Semi-Quantitative Dermal Exposure Assessment of Lead with DREAM Model in a Lead Mine in Iran

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ABSTRACT

Occupational exposure to toxic substances occurs in a variety of ways. The DREAM model is suggested for assessing skin exposure using preset values. The purpose of this study is to investigate the exposure of lead in workers at a mine lead using the DREAM model.

This research was done in several steps. First, collect information about people and the work environment. Then design the model in Excel2016 by the authors. This research was descriptive-analytic research and included 46 miners. The DREAM model has a total of 33 variables included. In the DREAM model, exposure assessment was performed for 9 body parts at task level 2.

The DREAM model was completed for 5 jobs. Jobs were in the lab, tunnel-74, tunnel-34, entrance to the tunnel and flotation workshop. The results were calculated for each of the 9 parts of the site for propagation, transfer, deposition, and potential and actual exposures, and eventually total exposures.

The DREAM model, in comparison with similar methods, estimates the skin exposure level in a semi-quantitative fashion. This method has been used to estimate skin exposure in a variety of industries. This method was used to assess the skin exposure of workers in a mine, which resulted in training workers and providing personal protective equipment appropriate to the environment.

Key Words: DREAM MODEL, Dermal Exposure, Lead Mine

INTRODUCTION

In the workplaces exposure to toxic substances may occur through inhalation, ingestion, or dermal route. Occupational hygiene has focused on the inhalation exposure pathway because it was considered to be the most important route of exposure except for exposure to pesticides and several solvents [1]. Many methods have been developed to measure inhalation exposure levels. Exposure by inhalation has been reduced over the years, and some authors have suggested that dermal exposure might be more important [2]. Because measuring exposure to toxic substances is often considered time-consuming, too expensive or impossible, several researchers have evaluated the accuracy of some exposure assessment methods for occupational exposures to chemical agents [3-7]. Validated semi-quantitative occupational dermal exposure assessment methods for a broad range of substances are practically non-existent. Skin exposure to substances may arise in many different ways. The toxic substance can land on or be absorbed into the skin directly from the air. Toxicants may be transferred to the skin from contact with contaminated surfaces or by submersion into the substance. The contaminant may be lost from the skin, by evaporation or some other mechanisms such as washing or abrasion. Protective clothes may affect the rate at which hazardous substances come into contact with the skin. All of these processes are important to the assessment of dermal exposure(8). Ignoring the dermal route for exposure assessment in researches results in imprecise exposure estimates, which may lead to a loss of precision, and attenuation in health risks assessment [2, 9, 10]. Proper assignment of dermal exposure levels in surveys requires knowledge about intensity, exposed surface areas, duration and exposure variability (between tasks, workers, and body location) [2]. Although various accidents and fatalities on dermal absorption of substances have been expressed in literature from the 1880s, dermal exposure assessment is an aborning field of scientific investigations for the twentieth century [11]. During the last decade, dermal exposure assessment has received more attention, and some conceptual model for dermal exposure assessment was developed [12]. In one study a Dermal Exposure Assessment Method (DREAM) was developed, to assess dermal exposures using pre-assigned default values based on a conceptual model for dermal exposure proposed by Schneider *et al.* [12].The method designed for dermal exposure assessment in epidemiological and occupational hygiene surveys. The outcome of this method is a numerical estimate for the dermal exposure level by toxic espoused workers performing certain tasks [13]. DREAM model systematically describes the transport of contaminant mass from exposure sources to the surface of the skin through three main exposure routes: emission, deposition and transfer. Emission involves mass transport of substances by direct release from a source onto skin or clothing, or immersion of hands into a liquid or powder. Deposition on skin or clothing describes mass transport from air. In this case, the contaminant mass is first released into the air and subsequently deposited on skin or clothing. A transfer is defined as the transport of mass from contaminated surfaces onto skin or clothing [14]. The DREAM model has an acceptable accuracy that may be used for specific exposure situations [13, 15, 16]. Lead is a well-studied metal toxicant with no known safe level of exposure [17].Researches show that low lead levels in adults can cause numerous adverse health outcomes, including hypertension, renal injury, cognitive impairments, and reproductive effects [18, 19]. Some research on the reliability of the DREAM model displayed good inter observer agreement [14]. Exposure to lead may also affect children, who can be exposed prenatally or through lead dust carried into the home [20, 21]. The result of these calls is noticeable among the population. Lead affects the functioning of a variety of cells, including those of the nervous system [22], the microvascular endothelium [23], the kidney [24], the immune system [25] and on the male reproductive system [26]. Considering the importance of exposure to lead with skin contact and its harmful effects on the workers and other peoples, the purpose of this study is the investigation of skin exposure to lead in workers in a zinc and lead mine using DREAM model.

MATERIAL AND METHODS

This research was done in several steps:

Initially, information was collected about workers and the workplace. This is descriptive and analytical research that was conducted in a mine in Isfahan province. The population includes 46 miners with a work experience of at least 1 year in the lead and zinc mine. 32 workers in the tunnels (Handling and transporting rocks in tunnels is carried out manually and with cart), and about 14 workers are in the flotation plant.

After identifying needs and collecting data, the DREAM model was designed by the authors in Excel 2016. Key items of the exposure module are the assessment of the probability and intensity of three dermal exposure routes: emission, deposition, and transfer [14, 27]. Fig. 1 summarizes the evaluation model of DREAM so, in total, 33 variables were included in this model. In this research, the Excel file was designed and implemented by the authors. In the DREAM model, exposure assessment for nine different body parts takes place at the task level, assessing both potential dermal exposure (Skin-PTASKBP) and actual dermal exposure estimates (Skin-ATASK.BP). Potential dermal exposure is defined as exposure on clothing and uncovered skin, whereas actual dermal exposure is about exposure on the skin the potential exposure estimate (Skin-PBP) for certain different body parts comprise the sum of dermal exposures due to three different exposure routes: emission (EBP), transfer (TBP) and deposition (DBP).

