Evaluation of hematological indices of workers exposed to benzene

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Abstract

Purpose: Benzene is a clear, colorless, flammable liquid that can be steamed and flowing. Benzene is a by-product of incomplete combustion of many materials. Due to its high utilization in the industry, it is one of the 20 major chemical products in the world. Benzene-induced industrial poisoning occurs almost entirely by inhalation of benzene vapors in the air. The goal of this study is to answer the questions about whether exposure to benzene is associated with changes in the level of human blood parameters under normal conditions.

Materials and Methods: This is a comparative and analytical cross-sectional study. In this study we examined 40 workers exposed to benzene compared with 40 healthy subjects with no history of being exposed to benzene as a control group with the same sex and age (26-40), with a work record of 5 to 15 years and an exposure of 8 hours. It was measured using standard methods for concentration of benzene in air. Blood samples were taken from humans for evaluation of hematological factors. An impedance method by cell counter device was used for measurement.

Results: The average concentration of benzene in workshops was 1.68 ppm. The results of blood tests showed that the mean concentration of red blood cells (MCHC) in the control group was higher and Erythrocyte sedimentation rate (ESR) in exposed benzene workers was higher than control group. However, in other parameters there was no meaningful difference between the two groups.

Conclusion: The average exposure of workers at different workshops with benzene vapors is not greater than the exposure limit values of these compounds. In the results of this study, other factors such as alcohol consumption, smoking, non-vegetarian diet and exposure to benzene are effective.

Key words: Benzene, Hematologic factors, Cell counter device, Impedance method

Introduction

Coke is a coal derivative and coal is a mixture of carbon, hydrogen, and sulfur-containing oxygen. Coke plays an important role in oxidative reactions. Workers in coking are exposed to pneumoconiosis in the presence of coke, which is a disease of the parenchyma tissue of the lung. It is caused by inhalation of coke and coal dust. Coke has a harmful effect on the liver, including cirrhosis of the liver. Liver diseases are generally classified into both acute and chronic types, in which liver cirrhosis is included as a chronic disease (1).

Benzene is produced during the process of coal-to-coke conversion; benzene is a coke derivative and is caused by the coke's heat and coke gas purification. Michael Faraday discovered benzene in 1825. Benzene was previously obtained by heating coal tar and then converting vapor into liquid, but today benzene is extracted from high amounts of crude oil (2).

A very low amount of benzene is found in oil and coal. This is a by-product of incomplete combustion of many materials. For commercial use, benzene was obtained as a coke or lightweight coke furnace product for the steel industry until the Second World War (3).

Benzene is a clear, colorless, flammable liquid, with a gas like smell that can be steamed and flowing. Benzene is an organic compound found in the air most of all due to the burning of coal and oil, gasoline vapors, vehicle smoke, smoke, fire from wood and other sources. The major cause of environmental pollution is by industry benzene. Urban weather is becoming more polluted with benzene due to transportation systems. Benzene is a pollutant that is everywhere, like the workplace and the environment. It categorizes risks for humans and animals due to its carcinogenic effects in the first group of carcinogenic substances (4).

The two main sources of exposure to benzene include the following:
1. Synthesis and construction activities.
2. Its use in the production of other chemical materials.

Other businesses may also be exposed to benzene, such as jobs that use petroleum products or solvents. The routes of contact with benzene in the workplace are usually breathable and absorption through the skin, and the assessment of the exposure is relatively easy. Human contact with benzene does not occur solely through breathing and absorption of the skin. Swallowing food or drinking water can be another way. High levels of accumulation of benzene in groundwater can be dangerous to human health and change the diversity and structure of ecosystems (4). Benzene is one of 20 major chemical products in the world due to its high utilization in industry. In many industries, benzene is used for the production of styrene, plastics and nylon and rubber, synthetic fibers, various resins, paints, reagents, drugs, insecticides, glues, solvents, explosives, inks, glosses and lubricants. The use of benzene in vehicles is to increase fuel consumption and octane number. Environmental Protection Agency (EPA) has classified benzene as a carcinogenic category A, and the International Agency for Research on Cancer (IARC) has identified benzene as a carcinogen for humans (5).

