body, the higher the absorption of fat-soluble toxic substances (Darwis, D., Mubarak, M. and Anita, 2018).

Workers who have worked in car painting workshops for years and are exposed to benzene for a long time (> 5 years of work) will have a higher risk of problems than workers who are new (≤ 5 years of work) in that place (Kusgiyanto, 2017). There are 11 workers in the car painting workshop in Kalijudan, Surabaya who have worked for more than 5 years, and 9 workers who have worked for 5 years. Health problems that may occur due to exposure to benzene include leukemia and disruption of DNA structure. The longer a person works in a

place containing benzene with a certain concentration, the higher the accumulation of benzene in the worker's body (Timbrell, 2009).

Cigarette smoke is one source of exposure to benzene through inhalation or breathing. An active smoker every day will inhale cigarette smoke that contains benzene. If a person smokes as many as 32 cigarettes per day, then that person inhales as much as 1.8 mg of benzene per day (Agency for Toxic Substance and Disease Registry (ATSDR), 2015). 16 workers smoked in a car painting workshop in Kalijudan, Surabaya, and 4 workers did not smoke. Based on research by Salem et al., 2018, smoking habits can significantly affect the level of DNA damage in gas station workers in Africa. The DNA repair process is also delayed due to smoking habits (Salem, E., El-garawani, I. dan Allam, 2018).

Benzene Concentration in Workplace Air

Regulation of the Minister of Health No. 70/2016 states that the duration of exposure to benzene must not be more than 8 hours/day or 40 days/week because these substances can cause health problems. The results of table 2 show the distribution of exposure to car painting workshop workers in Kalijudan, Surabaya in hours/day, day/year, and year. From the table, it can be seen that the smallest tE (hours/day) was 7 hours/day, and the largest working hours/day were 11 hours/day, the mean was 7.925, the median was 7.75, and the standard deviation was 1.1. Meanwhile, the minimum value for Dt (years) was 0.083 years or 1 month, the maximum value was 25 years, the mean was 9.029, the median was 9, and the standard deviation was 7.701.

Table 2. Exposure Patterns of Car Painting Workshop Workers in Surabaya 2019

Descriptive Statistics	Exposure Time (tE) (Hour/Day)	Exposure Frequency (fE) (Day/Year)	Exposure Duration (Dt) (Year)
Minimum	7	312	0,083
Maximum	11	312	25
Mean	7,925	312	9,029
Median	7,75	312	9
Standard Deviation	1,1	0	7,7

Respondent workers were exposed to benzene in paint while working with a pattern with several variables such as length of working hours in one working day, the number of working days in one year, and respondent's working period in years. The working hours of the painting worker at the car painting workshop in one day were 7 hours per day to 11 hours per day. So that the average time the painting workshop workers were exposed to benzene was 7.9 hours per day. The car painting workshop in Kalijudan, Surabaya applied 6 working days a week, so the workers had 312 working days/year.

Based on Law number 13 of 2003 concerning Manpower, it is stated that the working hours in one day are 8 hours/day for 5 working days in one week, and 7 hours/day for 6 working days in one week. This shows that the average working hours at the car painting workshop in Kalijudan, Surabaya exceeded the provisions that have been made. Painting workers who have worked for many years would be more at risk of getting the effects of exposure to hazardous chemicals during work activities. The working period of the painting workshop workers varies, from the newest one, the worker who has only worked for 1 month or 0.083 years, to the worker who has worked for 25 years.

Based on research data conducted by the umbrella research team, benzene concentrations were measured at 20 points where workers used to do their daily work (*personal sampling*) conducted by UPT K3 Surabaya. The measurement results using the NIOSH 1501 reference were obtained in units of mg/m3, so it needs to be converted into ppm units to compare with the NAV of the applicable regulations. Table 3 presents the results of measuring the concentration of benzene in the air of the painting area at a car painting workshop in Kalijudan, Surabaya. It can be seen that the lowest benzene concentration was 0.6768 ppm, and the highest benzene concentration was 1.4933 ppm. Table 3 also shows that the mean was 1.0904 ppm, the median was 1.4933 ppm, and the standard deviation was 0.5309 ppm.

