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Original

Evaluation of Dermal Exposure to Polycyclic Aromatic Hydrocarbons Using DREAM Method in Production of Bituminous Waterproofing

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Abstract

Background: Research has shown that dermal exposure to multi-ring aromatic compounds can lead to skin and systemic absorption of these materials. Due to the low vapor pressure of these materials, the main cause of occupations exposure in certain occupations is skin contact. The production of bitumen products due to the presence of polycyclic aromatic hydrocarbons (PAHS) in the bitumen of the production line has a health hazard. It is noteworthy that skin rashes with polycyclic aromatic hydrocarbons in this industry can cause skin problems in the workplace. This study evaluates skin exposure to these compounds in the ISO-industry using DREAM method. **Methods:** In this study, we evaluated 120 different workers in different groups of four waterproofing plants with aromatic hydrocarbons. In the DREAM method, five types of skin exposures including distributing exposure, transitional exposure, displacement exposure, probable exposure, and actual exposure are assessed and calculated using tables and software. **Results:** The highest transmission and distribution exposure was found to be 28.81 (19.5) and 9.1 (4.86), respectively, in the manufacturing jobs and bitumen ponds. Displacement exposure was observed only in roll-up and labeling groups. The areas of the hand and shoulder were more likely to be exposed than other parts of the body. The probable and real exposure to the head and arm was lower than elsewhere. In all occupations, the most important exposure to the skin was transmission and distribution exposure. **Conclusion:** DREAM method can be used to assess skin exposures. In this study, the actual and probable skin exposure levels were approximately the same, indicating a lack of proper skin protection in the workforce. Unhealthy behaviors, non-use of personal equipment and inappropriate connection are the causes of this finding.

Keywords: Dermal exposure; Multi-rheological aromatic hydrocarbons; Bituminous waterproofing industry; DREAM method

Introduction

The materials in the work environment are contacted by the human body in many ways and enter the human body through inhalation, transit through the skin and sometimes by swallowing.[1] The importance of skin contact has increased in recent years. Polycyclic Aromatic Hydrocarbons (PAHs) are a group of persistent

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pollutants that contain multi-nuclei arenes or poly-arenes.[2] These compounds have been of interest to the scientific community due to carcinogenesis, mutagenesis, sustainability, and bioavailability.[3]

PAHs are produced due to incomplete combustion of organic materials such as charcoal, wood, oil and oil residues, including bitumen and asphalt. Research has shown that skin exposure in chemical workers is known to be a major contributor to skin cancer and dermatitis.[4] The acute effects of exposure to PAHs and their effects on human health depend on factors such as the severity and contact time, the concentration of contaminants, the toxicity of the compound, and the way in which contaminants enter the body. Chronic and prolonged exposure to PAH compounds causes cancer (lung, skin, bladder, stomach, and intestines) in laboratory animals and humans cause damage to DNA, cataracts, and kidney and liver damage.[5] Skin contact with these materials is more important than the solvents because the solvents facilitate the passage of these materials through the skin.[6-8]

Due to vapor pressure, PAHs can be seen in two phases of gas and particles. In total, PAHs that have more than 5 rings are often seen in particle phase, two or three rings are in gas phase, and 4 rings are both gas and particle forms. Evaluation of the exposure includes detection and investigation of hazardous materials (type, material amount, geographic area), measuring the concentration of pollutants in various sources (air, water, food and soil), diagnosis of major confrontation, recognize the severity, duration and frequency of exposure, diagnosis of exposure dose, estimation of the number of people exposed to exposure and detection of high risk groups.[5] Due to its high creatine, pigmentation, and elasticity, the skin can provide a barrier against damage. Despite the high ability of the skin to deal with harmful substances, it is still one of the most vulnerable parts of the body in today's industry.[9]