Absorption and excretion of benzene and disease

Industrial benzene-induced poisoning occurs almost entirely by inhalation of benzene vapors in the air. Blood flow in the human body is quickly saturated with this substance and after half an hour, the saturation of the blood will be 70% to 80%; it will take several days for all body fluids and tissues to saturate with benzene. Benzene is almost insoluble in the blood, and its balance is in mg benzene per liter of blood, divided by mg of benzene per liter of air. This means that the average concentration of benzene in the blood in balance is about 1.2 mg per 100 ppm of benzene in the inhaled air. Benzene in the circulating blood enters the tissue and fat tissue stores some of it. Excretion of this substance is also done vice versa, this means it is transmitted to the lungs by blood and through the capillaries, and placed in the balance with air inside the lung cavities and thus repelled. Some benzene is excreted intact in the urine and a portion of it is oxidized in the form of phenols and diphenols, which, in turn, are combined in liver with sulfate ions and excreted in the urine (6).

Benzene enters the liver, where it converts to toxic metabolites like benzene oxide, phenol, hydroquanone (HQ), muconic acid. The tendency of benzene toxin to the hematopoietic tissue is probably related to the capacity of these liver metabolites in their own community in bone marrow. Some evidence suggests that benzene may be cause of the following:

1. Acute and chronic lymphocytic leukemia
2. Non-Hodgkin's Lymphoma
3. Multiple myeloma
4. Anemia due to hematopoietic organs dysfunction (4).

The effects of benzene on body organs: Leukemia, particularly acute bone marrow leukemia and benzene exposure, are closely related. Additionally, exposure to benzene can have devastating effects on the body's immune system, nerves, and reproduction. Benzene can directly damage bloodstream cells, which in turn leads to the death of some cells or may reduce the response to cytokines and cellular adhesion molecules. Poisoning of bone marrow cells or mature blood cells by benzene can disrupt the process of hematopoiesis (4).
Benzene increases the risk of cancer and other diseases. Benzene causes aplastic anemia, acute leukemia and bone marrow disorders (7).

In cases where contact with benzene is relatively high but its duration is short, there is a significant reduction in white blood cell count. If the contact is relatively less intense,

but its duration is somewhat long, various changes will occur in blood. If benzene adsorption continues, an infectious poisoning occurs in the blood-forming generator and leads to death. In acute osmomethania, benzene has a sleeping and opiate effect. Excessive inhalation of benzene vapors may initially cause a rise in joy, resulting in confusion, drowsiness, fatigue, nausea, and headache. If the concentration is higher or the duration of contact is longer, seizure and then loss of sensation will eventually occur, and death may eventually occur by paralysis of the respiratory system. In chronic benzene poisoning, bone marrow testing may sometimes be normal, and in some cases be aplastic or hyperplastic. Symptoms and side effects include headaches, dizziness, fatigue, loss of appetite, feeling unwell, anger, nose bleeding, and other forms of bleeding (6).

Benzene has been used as a common solvent in laboratories in the past, but when scientists have found their carcinogenic identity, its use as a solvent has been very limited and have tried to use similar solvents such as acetone and others. Side effects of chronic exposure to benzene include the reduction of hematopoiesis, the inability of the immune system, as well as leukemia, disorders of the respiratory system, delay on embryonic skeletal system, damage to the reproductive system of humans, infertility, production of lymph node tumors and liver damage. Several institutes, including the World Cancer Research Association, the American Society for the Protection of the Environment, the US Department of Health, have identified benzene as a cause of leukemia and carcinogenicity level A. The secret period of leukemia usually occurs 5 to 15 years after the first contact with benzene. The acute effects of benzene include drowsiness, dizziness, headache, anesthesia and tremors, nausea, seizure, insomnia, stomach stimulation, and increased heart rate and coma (5).

