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ORIGINAL ARTICLE

Health Risk Assessment of Asphalt Workers' Exposure to Benzo-α-pyrene

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KEYWORDS

Benzo-α-pyrene;
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ABSTRACT: Benzo-α-pyrene is one of the most dangerous pollutants during working on asphalt, which is a carcinogenic. This study was aimed to perform health risk assessment of asphalt workers exposure to Benzo-α-pyrene using respiratory air monitoring data. The standard method of NIOSH 5515 (National Institutes of safety and health) was used for sampling and analyzing the Benzo-α-pyrene in the respiratory air. The sampling was done using polytetrafluoroethylene filter (PTFE) and XAD-2 sorbent tube (naphthylisocyanate) and the obtained samples were analyzed by Gas Chromatography with Flame Ionization Detection (GC-FID). The results of the study show that the highest and lowest concentrations belong to the functions of finisher assistance (0.058±0.011 mg m^{-3}) and roller driver (0.042±0.015 mg/m^3), respectively. The statistical test showed that the concentration of Benzo-α-pyrene in the respiratory air of different tasks is significantly different from each other (P<0.001). The results of the health risk assessment showed that all tasks are at a high risk level. In addition, comparison of the results of the concentration of Benzo-α-pyrene in the respiratory air and the assessment of health risk indicated that merely monitoring the concentration of the pollutants in the breathing air and comparing it with the allowable limits of exposure are not appropriate and reliable criteria to ensure the absence of disease or health problems.

INTRODUCTION

Working on asphalt is one of the most challenging works in a development area worldwide, where workers are exposed to hazardous pollutants. For many years, various studies have been done in this field. In the United States, there are about 300,000 workers in the hot mix asphalt industry and the asphalting of the streets as well as 50,000 workers in the asphalting operation of the rooftops [1-4]. Recent studies have shown that cancer risk has been increased among workers exposed to compounds present in asphalt [5-8].

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Various studies were performed on asphalt workers, indicating that these individuals face high amounts of polycyclic aromatic hydrocarbons (PAHs) raise from hot asphalt. Accordingly, the PAHs are a group of organic compounds consisting of two to seven benzene rings in the form of different structures (the most critical elements of which are carbon and hydrogen). PAHs are the products of incomplete combustion of fossil fuels and some other natural and artificial organic materials such as wood, coal, gas, oil, bitumen, waste, and tobacco. [9-13].

Burstyn et al. (2002) examined the extent of exposure of Norwegian asphalt workers to PAHs and asphalt fumes and also evaluated their control devices. The results showed that the average of individual's exposure to asphalt fumes ranged from 0.03 to 0.15 mg m^{-3}. In this study, PAHs with 4 to 6 rings were identified in 80-90% of the samples [14]. In 1994, Arey and Atkinson investigated the carcinogenesis factors of PAHs. The results of this study show that due to the reaction of PAHs with radical hydroxide in the atmosphere, the lifespan of these compounds is less than a day. Moreover, these results indicate that in assessing the health risk of these compounds, atmospheric secondary products of this material need to be considered [13]. Aghaei et al. (2011) examined PAHs in the breathing air of asphalt workers in Tehran. Accordingly, the result of the study showed that the estimation of the concentrations of PAHs in the breathing zone of the asphalt workers in Iran is lower than the allowable limits of National Institutes of safety and health (NIOSH) and Occupational Safety and Health Administration (OSHA) [15]. The study also showed that the degree of exposure to PAHs has some significant differences due to various asphalting duties [15]. Benzo-α-pyrene is one of the compounds of PAHs, which has high carcinogenic properties. Of note, the first occupational cancer was discovered due to exposure of Benzo-α-pyrene [10, 16], which is one of important contaminant in the asphalt working. The conventional method for evaluating occupational exposure to chemical contaminants is comparing their concentration with allowable exposure limits. The OSHA has announced the Threshold limit value of Benzo-α-pyrene as equal to 0.2 mg/m^3. The NIOSH has also announced an occupational exposure limit equal to 0.1 mg/m^3 for Benzo-α-pyrene (15). Due to the fact that various factors besides the concentration of pollutants can affect chemical contaminants, so new methods have been developed to assess the health risks of occupational exposure to chemical pollutants. One of these health risk assessments to chemical exposure methods was proposed by the Singapore Professional Health Department [17]. Concerning the increased health problems for the asphalt workers in recent years, this study aimed to perform health risk assessment of asphalt workers' exposure to Benzo-α-pyrene using the method proposed by the Singapore Professional Health Department.