Table 3. Benzene Concentration in the Air Painting Area Car Painting Workshop in Surabaya 2019

Descriptive Statistics	Benzene Concentration (mg/m^3)	Benzene Concentration (ppm)
Minimum	0,534974	0,1678
Maximum	4,760884	1,4933
Mean	3,476124	1,0904
Median	4,760884	1,4933
Standard Deviation	1,692848	0,5309

The concentration of benzene in the air of a car painting workshop in Kalijudan, Surabaya was measured by taking air samples using a sampling procedure from NIOSH 1501 and carried out with the assistance of UPT K3 Surabaya. Sampling was carried out by personal sampling method on 20 respondent workers and the lowest concentration of benzene in the workplace was 2.16 mg/m3 or 0.68 ppm, and the highest concentration was 4.76 mg/m3 or 1.50 ppm. So, the concentration of benzene in the workplace air was 1.10 ppm on average.

Based on the Regulation of the Minister of Manpower of the Republic of Indonesia number 5 of 2018 concerning Occupational Safety and Health in the Work Environment, it is stated that the threshold value (NAV) for benzene exposure in the workplace for 8 hours of work/day is 0.5 ppm and STEL (Short Term Exposure Limit) of 2.5 ppm for maximum exposure of 15 minutes and with a distance between exposures of 1 hour. The average concentration of benzene in the air of the Kalijudan car painting workshop exceeded the predetermined NAV. This shows that workers who worked an average of 7.9 hours/day were exposed to benzene above the NAV which can be at risk for health impacts.

DNA Degeneration Laboratory Test Results on Workers Blood Samples

Laboratory tests to see DNA degeneration in blood samples of car painting workshop workers in Kalijudan, Surabaya was carried out using the acrylamide electrophoresis method with silver staining and the RT-PCR (real-time polymerase chain reaction) method. From the results of these laboratory tests, the results of DNA degeneration were obtained with the status of "DNA Degraded" and "DNA Not Degraded". Figure 1 shows that 13 out of 20 respondents or 65% of painting workers experienced DNA degeneration or DNA degradation.

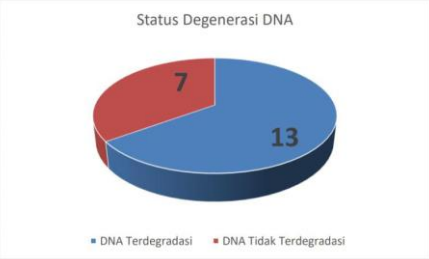

Figure 1. Circle Diagram of DNA Degeneration Laboratory Test Results on Blood Samples of Car Painting Workshop Workers in Surabaya 2019

DNA degeneration or in other terms DNA degradation is a setback or malfunction that causes unwanted cell reproduction death or vice versa, DNA malfunctions can cause failure to control cell reproduction which often leads to cancer (cell division uncontrolled) (Manahan, 2003). The results of the examination of blood samples from respondent workers who were carried out in the laboratory showed that most of the workers had DNA degeneration. It was found that 13 of the 20 respondent workers experienced DNA degeneration, of which 11 workers were exposed to concentrations of benzene in the workplace air above the NAV, while 2 other workers who experienced DNA degeneration were exposed to concentrations of benzene in the workplace air below the NAV.

Relationship of Individual Characteristics (Age, BMI, Working Period, and Smoking Behavior) with DNA Degeneration

To determine the relationship between individual characteristics of workers (age, BMI, years of service, and smoking behavior) with DNA degeneration, a phi correlation test was used. Some variables need to be converted into categorical data based on related references, such as age and years of service.