However, in most cases deadly benzene poisoning occurs if the concentration of this substance is 200 parts or more in million. However, many cases have been reported that exposure to benzene is much lower and even reported deaths with an average concentration of 100 to 105 parts per million. In addition, some reports, suggests that concentrations below 100 ppm are also dangerous. As noted, the maximum allowable benzene concentration is 10ppm, and this is the extent to which the average and normal person has the necessary safety against the dangers of this substance. Blood tests are far more valuable than other tests for determining the amount of urinary sulfate. It is therefore logical that continuous hematologic tests and cellular counting should be carried out at all intervals of every thirty days for all workers who deal with benzene vapors, as well as a test for sulfate amount per week. In addition, determination of the amount of benzene from the air of the workshop environment is also required at different intervals (6).

Materials and Methods

This study is a comparative and cross-sectional analytical study, in which 40 benzene exposed workers are compared to 40 healthy subjects with no exposure to benzene as the control group with the same sex and age (26-40). The number of people working in benzene refining and biochemical energy was about 200 people who were randomly assigned to one day of the week and a special shift based on the willingness and satisfaction of the person. The number of people was 80, 40 people selected based on entry criteria: lack of exposure to metals such as plumbum and zinc, lack of alcohol consumption, supplemental antioxidants and psychotropic drugs, lack of chronic disease and mental illness, lack of radiation therapy background, surgery and anesthesia over the past year, work experience, and ability to answer questions. 40 people who did not have entry criteria were excluded from the study. It should be noted that all 80 people filled out clinical symptoms and inclusion criteria questionnaires, and an expert interviewed all of them. Then, 40 cases were examined for blood samples at 8:30 am in the morning and immediately transferred to the hospital. Then, according to age, sex, entry criteria, and place of residence, 40 healthy people from the sales office (office jobs) 50 kilometers away from the factory, were matched to the group. The blood samples of these individuals after clinical interviews and entry criteria were taken at 8:30 am and immediately transferred to the hospital laboratory and factors of hematologic evaluation was performed in both groups. Impedance method was used to measure blood factors using cell counter.

CBC measurement with Cell Counter method

The KX-21 delivers decomposing eighteen blood parameter quickly and accurately, and reveals abnormal samples. In order to facilitate the sampling of abnormal samples in the laboratory, the device displays the information associated with abnormal analysis with unusual symptoms on the monitor screen. Therefore, abnormal specimens are exposed to further analysis and review. The KX-21 is used for separation of blood by three separators and two types of reagents. The number of white blood cells (WBCs) is calculated by using the DC discovery method in WBC explorer container. The RBC and platelets are stopped in the RBC explorer container, and they are measured using the DC discovery method. In hemoglobin (HGB) explorer container (HGB), using the non-cyanid e method carried out hemoglobin analyzer and measured hemoglobin concentration (8).

Detection method via DC (Direct Current)

We take the blood sample to a predetermined amount, dilute it to a certain degree, and then enter into the energy converter. The energy converter enclosure has a small hole that is called an aperture. On both sides of the aperture, there are electrodes through which passes direct flow. The blood cells stored in the diluted sample pass through the aperture and cause the direct current resistance (i.e., the opposite current) change between the electrodes. With this change and by the pulse of electricity (showing itself)

the size of the blood cell is discovered. The number of blood cells is calculated by counting the pulses, and by specifying the size of the pulse, a blood cell size chart is plotted. In addition, the analysis of the graph can be used to obtain various analytical data (8).

Analysis Parameters
This device analyzes and decomposes the following parameters using three explorer containers and two types of reactants.

1. Total WBC (White Blood Cell) (Analysis Law: Using the Discovery Method via DC)
Unit: The ratio of the number of WBCs in 1 µL to the whole blood, the WBC unit 10 to power 3 on millimeters square (10 ^ 3 / Cumm).

2. Lymphocyte percentage (white blood cells and small cell volume)
Unit: ratio (because it is uncountable with percentage). The ratio (percentage) of lymphocytes (small cells) to the total WBC.

3. MXD% (WBC and middle cell volume)
Unit: Ratio (percentage total sum of basophils, isinophils and monocytes (middle cells) to total WBC)

4. Neutrophil percentage (WBC and large cell volume)
Unit: ratio (%) of neutrophils (large cells) to the whole WBC

5. Lymphocyte count (WBC and small cell count)
Unit: The ratio of the absolute number of lymphocytes (small cells) in 1 µL of the total blood (8).

