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The Effect of Exposure to Respirable Dust on Blood Parameters of Workers in a Tile and Ceramic Industryin, Yazd

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ABSTRACT

Introduction: The relationship between elevated level of gas and particulate pollutants with increased mortality resulting from cardiovascular and respiratory diseases has been presented in epidemiological studies. Although the principal mechanisms of diseases are still unknown, inflammatory and homeostatic processes have been known to be related to this issue. Accordingly, this study was conducted with the aim of evaluating the relationship between exposure to respirable particulates and blood parameters of workers in a tile and ceramic industry in Yazd

Materials and Methods: In this cross-sectional study, 80 healthy workers who were exposed to mineral particulates participated. To determine the concentration of respirable particulates, sampling was performed on the respiratory area based on NIOSH_0600 method, and the blood parameters were measured using standard method.

Results: The mean concentration of respirable dust was 2.55 mg/m^3, which is lower than standard limit (3 mg/m^3). To determine the relationship between the concentration of respirable dust and blood parameters, robust regression test was used and this concentration was significantly and positively correlated with WBC. There was also a significant and negative relationship between MCH and respirable dust in the crude model.

Conclusion: Exposure of individuals to respirable dust within a level of 0.05-82.84 mg/m^3 has been followed by elevated WBC. As a significant number of people work in tile and ceramic industry and are exposed to high levels of pollutants and are also susceptible to different diseases, change to improve the work and preventive measures are essential.

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Introduction

The pollution caused by particulate matters is an important factor in the incidence of many diseases. A total of 75% of the world population are exposed to $PM_{2.5}$ particles with a concentration above the limit recommended by World Health Organization (WHO), determined for air quality (10 µg/m^3 per year). Meanwhile, the Global concentration of air particulate pollutions is increasing (a mean concentration of 20-25 µg/m^3) [1].

Exposure to polluted air has numerous negative impacts on human health. Polluted air contains compounds that can enter the blood stream through the nose, mouth, skin, and digestive system. It appears that most air pollutants do not have a considerable negative effect in the blood [2, 3]. However, animal studies indicate that tiny particles precipitate on alveolar surface and are then phagocytized by macrophages, resulting in the generation of intermediates which stimulate the bone marrow to increase the production of white blood cells through the bloodstream [4, 5].

Various epidemiological studies have indicated a relationship between exposure to air pollutant particles and human mortality [6], histopathological changes of airways [7] , pulmonary inflammation [8] , incidence of acute respiratory complications, lung cancer, as well as chronic respiratory and cardiovascular diseases [9, 10]. The intensity of the effects observed in studies is dependent on the size and chemical composition of these particles, such that particles with a smaller diameter develop more severe complications [11- 13]. Owing to their very small size, respirable gases and tiny particles easily pass through the epithelium of the lung and enter the bloodstream [14] where they can have systemic effects, resulting in elevated activity of platelets and production of thrombin [15- 17]. In contrast, the larger particles which cannot pass through the alveolar-blood barrier, stimulate the lungs and develop inflammation [18, 19].

Various studies have shown changes in biochemical and hematological parameters of blood in response to short-term and long-term exposure to air suspended solids, whereby changes in blood parameters have been significantly correlated with the concentration of $PM_{2.5}$ particles [20].

Ghio et al. investigated hematological indicators of healthy youth exposed to air pollution particles and concluded that this exposure can be accompanied by decreased level of white blood cells and increased concentration of blood fibrinogen [21]. Other studies have shown that exposure to exhaust fume led to increased neutrophil and blood platelets [19]. Also, diminished level of red blood cells [22] and increased number of white blood cells in response to exposure to air pollutant particles have been reported [23]. On the contrary, in the study by Pope, no significant relationship was observed between exposure to $PM_{2.5}$ particles and white and red blood counts as well as blood platelets [24]. In addition, in other investigations, alteration in the number of red blood cells, hematocrit, and hemoglobin has been associated with inhalation of particles [25].