MATERIALS AND METHODS

Target community

This was a cross-sectional study conducted on asphalt workers in Tehran. According to the previous studies performed on this subject, by considering the confidence level of 95%, the standard deviation of the air-monitoring samples for Benzo-α-pyrene, and the maximum allowable error equal to 1%, the actual size of 138 samples were determined. The inclusion criteria were as follows: obtaining informed consent prior to the participation in the study and at least two years' experience of asphalt working. Moreover, the exclusion criteria were having another job, the participants' request to leave the study, and feeling of physical discomfort after the onset of the experiment. For this study, ethical Code of IR.IUMS.REC. 691 was received from Research Morals Committee of Iran University of Medical Sciences and informed consent form was obtained from the participants.

Sampling of respiratory air

The standard method of NIOSH 5515 was used for sampling the Benzo-α-pyrene in the respiratory air. Firstly, by a penny, a polytetrafluoroethylene filter (PTFE) was carefully placed in a holder filter. Thereafter, two sides of the XAD-2 sorbent tube (naphthylisocyanate) were broken. Using a small adapter pipe, the outlet of the holder's filter vent was attached to the absorber tube inlet, and using a long adapter tube, the output of the adsorbent tube was then connected to the inlet of the sampling pump. Subsequently, the holder was attached to the person's collar by a clamp so that it was placed near the respiratory region of him, and while the worker was doing his usual job, the sampling process was done. The individual samples were collected at a rate of 2 l/min to reach a total volume of 1000 liters. Finally, the flow rates were checked hourly by the researcher.

Sample analysis

The standard method of NIOSH 5515 was used for sample’s analyzing. To extract the analytes from the filter and absorbent, an Ultrasonic bath was used. Next, the Gas Chromatograph device (GC-2010, shimadzu, Japan) equipped with a hydrogen flame ionization detector (FID) and 25 m long SGE capillary column (fused silica, film thickness: 0.25 micron, I.D: 0.22 mm) was used for sample’s analyzing. The sensitivity of the method (LOD) was 0.3 to 0.5 µg per each sample. Of note, Excel 2013 and SPSS software (One-way ANOVA) versions 24 were used to analyze the obtained data.

Health risk assessment of occupational exposures

In this study, to assess the exposure risk of individuals with Benzo-α-pyrene, the method proposed by the Singapore Professional Health Department was used [17]. In this method, the level of health risk is determined by the equation 1.

$$Risk = \sqrt{DR \times ER} \qquad (1)$$

DR: Danger Rate

ER: Exposure Rate

Danger Rate

The DR is determined based on the toxic effects of chemicals through the relevant table. Another method of determining the DR is the lethal dose (LD50) and lethal concentration (LC50) of chemicals. In this study, the DR was determined based on the toxic effects of the chemical substances, which was equal to 5.

Exposure index

According to the guidelines of the Singapore Professional Health Department, the ER can be obtained using the data available about measuring the concentration of the existing chemicals (air monitoring results) or using the table presented in this guide. In this study, due to the existence of concentrations, the amount of exposure was determined using equation 2.

$$E = \frac{F \times D \times M}{W} \qquad (2)$$

E= the amount of exposure (mg/m^3 or ppm)

F= the number of exposure per week

D= the average duration of each exposure (hours)

M= the amount of each exposure (mg/m^3 or ppm)

W= Average working hours per week (40 hours)

The amount of exposure (E) calculated from the equation 2 were divided into the permission exposure values (PEL), and the amount of ER was determined based on table 1. In this study, the recommended exposure limit of NIOSH organization, which is 0.1 mg /m^3, was used [16].