6. MXD% (WBC and middle cell count)
Unit: ratio of absolute number of basophils, isinophils and monocytes (middle cells) in 1 µL of total blood

7. Number of neutrophils (WBC and large cell count)
Unit: The ratio of absolute number of neutrophils (large cells) in 1 µL of the total blood

8. RBC (red blood cell) (Analysis Law: Using Discovery Method via DC)
Unit: The ratio of RBC to 1 µL of the total blood. The RBC unit is million / Cumm.

9. ESR is the erythrocyte sedimentation rate. Sedimentation rate is total amount of RBC in a saline or plasma solution at a given time, which is nonspecific. The ESR unit is millimeter per hour (mm / hr).

10. RDW The distribution of the red blood cells represents the amplitude of the dispersion of the total volume of the RBC.
Unit of measurement: percentage (%).

11. MCV is the average volume of red blood cells.
Unit is femtolite (fl).

12. HGB (Hemoglobin) (Analysis Law: Using “non-cyanide analysis of hemoglobin”)
The proportion of hemoglobin in 1 dL of the total blood.
Unit of measurement: gram-per-decilitre (gr / dl).

13. HCT (hematocrit values) (Analysis Law: Using the Red blood cell pulse rate detection method)
Ratio (percentage) of total RBC volume in the whole blood

14. Average red blood cell volume
The average volume of RBC (fL) in total blood, measured by hematocrit / RBC

15. Average hemoglobin red blood cell
The average volume of hemoglobin (pg) in RBC, which is measured by hemoglobin / RBC
Unit of measurement: picogram (pg) (8).

16. Average hemoglobin concentration of red blood cells
The average hemoglobin concentration in RBC, which is measured by hemoglobin / hematocrit.
Unit of measurement: gram-per-decilitre (gr / dl).

17. Platelet (Analysis Law: Using “Discovery Method via DC”)
The number of platelets in 1 µL of the total blood
Platelet distribution width
The distribution width (fL) with a height of 20% of the floor, when the peak in the distribution of platelet particles is assumed to be 100%.

18. The average platelet volume of the MPV in a platelet similar to MCV is for RBCs (8).
Unit of measurement: The femtoliter (fl)

Results

Data from the studied subjects were analyzed by KS test for normalization. Then, normal data were analyzed by t-test and non-normal by Mann Whitney U test. p value less than 0.05 was significant. In our study 80 subjects participated (40 experimental and 40 control).

Table 1: Frequency tables

Groups	Frequency	Frequency percentage
Test (benzene)	40	40 %
Control	40	40 %

Table 2: Age of test and control group

Variable (age)	N	The least	The most	Average	The standard deviation
Test (benzene)	40	26	40	31/55	4/662
Control	40	26	40	32/4	4/447

Table 3: Default Testing Normality of Data Distribution

	K-S test	
	Z	P-value
WBC(10^3/Cumm)	1/293	0/071
RBC(Mil/Cumm)	0/852	0/462
HB(gr/dl)	0/636	0/813
HEM(%)	5/221	0/001
MCV(fl)	1/077	0/196
MCH(pgr)	1/25	0/088
MCHC(gr/dl)	1/142	0/148
RDW(%)	1/571	0/014
MPV(fl)	1/226	0/099
ESR(mm/hr)	0/706	0/009

Default Testing Normality of Data Distribution using the K-S test shows that most variables have a normal distribution (the significant level of most variables is higher than 5%).

Table 4: Red blood cell count (RBC Mil / Cumm) of exposed workers to benzene with control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	5/298±0/426	0/0603	0/903
Control	5/338±0/465	0/065	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of data analysis, there was no significant difference between the levels of red blood cells (RBC) of workers exposed to benzene with the control group (P> 0/05).

Table 5: The white blood cell (WBC 10 ^ 3 / Cumm) of workers exposed to benzene with control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	6/576±1/437	0/203	0/914
Control	6/648±1/402	0/198	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of data analysis, there was no significant difference between the levels of white blood cells (WBC) of workers exposed to benzene with the control group (P> 0/05).