Table 4. Age Relationship with DNA Degeneration of Car Painting Workshop Workers in Surabaya 2019

Age	DNA Degeneration				Total		Value	Approx Sig.
	Yes		No					
	N	%	N	%	N	%		
≤ 45 years	9	60	6	40	15	100		
> 45 years	4	80	1	20	5	100	-0,182	0,417
Total	**13**	**65**	**7**	**35**	**20**	**100**		

It can be seen in Table 4 that the chi-square relationship test for the two variables produced a p-value that can be seen in the approx sig. column. The value was 0.417 ($\alpha = 0.05$) which indicates that there was no relationship between the two variables. From the results of the relationship strength test using the phi correlation test above, the result of the phi coefficient value that can be seen from the value column was -0.182. This value indicates that there was a very weak relationship between age and DNA degeneration of painting workers. Then, the minus value of these results states that the relationship between the two variables is not unidirectional. As shown in Table 4, out of 15 workers aged 45 years, 9 workers (60%) experienced DNA degeneration, and 6 workers (40%) did not experience DNA degeneration. Meanwhile, from 5 workers aged > 45 years, 4 workers (80%) experienced DNA degeneration, and 1 other worker (20%) did not experience DNA degeneration.

Age is one of the factors that can affect the condition of a person's body. Someone over the age of 45 years tends to experience a decrease in the physiological function of organs that can affect a person's metabolic rate and excretory ability (Darwis, D., Mubarak, M. and Anita, 2018). This is in line with research conducted in Egypt on the genotoxic effects of gas station workers from exposure to benzene in the workplace which stated

that there was no relationship between the age of workers and the genotoxic effects experienced by workers, one of which was DNA damage (Salem, E., El-garawani, I. dan Allam, 2018).

Table 5. Relationship between Body Mass Index (BMI) and DNA Degeneration of Car Painting Workshop Workers in Surabaya 2019

BMI	DNA Degeneration				Total		Value	Approx Sig.
	Yes		No					
	N	%	N	%	N	%		
Underweight	2	100	0	100	2	100		
Normal	10	66,7	5	33,3	15	100	0,348	0,299
Overweight	1	33,3	2	66,7	3	100		
Total	**13**	**65**	**7**	**35**	**20**	**100**		

The result of chi-square to analyze the relationship between the two variables was 0.299 ($\alpha = 0.05$) which indicates that there was no relationship between the two variables. From the results of the relationship strength test using the Cramer's v correlation test above, the results of the v coefficient value which can be seen in the value column was 0.348. This value indicates that there was a sufficient relationship between body mass index (BMI) and DNA degeneration of painting workers. As presented in Table 5 above that of the 2 workers who were included in the thin BMI category, all workers (100%) had DNA degeneration. In the normal BMI category, 10 workers (66.7%) experienced DNA degeneration, and 5 other workers (33.3%) did not experience DNA degeneration. Meanwhile, of the 3 workers included in the overweight BMI category, 1 worker (33.3%) experienced DNA degeneration, and 2 other workers (66.7%) did not experience DNA degeneration.

Body Mass Index (BMI) is grouped into 4 categories, namely thin, normal, overweight, and obese. Someone who is obese will be more at risk of experiencing health problems. These results are in line with other studies on DNA damage, which stated that BMI was not significantly associated with DNA damage (Fenga. *et al*., 2017).