Table 1. Exposure index of the risk assessment method

ER	E/PEL
1	< 0.1
2	0.1-0.5
3	0.5-1
4	1-2
5	> 2

After determining the DR and ER for Benzo-α-pyrene, the risk number was calculated by equation 1. The obtained risk numbers were ranked according to Table 2.

Table 2. Risk level and amount of risk

Risk Rating	Risk score
Minimal Risk	0-1.7
Low Risk	1.7-2.8
Medium Risk	2.8-3.5
High Risk	3.5-4.5
Very High Risk	4.5-5

RESULTS

There were various duties such as screed man, paver operator, roller driver, rubber, and rake man in asphalting. Table 3 shows the frequency and frequency percent of individuals studied from each task.

Table 3. Frequency of studied individuals from each task.

Duties	Frequency	Frequency percentage (%)
Screed man	30	22.39
Paver operator	16	11.60
Roller driver	20	14.49
Rubber	38	27.54
Rake man	34	24.63
Total	138	100

As observed in Table 3, the highest frequency was corresponds to the rubber duty and the minimum frequency for the roller driver. Table 4 shows the demographic characteristic of studied individuals. As can be seen, the maximum work experience is given to the task of screed man, and the least experience work belongs to the duty of rubber.

Table 4. Demographic characteristic of the studied individuals.

Duties	Age (year)		work experience (year)		Daily work time (hour)	
	Mean	SD	Mean	SD	Mean	SD
Screed man	38.23	2.37	16.32	0.83	9	0.23
Paver operator	34.82	1.42	10.54	1.32	10	0.18
Roller driver	35.45	3.25	9.68	1.25	9	0.17
Rubber	32.24	3.43	4.33	2.35	9	0.42
Rake man	36.76	4.81	7.37	1.63	10	0.36

The mean and standard deviation of the concentration of the Benzo-α-pyrene concentration measured in respiratory air based on the tasks are presented in Table 5. As observed, the maximum and minimum concentration, respectively, belongs to the duties of the screed man and the driver of the roller. The statistical test showed that the concentration of the Benzo-α-pyrene on the breathing air differs meaningfully from one to another.

Table 5. Average of measured Benzene (a) Pyrene concentration in respiratory air

Duties	Mean (mg/m^3)	SD	P-value
Screed man	0.058	0.011	0.000
Paver operator	0.049	0.012	
Roller driver	0.042	0.015	
Rubber	0.052	0.009	
Rake man	0.055	0.012	

The results of the health risk assessment of occupational exposures for the reviewed tasks are presented in Table 6. As can be seen, the risk score for the screed man is more than the other tasks.

Table 6- The results of occupational health risk assessment for the studied tasks

Duties	DR	A weighted exposure (E)					E/EL	ER	Risk Score	Risk level
		F	M (mg m^{-3})	D (h)	W (h)	E (mg/m^3)				
Screed man	5	6.32	0.058	8.24	40	0.075	0.75	3	3.87	High
Paver operator	5	6.42	0.049	8.54	40	0.067	0.67	3	3.87	High
Roller driver	5	6.21	0.042	8.58	40	0.056	0.56	3	3.87	High
Rubber	5	6.48	0.052	10.43	40	0.087	0.87	3	3.87	High
Rake man	5	6.86	0.055	12.28	40	0.115	1.15	4	4.47	High

Based on the results of table 6, the risk level of all tasks is at large, despite the difference in the risk score for different duties.

DISCUSSION

In this study, five tasks of screed man, paver operator, roller driver, rubber, and rake man were investigated. The results show that in the cases studied in this research, the maximum exposure amount to the Benzo-α-pyrene related to the task of the screed man with 0.058 ± 0.011 mg/m^3. Additionally, the minimum amount of exposure related to the task of the driver of the iron roller was obtained as 0.042± 0.015 mg m^{-3}.

In a study by Cirla et al. performed in the city of Milan, respiratory exposure amounts to the Benzo-α-pyrene were reported as 0.83, 0.19, 6.24, and 0.27 ng m^{-3} in the functions of the finisher driver, finisher assistant, troweler, and shovel in hand, respectively[6]. In another study, Posniak studied the exposure of asphalt workers to PAHs. The average exposure to Benzo-α-pyrene was found to be 6 ng m^{-3} [18]. The results of the present study show a higher rate of respiratory exposure compared to those of the studies by Milan and Posniak. Accordingly, this difference could be due to the combination of asphalt used, technology and equipment used, and asphalt's temperature.