Table 6: The average volume of red blood cells (MCV fl) of workers exposed to benzene and a control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	88/858±4/997	0/706	0/431
Control	87/728±5/718	0/808	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of data analysis, there was no significant difference between the average volumes of red blood cells (MCV) of workers exposed to benzene with the control group (P> 0/05).

Table 7: Distribution of red blood cells (RDW %) of workers exposed to benzene and control group.

	RDW
Mann-Whitney	1094/5
Wilcoxon	2369/5
Z	-1/073
Significant level of p-value	0/283

	RDW
Test (benzene)	12/636±0/806
Control	12/922±1/196

Due to the unusual nature of the data in the RDW distribution, Mann-Whitney test was used to compare the study parameters. Based on the results of the data analysis between the red blood cell distribution (RDW) there was no significant difference between subjects exposed to benzene and control group (P> 0.05).

Table 8: Average hemoglobin in each cell (MCH pgr) of exposed workers to benzene with control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	29/796±2/175	0/307	0/104
Control	29/334±2/641	0/373	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of data analysis, there was no significant difference between the Average hemoglobin in each cell (MCH) of workers exposed to benzene with the control group (P> 0/05).

Table 9: Mean red blood cell concentration (MCHC gr / dl) of workers exposed to benzene and a control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	33/508±1/046	0/147	0/011
Control	33/604±1/586	0/224	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of the data analysis, there is a significant difference between the mean concentration of MRC in red blood cells (MCHC) of workers exposed to benzene and the control group (P <0.05). According to the mean of the two groups, the mean concentration of red blood cell (MCHC) in the control group is more than exposed group of benzene.

Table 10: The mean platelets volume (MPV fl) of workers exposed to benzene and control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	9/85±1/057	0/149	0/902
Control	9/81±1/687	0/238	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of data analysis, there was no significant difference between the mean volumes of platelets (MPV) of workers exposed to benzene with the control group (P> 0/05).

Table 11: Hemoglobin (HBg / dl) of workers exposed to benzene and control group

Indicator	Standard deviation ± Mean	Standard mean error	Significant level (P-value)
Test (benzene)	15/674±1/169	0/165	0/557
Control	15/514±1/053	0/149	

Due to the normal distribution of data, independent t-test was used to compare the mean of two groups. According to the results of data analysis, there was no significant difference between hemoglobin levels of workers exposed to benzene with the control group (P> 0/05).

Table 12: Hematocrit (HEM %) of workers exposed to benzene and control group

	HEM (%)
Mann-Whitney	1130/5
Wilcoxon	2405/5
Z	-0/824
Significant level (P-value)	0/410

	HEM (%)
Test (benzene)	31/78±19/661
Control	30/68±14/2305

Due to the lack of normal Hematocrit data (HEM), Mann-Whitney test was used to compare the study parameters. According to the results of the data analysis, there was no significant difference between the hematocrit (HEM) subjects exposed to benzene and the control group (P> 0.05)

Table 13: Red blood cell sedimentation rate (ESR mm / hr) of workers exposed to benzene and control group

	ESR(mm/hr)
Mann-Whitney	715/5
Wilcoxon	1990/5
Z	-3/706
Significant level (P-value)	0/001

	ESR(mm/hr)
Test (benzene)	8/72±4/0519
Control	5/86±2/835

Due to the non-normalization of the ESR data, the Mann-Whitney test was used to compare the study parameters. According to the results of the data analysis between the sedimentation rate of red blood cells (ESR) there was a significant difference between subjects exposed to benzene and the control group (P <0/05).

Discussion

The results of this study showed that blood parameters (RBC, WBC, MCV, RDW, MCH, MPV, HB, HEM) were not significantly different in the exposed group compared to the control group; only MCHC had a significant difference. Due to Normal distribution of data, independent t-test was used to compare the means of the two groups. According to the results of the data analysis, there is a significant difference between the mean concentration of red blood cells (MCHC) exposed to benzene and the control group (P <0.05). Regarding the mean of the two groups, the mean concentration of red blood cells (MCHCs) in the control group was higher than the benzene group. Based on the results of the data analysis, there was a significant difference between the sedimentation rates of red blood cells (ESR) in the benzene-exposed group with the control group. In studies of blood factor changes such as anemia, aplastic anemia and leukemia caused by exposure to benzene, there are conflicting results that require data from long-term studies (9).