Assessment of human exposure is done directly and indirectly. The direct method involves monitoring individual and biological exposures. The indirect method includes a questionnaire, environmental observation, and modeling. The indirect method provides information with less cost in comparison to the direct method typically. Of course, this method cannot show the dose of contaminating concentration entering the body of an individual and environmental monitoring.[10] Current methods of skin exposure measurement are divided into five main categories. The patch method and displacement method can be used to measure the probable exposure to the whole or part of the human body.[11] Separation methods such as washing, the VAIP test are used to measure the amount of material on the skin over different periods of time. In the detection method, fluorescence materials are used to measure local exposure to the substance[12], and also using the bioassay for indirect assessment of absorption Skin is used.[13] Extensive efforts have been made to evaluate skin contact with materials; Dermal Exposure Assessment (DREAM) is a result of these efforts, which is a semi-quantitative method for assessing skin exposures with biological and chemical agents that can be used in occupational and epidemiological health studies. In this model, the contaminant exposure to skin is investigated in three ways: release, substitution, and transfer. In this release model, there is direct exposure to contaminants with skin or clothing. Displacement on the skin or clothing involves contact with the substance through the air, and the transfer involving contact contaminants with skin or clothing through surfaces and tools.[1] In the manufacturing industry, the occupational exposure to PAHS compounds is due to the skin contact of the workers with the bitumen layers during the production of the bituminous waterproofing. Bitumen is produced as a byproduct of the chemical processes that take place on crude oil. Tar is also produced as a viscous distillation of coal, which contains many organic compounds, most of which are PAHs.[14] Bitumen contains about 1%, and tar contains 90% PAHs. Therefore, tar is considered as a human carcinogen in group 1 and bitumen in Group 3.[15] In this study, DREAM method was used as a semi-quantitative assessment of occupational health to evaluate skin exposure to these compounds due to the occupational hazards and dermatological effects of bitumen as one of the most dangerous aromatic compounds in the bituminous waterproofing industry.

Methods

This is a descriptive-analytic study that was carried out on 120 workers in 4 waterproofing plants with at least one year of work experience. The studied population was selected from the working units of materials, preparation, bitumen pond, cooling and packaging, which were classified in 7 tasks of building materials, user gardening, pool user, polyester user, rolling, labeling, and packing. A researcher-made questionnaire for demographic information and the presence of skin signs of dermatitis and acne was used through self-declaration of the subjects. The medical records of the practitioner were reviewed by the supervisor of the medical practitioner to confirm the statements of the individuals. Each person was carefully monitored and recorded during three shifts and within a maximum of one-week interval. Exposure of distribution, transfer, displacement, probable and real through the skin was calculated for the 9 parts of the body including head, arm, forearm, hand, front, body, back, lower body, lower legs, and feet, according to the method provided by De Joode.[16-18] The probability and severity points were calculated according to the following equations:

EBP = PE.BP .IE.BP .EI . ERE Distribution exposure

TBP = PT.BP.IT.BP .EI . ERT Transmission exposure

Displacement exposure DBP = PD.BP . ID.BP .EI . ERD

In the above equations, "P" is the probability and "I" is the intensity in distribution (E), transitional (T) and displacement (D) exposures. The invoice EI shows the intrinsic distribution, and the ER factor is rated 3 in the face of the publication, and in other exposures, it has a score of 1. Total skin exposure for the whole body is calculated according to the Skin-PBP = EBP + DBP + TBP equation. The true skin exposure of the ninth part of the body, and ultimately the whole body, was calculated taking into account the potential skin exposure and the protective factor of clothing for hands and other parts of the body. Protective clothing factor for hands was calculated according to the equation OHA = M.PFMHA.RF.GC. GD.UG.URF.BC (Protective Clothing Factor for Hands) and protective clothing for other parts of the body was calculated according to the OBP = M.PFMBP.RF (Other Body Parts) equation. The protective factor was determined according to the type of clothing or gloves, the number of displacements, appropriate contact of hands with gloves, time of wearing gloves, wearing additional gloves on the first gloves, the frequency of displacement of second gloves and the use of protective cream. The calculated values of actual skin exposure were finally classified in 0 to 6 according to Table 1.

After collecting the data and performing necessary controls, SPSS 20 software was used to analyze the data. Spearman correlation test was used to determine the correlation between quantitative data due to non-normalization of data. To compare the mean score of occupational exposure, the Kruskal-Wallis test was used. Also, using post-test R, the true exposure of different areas of the body between different occupational groups was investigated. Results were analyzed with assurance level of 95%.