Exposure to pollutant particles in working environments especially in jobs associated with mineral compounds is very common. The intensity of exposure in these jobs is dependent on the type of tasks, production process, the machines used and the health behavior of individuals [26]. The extent of exposure to pollutant particles and toxicity of these particles in working environments is typically greater than in public places and the open air. However, fewer studies have dealt with investigating the relationship between short-term and long-term exposure to these particles in people and the changes in their blood and cardiovascular parameters.

And in Iran, no study was found either regarding the effects of exposure to mineral pollutants in working environments on blood parameters. Therefore, this study was conducted with the aim of determining the effect of exposure to respirable dusts on blood parameters of the workers in one of the tile and ceramic industriesin in Yazd.

Materials and Methods

This cross-sectional study was conducted in 2017 in Yazd city on 80 workers of different working units of a tile and ceramic industry including packaging, crusher, ball mill spray, press, and glaze line, who were chosen randomly. To determine the relationship between long-term exposure to air pollution and blood parameters of the workers, having at least one year of working background in the mentioned units was chosen as the inclusion criteria. Also, based on study of the medical files of the beginning of employment, those who had a history of cardiovascular diseases, blood pressure, diabetes, anemia, pulmonary fibrosis, cancer, consumption of medication, and a special diet were excluded from the study. All the workers were socioeconomically identical based on their own statements. Therefore, it was assumed that all had similar lifestyle and dietary patterns. The data related to the demographic information, background of environmental exposures, and lifestyle (smoking, hookah smoking, and respiratory protection) was obtained through a questionnaire. Prior to data collection, informed oral and written consent was obtained from each participant.

Sampling and measurement of biomarkers

In this study, 1 ml of blood was taken from each person early in the morning and in a fasting state to perform CBC test through intravenous injection to EDTA tube, having received informed consent. The samples were transferred to the laboratory in coldbox with a temperature of below 3°C within less than two hours. All of the hematological experiments were carried out according to standard method and white blood cells (WBC), red blood cells (RBC), platelet count (PLT), hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) parameters were determined based on the results and compared with standard values [27].

Evaluation of respirable exposure

In this study, samples were taken from the respiratory air region of workers (a hemisphere with an approximate diameter of 30 cm around the mouth and nose of the workers [20]) within a 4-hour period, which represented all working activities of the person. The sampling on respirable particles was performed according to NIOSH_0600 method with PVC membrane filter with a diameter of 25 mm and pore size of 5 mm made by SKC (England), aluminum Cyclone (SKS aluminum Cyclone, UK), individual sampling pump SKS with a flow rate of 1.7 L/min (calibrated using a rotameter according to the recommended flow rate). To enhance the accuracy of the sampling, the utilized filters were placed inside a desiccator containing silica gel for 24 h, so that their possible humidity would be removed. Once weighed down, the dried filters were placed inside special holders.

To eliminate the factors that develop error in the sampling and analysis along the sampling, one control sampleper every five samples was also considered. After the time of sampling, the filters were placed inside the desiccator again for 24 h and then the filter was weighted three times and the mean weight of the filter with the collected dust was determined. To weigh the filters, calibrated digital balance (AND, GR-200) was used. Finally, by considering relation in NIOSH_0600 protocol the concentration of the respirable dust on the filters was calculated.

Statistical analysis

After completion of the sampling and data collection and entrance of information into SPSS 20, mean, standard deviation, minimum and maximum values, etc. were used to describe the data. Kolmogorov-Smirnov test was employed to measure the normality of the data. In order to consider the effect of outlier data, robust multiple linear regression was used to examine the relationship between blood parameters and the concentration of respirable dust. The variable of exposure to respirable dust was considered as the intervening variable, while the variables of age, BMI, and distance off the main road were considered as the corrector variables.

Ethical issues

This article was confirmed by the Ethical Committee (ethical code: IR.SSU.SPH.REC. 1395.24) school of Health of Shahid Sadoughi University of Medical Sciences and Health Services.