Parts of the studies in this regard are in line with the findings of this study. For example, Mow and Fow (2004) concluded in their studies that there was a negative correlation between exposure levels of benzene and red blood cell count (10). In addition, Keh et al. (2015) in a study conducted between 2005 and 2008 on a group of Korean workers, it is stated that the number of RBCs in the exposed workers with low levels of benzene has a significant negative relationship (11). Posotori et al. (2009) also in their research concluded that benzene had no effect on examined blood factors the 153 Bulgarian petrochemical workers (239 ppm - 0/01) (12). Rajia and Hall (2014) in their study on 60 gasoline workers, of which 40 were exposed to benzene, compared to 20 controls concluded that exposure to benzene with concentrations of less than 1 ppm has no relevance with the reduction of red blood cells (9). Drummond et al. (1988), in their study on the bioavailability of workers exposed to benzene, stated that hematotoxic effects were found at high concentrations of 300 ppm and leukemogenetic effects at concentrations above 100 ppm (13). Kirkliet et al. (2008) examined the effect of benzene on human blood and stated benzene altered the gene expression and caused hematological disorders (14). In numerous studies, the blood-induced effects of exposure to benzene have been shown in low concentrations. Here can be pointed out blood toxicity especially in sensitive individuals exposed to concentrations of 1 ppm or less (15) changes in red blood cells, white blood cells and neutrophils in concentrations of less than 0.2 ppm (16), increased hemoglobin concentration in less than ppm 5 (17) reduction of lymphocytes, platelets, white blood cells and increase of average cellular mass of red blood cells in the presence of concentrations of 10-1ppm (18). A number of studies have also pointed to the lack of observation of abnormal blood parameters in exposure to benzene at low concentrations in occupational environments (19, 20). In concentrations of ppm of 0/01 - 1/4 benzene has no detectable blood abnormalities, and there are no significant abnormalities in the periodic observation of workers in the presence of

benzene 1 to 30 ppm concentrations, except temporary reduction in the number of red blood cells (21). In addition, in the study, Neqab et al. (2011), at a concentration of 0.24-ppm benzene in a gas station in Shiraz examined 400 people, 200 exposed to benzene and 200 controls. According to the findings, average number of white cells blood, red blood cells, hemoglobin, platelets, mean cellular RBC, average cell hemoglobin, mean hemoglobin concentration, lymphocytes, monocytes, neutrophils and eosinophils were similar in both control and exposure groups (22). A similar study during the years 1981 and 2007 Sevan et al. (2010) was conducted on 701 workers exposed to concentrations of 0/1-0/85 ppm benzene, compared to 1059 administrative staff. There were no significant differences in the blood factors between the two groups (it should be noted that hemoglobin, hematocrit, white blood cell, lymphocyte, monocytes, neutrophils, basophils were studied in this study) (19). Zamanpour et al. (2003) examined 400 workers with an average exposure of 3.99-ppm benzene and 40 employees. The average number of white blood cells, red cells, the average cell hemoglobin, mean hemoglobin concentration had no significant difference in the two groups of exposure and control (23). Of course, there are conflicting results for example, Ward et al. (1996) study in a 35-year on tyre manufacturing factory workers indicated that there is a significant relationship between exposure to benzene and anemia, and this result is dependent on exposure to 34-ppm benzene (24). Many cases of anemia have been reported for years, when benzene was used as a solvent in the workshops, including shoe manufacturing and tyre manufacturing workshops in high concentrations (hundreds of milligrams of benzene per m3) of benzene. When according to the past, the examination of workers' blood tests was done, the effect of reduction over time was observed parallel to the level of benzene reduction in the workshop air from 240 mg/m3 to 64-48 mg/m3 (25). In addition, it was found that workers exposed to benzene (above 120 mg/m3) had a high concentration of average levels, and their red and white blood cells were significantly lower than those exposed to benzene in the concentration below the average levels (20). Reduced red and white blood cell count has been reported at a concentration above the benzene average level (120 mg / m3), and below 32 mg/m3 was observed weak effect, and at concentrations of 0/03-4/5 mg/M3 have no effect (26). Hepatotoxicity studies of benzene show its myelotoxic effects (27, 28, and 29). Also, several studies on mice exposed to a minimum of 320 mg/m3 of benzene for several weeks showed that a decrease in the number of blood cells and bone marrow cells occurs as a result of exposure to benzene, some of which effects of benzene have been reported at lower concentrations. For example, in the amount of 32 mg/m3 or 10 ppm for 25 weeks, there is a decrease in the number of red blood cells and blood lymphocytes. Other evidence of adverse effects of benzene on blood-forming units on animals are reported at concentrations ranging from 10 to 300 ppm and above (25).