Table 1. Grouping real skin exposures

Group	Exposure level
0	Without exposure, the numeric value is 0
1	Extremely low exposures with a numerical value of less than 10
2	A small enclosure with a numerical value of between 10

	and 10
3	Medium exposure is a numerical value of between 100-30
4	Exposure to large numbers is between 300-100
5	Extremely high exposure is a numerical value of between 1000-300
6	Excessive exposure to a numerical value greater than 1000

Results

Based on the results of this study, among the job tasks, the user of the patch with mean and standard deviation was 34.1 (18.9), and for material making user, it was 31.62 (11.17) which respectively had the highest distribution exposure to skin. Transitional skin exposure in the user's occupation has the highest amount (9.85), due to contamination of the tar caldron with bitumen and contamination of clothing, and the smallest one is related to a labeling job (1.73) Table 2.

The score of hand distribution exposure was higher than other organs, which the caldron user had the most exposure to Table 3. According to Table 4, the average real exposure to hand was higher than other areas of the body in all occupations, with the highest and lowest hand exposures related respectively to the caldron user 41. 8 (17.12), and labeling 1.71(0.09). Rolling, labeling, and sharing, with a mean and standard deviation of 0.02 (0.001), have the lowest amount of real exposure to the forearm in occupations. Real exposure has only a significant difference between hand and foot areas between different occupational groups. In all occupational tasks, hand skin contamination plays a major role in contamination. Real exposure to the head area was found only in the building materials jobs. The contamination of arm area was observed in the building materials and the caldron users, and the head and back of the body had the smallest mean of real exposure across all areas of the body. Comparing the building material and caldron users, it was concluded that the two groups had significant statistical differences in hand. The comparison of the two job groups of caldron users with rolling, labeling, and sharing showed that there was a significant statistical difference between forearm and arm.

Table 2. Mean and standard deviations of distribution, transfer, and displacement exposure in various job tasks

job responsibilities	Distribution exposure	Transmission exposure	Displacement exposure	Real exposure
Caldron user	34.01(18.90)	9.85(5.21)	0	44.04(20.82)
Building materials	31.62(20.11)	8.35(4.51)	0	39.97(23.10)
Polyester user	18.20(9.76)	4.32(3.22)	0	22.36(14.60)
Pool user	17.22(10.46)	4.05(2.74)	0	21.37(14.71)
Rolling	0	2.13(1.50)	0.12(0.08)	2.25(1.10)
labeling	0	1.73(1.32)	0.03(0.09)	1.76(1.01)
Sharing	0	1.85(1.12)	0	1.85(0.89)
p-value	0.64	0.001	0.07	P<0.01

Kruskal waliss

Table 3. Comparison of exposure scores according to different parts of the body in the studied occupations

	Mean (sd)				
Job	head	arm	hand	Body front	foot
Material building	0	(0.001)0.01	(8.30)29.20	(0.001)0.02	(0.002)0.03
Caldron user	(0.002)0.03	0.001)0.05(	(14.63)32.10	(0.001)0.02	(0.002)0.04
Polyester user	0	(0.002)0.03	(5.10)16.2	(0.001)0.01	(0.001)0.02
Pool user	0	(0.001)0.05	(4.60)15.70	(0.001)0.01	(0.001)0.02
P-Value	0. 90	0.20	P<0.01	0.73	0.8

Table 4. Comparison of actual exposure score in different parts of the body in the studied occupations

	Mean (sd)					
Job	head	arm	forearm	hand	Body front	foot
Material building	0	0.01(0.001)	2.39(0.35)	37.40(12.18)	0.03(0.002)	0.05(0.00)
Caldron user	0	0	1.94(0.61)	41.48(17.12)	0.03(0.002)	0.06(0.003)
Polyester user	0	0	1.78(0.47)	20.40(9.81)	0.02(0.001)	0.03(0.002)
rolling	0	0	0.02(0.001)	2.30(0.87)	0.02(0.001)	0
labeling	0	0	0.02(0.001)	1.71(0.09)	0.02(0.001)	0
sharing	0	0	0.02(0.001)	1.80(0.09)	0.02(0.001)	0

Pool user	0	0.05(0.00)	1.57(0.72)	19.60(7.57)	0.02(0.001)	0.05(0.00)
	0.9	0.76	0.01	P<0.01	0.50	0.79