Table 6. Relationship between years of service and DNA degeneration of car painting workshop workers in Surabaya 2019

Working Period	DNA Degeneration				Total		Value	Approx Sig.
	Yes		No					
	N	%	N	%	N	%		
≤ 5 years	5	55,5	4	44,5	9	100		
> 5 years	8	72,7	3	27,3	11	100	-0,179	0,423
Total	**13**	**65**	**7**	**35**	**20**	**100**		

The p-value obtained from the chi-square was 0.432 ($\alpha = 0.05$) which indicates that there was no relationship between the two variables. From the results of the relationship strength test using the phi correlation test above, the result of the phi coefficient value that can be seen in the value column was -0.179. This value shows a very weak relationship between tenure and DNA degeneration of painting workers. Then the minus value can be interpreted that the relationship between the two variables was not unidirectional. As shown in Table 6 above that of 9 workers who worked for 5 years, 5 workers (55.5%) experienced DNA degeneration, and 4 other workers (44.5%) did not experience DNA degeneration. Meanwhile, of the 11 workers who worked > 5 years, 8 workers (72.7%) experienced DNA degeneration, and 3 other workers (27.3%) did not experience DNA degeneration.

Workers who work with exposure to toxic materials from the workplace are at greater risk of experiencing health problems than new workers. This is in contrast to a study conducted in Italy on DNA damage in gas station workers due to exposure to benzene. The study stated that there was a significant relationship between job seniority and DNA damage in workers (Fenga. *et al*., 2017). However, the results of the phi correlation test that was carried out are in line with other studies that state that tenure is negatively related to DNA damage (Salem, E., El-garawani, I. dan Allam, 2018).

Table 7. Relationship between Smoking Behavior and DNA Degeneration of Car Painting Workshop Workers in Surabaya 2019

Smoking	DNA Degeneration				Total		Value	Approx Sig.
	Yes		No					
	N	%	N	%	N	%		
Yes	11	68,7	5	31,3	16	100		
No	2	50	2	50	4	100		
Total	**13**	**65**	**7**	**35**	**20**	**100**	0,157	0,482

After running the chi-square test for the two variables, a p-value of 0.482 ($\alpha = 0.05$) was obtained. This indicates that there was no relationship between the two variables. From the results of the relationship strength test using the phi correlation test above, the result of the phi coefficient that can be seen in the value column was 0.157. This value shows a very weak relationship between working mass and DNA degeneration of painting workers. As seen in Table 7 above that of the 16 workers who smoked, 11 workers (68.7%) experienced DNA

degeneration, and 5 other workers (31.3%) did not experience DNA degeneration. Meanwhile, from 4 workers who did not smoke, 2 workers (50%) experienced DNA degeneration, and 2 other workers (50%) did not experience DNA degeneration.

Cigarettes contain harmful chemicals that can affect a person's health. In this study, cigarettes were considered as an additional exposure chemical obtained by workers in addition to the main exposure chemical, namely benzene. This is in line with research conducted in Egypt on the genotoxic effect of gas station workers due to benzene exposure at work. The study stated that workers who smoke indeed increase the intake of toxic substances that enter the workers' bodies, but the results of the study state that workers who smoke do not affect the incidence of DNA damage in workers (Salem, E., El-garawani, I. dan Allam, 2018).

Relationship between Benzene Concentration in Air and DNA Degeneration

By using the chi-square test to analyze the relationship between the two variables, obtained a p-value of 0.948 ($\alpha = 0.05$). This value indicates that there was no relationship between the two variables. The results of the strength test of the relationship using the phi correlation statistical test between the independent variable benzene concentration in the workplace and the worker's DNA degeneration status showed that the phi coefficient value which can be seen from the value column was 0.015. This value indicates that the relationship was very weak between benzene concentration in the workplace and DNA degeneration of paint workers. As presented in the cross-tabulation of Table 8, out of 3 workers exposed to benzene concentrations 0.5 ppm, 2 workers (66.7%) experienced DNA degeneration, and 1 other worker (33.3%) did not experience DNA degeneration. Meanwhile, of the 17 workers who were exposed to benzene concentrations > 0.5 ppm, 11 workers (64.7%) had DNA degeneration, and 6 workers (35.5%) did not experience DNA degeneration.