Results

Descriptive statistics (minimum, maximum, mean, standard deviation, and quartits) of demographic information, background of exposure (distance of the house off the main road and working background), and exposure to respirable dusts are reported in table 1. A total of 80 workers of the ceramic industry with no disease history, who had the mean age and working background of 29.54 and 3.98 years, respectively participated in this study. A total of 73.8% (59 individuals) were on shift. A total of 8.8% of the people (7 persons) were smokers, and 13.8% (11 individuals) used Hookah throughout the previous year. Therefore, 22.6% of the studied individuals smoked tobacco in the past year. Further, when investigating the index of BMI, it was observed that its value was 43.8% in people below 25 kg/m^2, 41.3% in 25-30 kg/m^2, and 15% in over 30 kg/m^2. The mean concentration of respirable dusts was 2.55 mg/m^3, which is lower than the standard limit (3 mg/m^3). The results obtained from assessment of exposure to respirable dusts indicated that exposure of 91.25% of the participants (73 individuals) was also below the recommended standard limit.

Table 1: Distribution of frequency of the variables of age, distance off the main road, working background, BMI, and concentration of respirable particles (n = 80)

Variable	Min	Max	Mean	Std. Deviation	p50 (p25-p75)
Age (year)	22	40	29.54	4.69	28 (27-32.75)
Distance off the major road (meter)	2	1000	227.78	221.12	200 (60-300)
Work History (years)	1	7	3.98	1.66	4 (2-5)
BMI (kg/m^2)	16.14	41.65	25.85	4.86	26.27 (22.19-28.63)
Respirable dust (mg/m^3)	0.05	82.84	2.55	9.35	0.98 (0.49-1.47)

The results obtained from comparison of the values obtained from CBC test with standard values as provided in Table 2, indicated that the number of white blood cells was higher than the normal limit in 5% (4 individuals), while in 93.8% (75 individuals), it was within the normal limit. Furthermore, by comparing the values of red cells with the standard values, 3.8% (3 individuals) had an RBC higher than normal, while 96.3% (77 individuals) had a normal RBC.

Table 2: The frequency distribution of blood parameters (n = 80)

Variables	Level	Frequency	Percent
WBC (*10^3/µL)	< 4	1	1.25
	4.1- 10.9	75	93.75
	> 11	4	5
RBC (*10^6/µL)	< 4.3	0	0
	4.3- 6.2	77	96.25
	> 6.2	3	3.75
HGB (gr/dL)	< 13.2	1	1.25
	13.2- 16.2	66	82.5
	> 16.2	13	16.25
HCT (%)	< 40	0	0
	40- 51	74	92.5
	> 51	6	7.5
MCV (fL)	< 80	5	6.25
	80- 95	74	92.5
	> 95	1	1.25
MCH (Pg/cell)	< 27	10	12.5
	27-34	70	87.5
	> 34	0	0
MCHC (Mg/dL)	< 20	0	0
	20-35	80	100
	> 35	0	0
PLT (*10^3/µL)	< 150	6	7.5
	150-400	74	92.5
	> 400	0	0

The level of blood parameters in those who had a TLV lower and higher than the standard limit to respirable dusts was determined and as can be observed in Table 3, the average value of blood parameters in the two exposure groups is lower than the TLV allowable limit, and overexposure of TLV torespirable particles is not different (p-value > 0.05).

Table 3: The descriptive statistics of blood parameters in two groups of higher and lower than the standard limit of exposure to respirable particles(n = 80)

	Exposure < TLV (n = 73)		Exposure > TLV (n = 7)		p-value*
	Mean (Min-Max)	**Std. Deviation**	**Mean (Min-Max)**	**Std. Deviation**	
WBC	7.24 (3.7-16.2)	1.95	7.84 (6-12.5)	2.45	0.65
RBC	5.37 (4.5-8.06)	0.54	5.44 (4.95-6.21)	0.39	0.51
HGB	15.42 (12.8-23.5)	1.52	15.09 (14.1-16.3)	0.96	0.55
HCT	46.23 (40.3-71.4)	4.14	45.49 (42.5-50.2)	3.02	0.66
MCV	86.37 (62.1-97.7)	4.78	84.51 (80.8-88.3)	3.17	0.16
MCH	28.72 (19.2-32.4)	1.9	28.04 (26.2-29.7)	1.18	0.10
MCHC	33.24 (31-34.5)	0.6	33.17 (32.5-33.7)	0.45	0.61
PLT	210.78 (126-312)	44	210 (152-273)	42.9	0.96**

*mann-whitney
**student t-test

According to Table 4, no significant difference was observed between respirable particles and blood parameters, except in WBC and MCH. The concentration of respirable dust was significantly and positively correlated with WBC in the crude and adapted model (95% CI: 0.7- 0.1×10^3/μL; P = 0.01) (Table 4). Furthermore, there is a significant and negative relationship between MCH and concentration of respirable dust in the crude model (95% CI :-0.07- -0.003P g/cell; P = 0.032). However, the relationship between MCH and concentration of respirable dust in the adjusted model after modification with age, BMI, distance off the main roads, and being a smoker was eliminated (p-value = 0.06).