Table 5. Comparison of Transition exposure in Different Parts of the Body in Studied occupations

	Mean (sd)					
Job	**head**	**arm**	**forearm**	**hand**	**Body front**	**foot**
Material building	0	0.02(0.001)	0.09(0.06)	8.20(2.34)	0.01(0.001)	0.02(0.001)
Caldron user	0.01(0.001)	0	0.09(0.007)	9.70(4.80)	0.01(0.001)	0.02(0.001)
Polyester user	0	0	0.08(0.004)	4.20(1.50)	0.01(0.001)	0.01(0.001)
rolling	0	0	0.01(0.001)	2.10(0.15)	0.01(0.001)	0
labeling	0	0	0.01(0.001)	1.70(1.10)	0.01(0.001)	0
sharing	0	0	0.02(0.001)	1.80(1.30)	0.02(0.001)	0
Pool user	0	0	0.07(0.005)	3.90(1.90)	0.01(0.001)	0.03(0.002)
P-Value	0.90	0.88	0.07	P<0.01	0.72	0.78

Table 6. Correlation of Demographic Parameters with real Skin and Dermatitis Exposure

		age	Work history	awareness
Real exposure	Correlation coefficient	0.038	0.22	-0.28
	P-Value	0.76	0.01	0.00
Dermatitis	Correlation coefficient	0.05	0.313	-0.32
	P-Value	0.55	P<0.01	P<0.01

Spearman's

Table 7. Frequency of contact dermatitis among job tasks

***p*-value**	**dermatitis**	**Material building**		**Caldron user**		**Polyester user**		**rolling**		**labeling**		**sharing**		**Pool user**	
		num	percent	num	percent	num	percent	num	percent	num	percent	num	percent	num	percent
0.021	yes	8	6.66	9	7.50	5	4.16	2	4.16	2	4.16	2	4.16	4	3.33
	no	9	7.50	8	6.66	12	10	15	10	16	13.3	16	13.30	13	10.80
	total	17	14.16	17	14.16	17	14.16	17	14.6	18	17.46	18	17.46	17	14.13

In transitional exposure, hand and forearm were the most exposed and lower parts of feet had the least exposure Table 5. Real exposure to skin and dermatitis had a direct relationship with work history, but there was an inverse relationship with invasive awareness. This means that the higher the level of awareness is, the less real exposure to the skin and dramatitis is, but with an increase in work experience, the amount of these two parameters also increases Table 6.

26.6% of people reported dermatitis and 24.1% of them reported having acne (skin rash), which is a small percentage of the studied population. According to the results, the frequency of dermatitis in different occupational groups was statistically significant Table 7.