Table 8 Relationship between Benzene Concentration and DNA Degeneration of Car Painting Workshop Workers in Surabaya 2019

Benzene Concentration	DNA Degeneration				Total		Value	Approx Sig.
	Yes		No					
	N	%	N	%	N	%		
≤ 0,5 ppm	2	66,7	1	33,3	**3**	**100**		
> 0,5 ppm	11	64,7	6	35,3	**17**	**100**	0,015	0,948
Total	**13**	**65**	**7**	**35**	**20**	**100**		

Sources of exposure to benzene in car painting workshops are thinners made of Volatile Organic Compounds (VOC) where the material easily evaporates in the air and can be inhaled by workers. Apart from steam, exposure to benzene in the workplace is obtained by workers when workers spray paint to the oven process in the oven room with a temperature of 40 – 80°C. Occupational activities that result in such exposure will be riskier for workers who are supported by inadequate ventilation.

The car painting workshop used 2 units of exhaust ventilation on one side of the building. It also relied on the gaps between the walls and the roof on each side of the building. This caused the air in the workplace filled with a pungent odor from paint and thinner. Workers who carried out activities in the workplace with these conditions need to be supported by the use of personal protective equipment (PPE) to reduce the risk of health problems from exposure to toxic materials during daily work activities.

The PPE was provided by the workshop owner. He stated in the questionnaire that 13 out of 20 workers did not wear the masks provided with the dominant reason being uncomfortable and used to the smell of paint. This can increase the risk of health problems due to exposure to toxic materials during work activities.

These results are in line with research on the analysis of respiratory benzene and benzene levels in the blood of chemical factory workers from exposure to benzene in the workplace environment. The study stated that benzene in the workplace air was not associated with benzene levels in the workers' blood (Perbellini. *et al*., 1988). So, because of the difference in the concentration of benzene in the air and the blood, it could be one of the factors. The results of statistical tests did not show a relationship between the concentration of benzene in the air and the degeneration of workers' DNA.

Benzene that enters through inhalation in very low concentrations, will be expelled from the body through expiration. If benzene vapor is inhaled in large enough concentrations, there will be some benzene remaining in the lungs and immediately absorbed into the bloodstream (Agency for Toxic Substance and Disease Registry (ATSDR), 2007b). Benzene that enters the body in the form of vapor through the inhalation route with a certain concentration, about 25% will be expelled through expiration, 50% will be retained in the upper respiratory tract, and 25% will be stored in the lower respiratory tract (Timbrell, 2009). Benzene metabolites that are retained in the lower respiratory tract (alveoli), will be transferred into the blood slowly and will be excreted through the urine in the form of biomarkers.

In another study, DNA degeneration could be analyzed based on biomarkers of oxidative stress produced by the body. A selective biomarker for oxidative stress in DNA due to benzene exposure is called 8-oxodG which can be analyzed in the blood and urine of workers (Li. *et al*., 2019). Meanwhile, for blood samples from painting workshop workers, laboratory examinations were carried out using the RTPCR method to

determine whether the worker had DNA degeneration or not. So there were differences in the function and accuracy of the two laboratory analysis methods.

CONCLUSION

After analyzing the relationship between individual characteristics variables and the concentration of benzene in the workplace air with DNA degeneration of car painting workshop workers in Kalijudan, Surabaya, the following conclusions were obtained:

1. Based on the statistical correlation test, it was found that there was a very weak relationship between the concentration of benzene in the workplace air and DNA degeneration in workshop workers.
2. The results of statistical tests carried out for the characteristics of individuals with DNA degeneration:
   a. Based on the statistical test of phi correlation, it was found that there was a very weak relationship between individual characteristics of workers (age, years of service, and smoking behavior) and DNA degeneration of painting workshop workers.
   b. Based on the statistical test of Cramer's v correlation, it was found that there was a sufficient relationship between BMI of workers and DNA degeneration of painting workshop workers.

REFERENCE

Agency for Toxic Substance and Disease Registry (ATSDR) (2007a) *ToxGuide for Benzene C6H6*.