Table 4: The crude and adjusted regression coefficient (95% CI) of blood parameters with 1 mg/m^3 change in the concentration of respirable particles (n = 80)

Variables	Crude effects (95% CI)	P-value	Adjusted effects (95 % CI)*	P-value
WBC	0.0673 (0.028; 0.1066)	0.001	0.0655 (0.027 ; 0.1034)	0.001
RBC	0.006 (-0.0303; 0.0432)	0.728	-0.0004 (-0.036; 0.035)	0.978
HGB	-0.025 (-0.135; 0.084)	0.645	-0.044 (-0.159; 0.0711)	0.448
HCT	-0 .104 (-0.399; 0.189)	0.48	-0.152 (-0.454 ; 0.1501)	0.319
MCV	-0.291 (-0.666; 0.084)	0.126	-0.0712 (-0.162; 0.197)	0.123
MCH	-0.037 (-0.0709; -0.0032)	0.032	-0.033(-0.0683; 0.0015)	0.061
MCHC	0.0115(-0.043; 0.066)	0.675	0.0111(-0.045; 0.0673)	0.693
PLT	-0.298 (-5.089; 4.492)	0.902	-1.543 (-5.734; 2.646)	0.465

*Thead justed variables in the model are age, BMI, the house distance off the main road (m), and smoking.

The results of this study show that exposure of individuals to respirable particles with mean concentration of 2.55 mg/m^3 and a working background of 3.98 years has been followed by elevated WBC level. Although the mean concentration of respirable particles is lower than the TLV standard limit, but it exerted its effect on WBC.

Discussion

Tile and ceramic industry is one of the industries in which many people are employed. Due to inhalation of dust particles, these individuals are susceptible to occupational diseases [28]. As a result of high risk of incidence of irreversible health effects on the workers of this industry, scientific studies should deal with evaluation of the extent of complications of exposure to particulate matters in these industries. This study aimed to investigat a hypothesis where particulate air pollution led to changes in blood parameters. The concentration of respirable dust was significantly and positively correlated with WBC in the crude and adjusted model. Also, a significant and negative relationship was observed between MCH and the concentration of respirable dust in the crude model.

Various studies conducted on animals and humans with regard to air pollution have reported abnormal red cells, altered level of neutrophils and platelets, elevated blood viscosity, alteration of the number of lymphocytes T and B, and increase of heart rate [19, 23, 29, 30].