Miaw and Faw (2004) in their studies showed using multiple regression analysis that there is a negative correlation between the levels of exposure to benzene and the number of white blood cells (10). Posotori et al. (2009) also concluded that benzene had no effect on the blood factors of 153 Bulgarian petrochemical workers exposed to benzene (ppm 0.01- 239). Only eosinophils numbers were influenced by benzene, which was only reported among smokers, in studies by Yishun Dera and Rana (2001) that confirmed this and stated that alcohol, tobacco and Non-vegetarian diet increases benzene's absorption and metabolism in the human body. In particular, excessive alcohol consumption can alter the sensitivity of the human body to benzene (12). In addition, the immunological effects of benzene are probably due to its effect on bone marrow. In this study, he reported a decrease in the ability to proliferate lymphocyte B week after inhalation of benzene at a low concentration of 32 mg/m3; this response developed for benzene inhalation of lymphocyte T at 96 mg/m3 concentration. Different types of blood diseases such as aplastic anemia, thrombocytopenia, granulocytes, lymphocytopenia are caused by exposure to benzene. As observed in laboratory animals, the organ that is the primary target of benzene, which causes blood disorders, is bone marrow (25). The results of this study indicated that minor leukopenia would occur after inhalation of 150 mg/m3 of benzene for 32 weeks. However, in another study, the reduction in the number of white blood cells in the 2 to 13 weeks was shown, or the reduction in bone marrow cells will occur in the amount of 960 mg/m3 or higher (25). Studies per year on 105 workers of an oil company between 1994 and 1997, exposed to benzene in concentrations between 0.14 and 2.08 parts per million benzenes indicate that time and duration of exposure to benzene is associated with changes in MCV and platelet count. Decline in MCV is only noticeable among workers who have worked for more than 10 years at this company. The findings of this study showed that low levels of benzene may affect CBC levels, and CBC can be a useful tool for biological monitoring for exposure to low benzene levels (30).

Studies of 928 workers in five factories in and around Shanghai, China have achieved a wide range of benzene concentrations, in which benzene-sensitive parameters have been introduced as neutrophils and mean platelet volume (MPV) in which effective benzene concentrations in the air is expressed from 7.8 to 8.2 in ppm (18).

The process of benzene poisoning occurs when benzene converts via metabolism into a number of metabolites that bind into the bone marrow, and are then converted by peroxidases into active and reactive species that, in turn, form reactive oxygen species (ROS) (31).

Conclusion

The average benzene concentration in the air of the studied workshops was 1.68 ppm. The results of blood tests showed that there was a significant difference between the mean concentration of red blood cell and the red blood cell sedimentation rate of workers exposed to benzene compared to the control group. So that the mean concentration of red blood cells (MCHC) in the control group is higher, and the rate of sedimentation of red blood

cells (ESR) of workers exposed to benzene is higher than control group. Moreover, in other parameters there is no significant difference between the two groups. The average exposure of workers at different workshops with benzene fumes is not exceeded from the permissible limits occupational exposure to these compounds. In addition, it seems that in the results of the study, other factors such as alcohol consumption, smoking, non-herbal diet and exposure to benzene are effective.

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