Agency for Toxic Substance and Disease Registry (ATSDR) (2007b) *Toxicological Profile for Benzene*. Atlanta: Agency for Toxic Substance and Disease Registry (ATSDR).

Agency for Toxic Substance and Disease Registry (ATSDR) (2015) *Benzene*.

Darwis, D., Mubarak, M. and Anita, S. (2018) 'Risiko Paparan Benzena Terhadap Kandungan Fenol Dalam Urin Pekerja Pengecatan Mobil Di Kecamatan Tampan Kota Pekanbaru Tahun 2017', *Dinamika Lingkungan Indonesia*, 5(1), p. 40.

Eka, H. and Mukono, J. (2017) 'Hubungan Kadar Timbal Dalam Darah Dengan Hipertensi Pekerja Pengecatan Mobil Di Surabaya', *Jurnal Kesehatan Lingkungan*, 9(1), pp. 66–74.

Fenga. et al. (2017) . '8- Hydroxydeoxyguanosine as a biomarker of oxidative DNA damage in workers exposed to low-dose benzene', *Toxicology Reports*, 4(4), pp. 291–295.

International Agency for Research on Cancer (IARC) (2018) . *IARC Monographs On The Evaluation Of Carcinogenic Risks To Humans. II Series ed*. Lyon: International Agency for Research on Cancer.

International Labor Organization (ILO) (2018) *Improving the Safety and Health of Young Workers. International Labor Office*. Geneva: International Labour Organization.

International Labour Organization (ILO) (2015) *Workplace Risk Assessment and Management Training Package for Small and Medium Enterprises*. Geneva: International Labour Organization.

Kusgiyanto, S. and E. (2017) 'Analisis Hubungan Beban Kerja Fisik, Masa Kerja, Usia, Dan Jenis Kelamin Terhadap Tingkat Kelelahan Kerja Pada Pekerja Bagian Pembuatan Kulit Lumpia Di Kelurahan Kranggan Kecamatan Semarang Tengah', *Jurnal Kesehatan Masyarakat*, 5(5), pp. 413–423.

Li. et al. (2019) 'Classification and Temporal Variability in Urinary 8-oxodG and 8- oxoGuo: Analysis by UHPLC-MS/MS', *Scientific Reports*, 9(1), pp. 1–9.

Manahan, S. E. (2003) *Toxicological Chemistry And Biochemistry. Third Edit ed*. London: Lewis Publishers.

Minister of Health Regulation (2016) *PERMENAKER 70/2016 Tentang Standar dan Persyaratan Kesehatan Lingkungan Kerja Industri*. Jakarta: Minister of Health.

Minister of Manpower Regulation (2018) *PERMENAKER 05/2018 Tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja*. Jakarta: Minister of Manpower.

Occupational Safety and Health Administration (OSHA) (2020) *Transitioning to Safer Chemicals: A Toolkit for Employers and Workers*. U.S.A: Departement of Labor.

Perbellini. et al. (1988) 'Environmental and Occupational Exposure to Benzene by Analysis of Breath and Blood', *British Journal of Industrial Medicine*, 45(5), pp. 345–352.

Salem, E., El-garawani, I. dan Allam, H. (2018) 'Genotoxic Effects of Occupational Exposure to Benzene in Gasoline Station Workers', *Industrial Health*, 56(2), pp. 132–140.

Timbrell, J. A. (2009) *Principles of Biochemical Toxicology. Fourth ed*. New York: Informa

Healthcare.

Tualeka. et al. (2020) 'Relationship of Benzene Concentration , ECR Benzene , Malondialdehyde , Glutathione , and DNA Degeneration in Shoe Industrial Workers in Osowilangun , Indonesia', 18(2), pp. 1–6.

Zhao. et al. (2012) 'Basis of miscoding of the DNA adduct N2,3- ethenoguanine by human Y-family DNA polymerases', *Journal of Biological Chemistry*, 287(42), pp. 35516–35526.