In this study, a significant and positive relationship was observed between the concentration of respirable particles and white blood cells, whereas a significant negative relationship was observed between this concentration and MCH. For the rest of the measured factors, however, no significant relationship was observed. Nevertheless, in the study by Seaton, a significant negative relationship was observed between the average value of three days of individual exposure to PM_{10} and hemoglobin, RBC, and platelet counts. In Seaton's study, 108 individuals with a mean age of 70.4 and 68.2 years in two cities were examined for 18 months with different meteorological conditions. The samples were taken from PM_{10} particles outside the house, inside the house, when commuting, and other environments[31]. However, in our study, only the extent of occupational exposure to respirable particles was examined in 80 people with an average age of 29.54 years old. Probably, these factors (age range, meteorological conditions, sampling in different environments, etc.) can affect the difference of the results. As the participants of this study were mostly young, the results revealed that air pollution can also affect young people and even those who have a strong and healthy immune system.Furthermore, in other studies, the effect of particulate air pollution on the elderly and athletes has also been demonstrated [32]. It seems that various intervening factors affect the intensity of the examined factors. In this study, the amount of pollution inhaled in the working environment is far greater than that of traffic pollution. Also, the effect of the factors of distance off the main road and extent of respirableexposure is greater than that of age, working background, and BMI. In other words, these factors have had no effect on CBC results. Similarly, in the results obtained by Rudez, a relationship was found between air pollution and increased platelet aggregation and elevated thrombin production [33]. However, in the results of this study, no relationship was found between the number of blood platelets and concentration of respirable particles [24]. The results can also be affected by the nature of pollutant particles. Urban air pollution results from traffic and fossil fuels and chemicals including heavy metals and poly aromatic hydrocarbons [9]. On the other hand, in a tile factory, most pollutants are mineral dust and particles with compounds of kaolinit, pheldespate, and silica. In this regard, it is different from other previous studies conducted in urban regions. On the other hand, the results of this study showed that mineral dust also affects the level of WBC. Although the effect of mineral dust is not greater than urban air pollution, these dusts have caused increased WBC count. Further, some studies have also stated that physical activity can influence reduction of the harmful effects of air pollutants [34]. As this study was conducted in a working population with a high physical activity level, possibly the lack of difference in the mean value of the blood factors in the two groups of lower and higher than the standard limit and the fact that over 80% of the people have had blood factors within standard limit could be due to this reason. In this study, the mean age is 29.54 years old, who have been chosen out of healthy individuals with known disease background. Being healthy and young can account for the finding of this research.

Fewer studies have been conducted on investigating the effect of particulate air pollution on blood factors and this study is among the few studies measuring the extent of the effect of exposure to respirable particles in the working environment on blood parameters. The studies conducted on investigating the effect of air pollution on the population have been conducted based on the measurement of pollution in a central point, covering all the studied individuals. However, in this study, for all of the individuals, a 4-hour air sample was taken from the respiratory region of the worker during their daily tasks to determine the extent of exposure to respirable dust. In addition, the extent of exposure of individuals to particles was determined within two ranges of lower and higher than the standard limit of exposure. The results indicated that the mean value of blood factors in the two groups of lower and higher than the standard limit has no significant difference. This can be due to the young and healthy body of the individuals or usage of respiratory mask, where in spite of the concentration of dusts over the standard limit, it has not had effect on blood factors. However, overall, a positive relationship was observed between white blood cells and concentration of respirable particles, which is also statistically significant. Elevation of white cells is possibly due to increased lung infection and elevated production of antibody in response to exposure to air pollution[35]. In this regard, it is in accordance with the study on athletes and firefighters [32, 36].

Air pollutant particles can cause development of changes in blood cells including diminished red cells and elevated WBC count. Elevation of WBCs can be due to response to the inflammatory state of the body following exposure to particles. The reason for part of elevation of WBC has been associated with the release of Granulocyte-Macrophage Colony-Stimulating Factor (GMCSF) and IL-6 from pulmonary macrophages [21].

Epidemiological studies have considered elevated level of gas and particulate pollutants to be related to increased mortality resulting from cardiovascular and respiratory diseases [37, 38]. However, the principal mechanisms of these diseases are not known, but inflammatory and homeostatic processes are associated with this issue [3, 39, 40]. Considering the previous studies conducted with the aim of determining the relationship between concentration of air pollution and their health effects including mortality or the relationship between controlled exposure to air pollution and different biological variables in human and animal models [41, 42], it seems that the inflammatory responses of lungs following exposure to inhaled particles do not have the main role in the rate of mortality. Instead, systematic changes including changes in blood properties are a more sensitive index for measurement of biological effects associated with exposure to particles and are potentially related to cardiovascular effects [43].

Conclusion

Exposure to respirable mineral dust at a level of 0.05-82.84 mg/m^3 is followed by WBC increase. This study states that a significant number of individuals are employed in tile and ceramic industry and are exposed to high levels of pollutants and are also susceptible to cardiovascular and respiratory diseases as well as some irreversible diseases like cancer. Thus by considering the results of this study, changes in the trend of improving the work and preventive measures are essential. Also, controlling measures including technical and engineering, managerial controls as well as monitoring of inhaled air should be considered to decrease exposure to respirable dust.

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Conflict of interest

The authors declare that there is no conflict of interest.

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