Discussion

The purpose of this study was to evaluate skin exposure to PAHs in the bituminous waterproofing industry using the semi-quantitative DREAM evaluation method. Several studies have been conducted to evaluate the dermal exposure of asphalt workers, although this has been done differently from the present study using different methods. However, DREAM's observations appear to have confirmed this study by McClean and colleagues.[17] Several studies have reported the effectiveness of this approach in skin exposures.[18-20] The DREAM method can be used as a tool for determining the factors affecting the level of skin exposure[21] and, like the real exposure of the skin, can detect differences in skin exposures between jobs with different potentialities.[22] This method evaluates the potential and real dermal exposure. Long-term factors such as the use of protective clothing are reflected in this method. Protective clothing factor is effective in potentially affecting skin exposure, which significantly reduces real exposure. The results of this study are consistent with the study by Agostini et al.[22] The advantages of the DREAM method include the comprehensiveness and ease of use of the method, the evaluation of the effectiveness of protective devices such as gloves and protective clothing, identifying areas of the body that require further protection. The time-consuming assessment of skin exposures, researchers' hypotheses influence due to the limited knowledge of people in the field of skin exposure[23], the need for a large number of evaluations for multi-tasked workers and a large number of calculations are disadvantages and limitations of this method.[22] However, in cases where the use of this method is available, it can be used to determine the causes of skin exposure and its importance. There are several ways to evaluate skin exposures with PAHs, such as fluorescence tracking, skin replacement techniques (patch technique and whole body technique), and surface sampling techniques. In the fluorescence tracking method, UV light is flashed on infected areas of the skin and infected areas are identified. Obviously, among the disadvantages of this method are the harmful effects of UV radiation on individuals as well.[24] In the replacement technique, the collector matrix traps and holds the chemicals the same as skin. The disadvantages of this method include requirement of a high amount of solvent, especially in the whole body technique, in addition to the environmental effects causing high costs and waste of time. Many studies have been conducted on the assessment of skin exposure to PAHs using alternative techniques.[25-28] Surface sampling techniques are the most common method for assessing possible infections with contaminants that provide information on contaminating masses. Lack of a proper ratio of surface contaminant and transitional contaminants to the skin is one of the disadvantages of this method. The accuracy and precision of this method depends on the nature of the surfaces, the type of material and the method of sampling.[29,30] The results of this study show that the highest skin distribution exposure was in the caldron user and material building jobs; the reason is body's contact (mostly hand and forearm) with the reservoir of building materials and bitumen caldron which have high contamination. In material building and caldron use due to the presence of liquid bitumen in the production and spraying line, the skin and clothing of the worker are contaminated with bitumen and increase the skin distribution exposure. Also, in occupations of polyester and pool users, due to the presence of a layer of bitumen on the polyester layer and the contact of the worker's hands with bitumen, there is less distribution exposure. In rolling, labeling and wrapping there is no exposure to bitumen due to the coating of bitumen with the polyester coatings. The most common exposure to the nine areas of the body is with hands and forearms, and the least is with head and feet. The results of this study indicate that skin transition exposure to liquid bitumen is the highest in material building and caldron use. In skin transition exposure, contact is made by exposure to contaminated surfaces and tools. In material building and caldron use, due to the presence of bitumen on the surface of the reservoir and bitumen pond, the skin and clothing of workers are contaminated and increase the amount of distribution exposure to the skin. The contamination of the work environment and the surfaces can be attributed to this phenomenon. Studies by Dehghan and Liu have also reported contamination levels of contaminants with pollutants as one of the effective factors in the skin exposure of repairers.[31,32] Displacement exposure is done when airborne particles are placed on the skin or working clothes. According to the results of this study, despite not bitumen contamination in rolling and labeling due to the presence of pollutants in the air, there is displacement exposure. The probable and real exposure is in caldron use and material building. The results of this study showed that the arms and legs were the highest and the head, arms and legs had the lowest probable skin exposure score respectively, which matches the studies by Agostini and Riala et al., who evaluated skin exposures in bitumen and roofing makers.[22-31]

According to calculated scores based on DREAM method, the occupations of material building and caldron user are in the middle exposure category, the occupations of the polyester users, the pool users, and the rolling are in the category of low exposure, and the labeling is in the category of very low exposure. The activities that deal with hot compounds seem to be the main contributors to this result.[22] Most of the dermatitis was found in the building materials, caldron users and the users of polyester, which confirms the high level of contamination of these occupations. The results indicate that a small number of workers used protective gloves, and 11.7% of the workers in the study had stated that they used protective gloves during work because of the inconvenience of the glove, hand palpation while using gloves and inappropriate quality of gloves. In other studies, it has also been observed that a limited number of people have used protective gloves, which did not have an acceptable protective effect due to high levels of contamination present in the workplace. Even the most often use of improper gloves can be the same as not to use gloves and cause high exposure.[32,33] In this study, 42 percent of people wash their hands between 0 and 5 times a day, and more than 38.5 percent wash their hands between 5-10 times a day, which due to the high levels of contamination in their occupations, is a relatively low level of hand-washing. The readers of the study found the hand-washing liquid to be the best and most desirable substance for washing the hands which only 34% of people use this material to wash their hands at work.

To reduce the skin exposure of workers in the industry, it is recommended to use non-detachable clothing and standard gloves due to the high contamination of bitumen and high exposure in the building materials and caldron users. Training is always the most important step in familiarizing people with workplace hazards. Therefore, training should be provided by qualified individuals. It is recommended that a training program be developed and implemented on the continued use of protective gloves and work clothes. Furthermore, regular hand wash during work shifts, and the maintenance of the work environment are also recommended.

Conflict of interest

No conflict of interest was reported

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