By comparing the results obtained in this study with the allowable limits of exposure, it can be said that the level of people's exposure to this combination is lower than the allowable level of exposure. Lin et al. in 2008 conducted a study entitled "Determining the rate of exposure to PAHs in the working environment and assessing the health risk in workers of an iron ore granules factory." Correspondingly, their results showed that the health risks of cancer and other duties due to multi-ring hydrocarbons in workers in this industry are lower than the allowed limit, and the concentrations obtained in the respiratory climate are acceptable [19].

The results of the statistical analysis showed that there is a significant difference in the exposure to Benzo-α-pyrene in different duties of asphalting. Among the different tasks of asphalting, the extent of the task exposure of finisher assistant with most of the other tasks indicates a significant difference, may be due to the proximity of these people to the source of PAH production, i.e., hot asphalt and exposure to output smoke from the road construction machinery exhausts. Additionally, because of the nature of their job, these people need to be placed next to the control panel of the finisher apparatus all the time during asphalting, which makes the time of facing with the fumes given off by the hot asphalt longer. After the asphalting processing, the confrontation of the tasks of the shovel in hand and the troweled with most other functions indicated significant differences, may be due to the proximity of these duties to hot asphalt and hence more exposure to the fumes emanating from it.

In this study, Benzo-α-pyrene was found to be less than the exposure limits to ensure about that, the health risk assessment of job encounters with Benzo-α-pyrene was performed for the tasks that were under review. The results show that the health risk is due to the permissible limit of organization exposure (NIOSH) for all tasks at a high-risk level. Comparison of Benzo-α-pyrene results between respiratory air and health risk assessment showed that despite the low concentration of Benzo-α-pyrene in the respiratory air, the health risk of exposures was found to be high. Recently performed studies have shown that cancer risk has increased among workers exposed to bitumen fumes and other compounds present in asphalt [5]. The results of the study performed by Tsai et al. (2001) on Benzo-α-pyrene exposure, reported that lung cancer health risk was $4.35 * 10^{-2}$ and skin cancer health risk was $1.13 * 10^{-3}$, both of which are higher than those approved by the Supreme Court of the United States in 1980 [20]. In the study by Bostrom et al. (200), Benzo pyrene was investigated as a carcinogenesis criterion. The results of this study show that the carcinogenic risk of Benzo pyrene was $9*10^{-5}$ for each Nano gram per cubic meter. In other words, exposure to 0.1 ng/m^3 was found to cause one cancer in 100,000 people [21].

According to the results, it can be said that merely monitoring the concentration of the pollutants in the breathing air and comparing it with the allowable limits of exposure, is not an appropriate and reliable criterion to ensure the absence of affection to disease or to health problems. Therefore, there is an urgent need to find new ways to assess the health risk of occupational encounters with chemicals.

Limitations: The limitations of this study were the followings: 1- The sampling and risk assessment were only for Benzo-α-pyrene that is known as one of the compound of PAHs, and 2- The risk assessment was done only on the pollutant concentration in the respiratory air.

CONCLUSIONS

The results of the study show that the concentration of Benzo-α-pyrene in the breathing air of asphalting workers is less than the permissible limits of exposure. The task of an individual was considered among the factors affecting the value of the concentration of the Benzo-α-pyrene in respiratory air. Moreover, the results show that despite the permissible concentration of Benzo-α-pyrene in the respiratory air, the health risk of occupational exposures was high in the participants of this study. Comparison of the results of the concentration of Benzo-α-pyrene in the respiratory air and the assessment of health risk indicated that merely monitoring the concentration of the pollutants in the breathing air and then comparing it with the allowable limits of exposure are not appropriate and reliable criteria to ensure the absence of disease or health problems. Therefore, there is an urgent need to find new methods for assessing the health risk of occupational exposures with chemicals.

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Conflicts of interest

The author declares that there is no conflict of interest regarding the publication of this article.

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