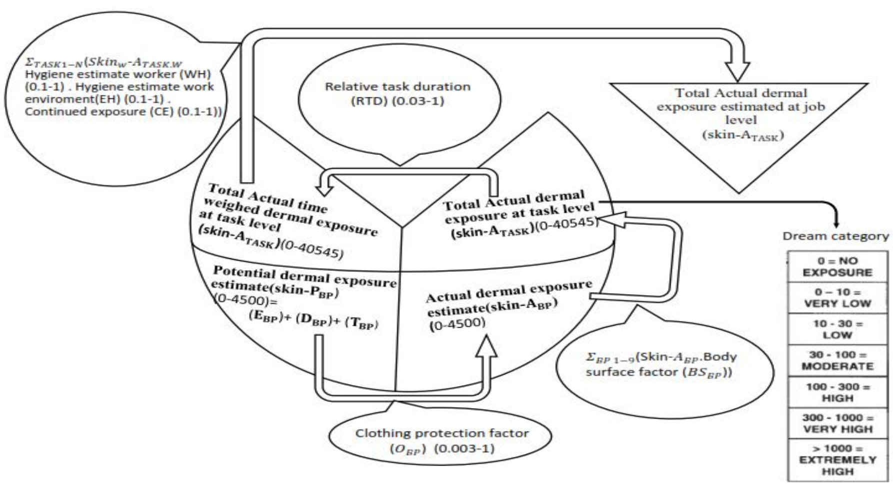

Fig. 1: Summary of the evaluation model of DREAM. Each estimate is determined by a set of underlying variables. The ranges of the estimates are in brackets [14]

Several equations are used in the model that also designed by the researchers in the Excel file (Table1). The formulas used in the DREAM model are given in Table 1. It should also be noted that in this research, Friedman's non-parametric test, correlation analysis and Spearman correlation coefficient tests were used to examine the relationship between DREAM model data.

Table1: equations that are defined in the DREAM model

Row	name	determining factor	Row	name	determining factor
1	$P_{D..BP}$	Probability of deposition on clothing and skin without coating.	14	EV	Vaporization: boiling temperature
2	$I_{E.BP}$	The number of contaminated surfaces in the exposure path.	15	SKIN-A_{BP}	Real skin exposure for every part of the body
3	ER_E	Propagation intensity	16	M	Gloves or special clothing
4	$P_{E.BP}$	Dissemination of clothing and skin without protection; and immersion of skin in contamination.	17	PFM_{HA}	Protection against pollution
5	$I_{T.BP}$	Transfer to clothing and skin without coating in contact with surfaces or tools.	18	GC	Proper attachment of gloves to clothing
6	ER_D	The amount of contaminated surfaces in the exposure path	19	GD	If non-woven gloves are worn during the day
7	$P_{T.BP}$	Deposition intensity in clothing and skin without coating	20	UG	Wear two pairs of gloves
8	$I_{D.BP}$	The amount of contaminated surfaces in the exposure path	21	URF	Replacement frequency of double gloves
9	ER_T	Transmission Intensity: Level of contamination of the contact surface	22	F	Formulation
10	PS	physical state	23	DU	The amount of dust
11	C	Concentration of pollution	24	SS	Moisture / Wet Wax (non-powder and non-dust solids)
12	RF	Frequency replacement of gloves and work clothes	25	SKIN-P_{TASK}	Potential skin exposure (total)
13	BC	Sunscreen is used	26	SKIN-A_{TASK}	actual skin exposure (total)

RESULTS

The DREAM model was conducted for five jobs, each of which was divided into five occupations: laboratory manager, tunnel extractor 74, tunnel worker 34, tunnel entrance and flotation workshop; the results of each of the jobs were calculated individually. Based on the calculations given in Fig. 1, the Excel file is designed for the model and the results are presented in the following tables. The parameters described in Table 1 for the 9 parts of the body, including the head, chest, arms, hands, abdomen, waist, thighs, legs, ankles, and, finally, the whole body, are arranged in five tables, respectively release, sediment, transfer, potential exposure skin and actual exposure skin are calculated with two statistical parameters, mean and median.

Table 2 shows the mean and median values of emission for 9 parts of the body for every five jobs and mean and median values of deposition and transfer in 9 parts of the body have been shown in Tables 3 and 4.

After determining the factors to emission, deposition and transfer, potential and actual dermal exposure were obtained for 9 parts of the body (Tables 5 and 6).

Table2: Statistical parameters for emission in 9 parts of the body for each job.

Task	Statistic parameter	Head	Upper arms	Forearms	Hands	Torso front	Torso back	lower body part	lower legs	Feet	Total Emission
*lab	Mean	24.3	.0	24.3	24.3	.0	.0	.0	.0	.0	72.9
	Median	24.3	.0	24.3	24.3	.0	.0	.0	.	.0	72.9
*T-74	Mean	21.87	2.43	7.29	2.87	.0	.0	.0	.0	7.29	60.75
	Median	21.87	2.43	7.29	2.87	.0	.0	.0	.0	7.29	60.75
*T-34	Mean	24.3	8.1	24.3	240.3	8.1	8.1	8.1	8.1	24.3	575.1
	Median	24.3	8.1	24.3	240.3	8.1	8.1	8.1	8.1	24.3	575.1
*ET	Mean	24.3	.81	2.34	7.29	.81	.81	.0	.00	2.34	38.88
	Median	24.3	.81	2.34	7.29	.81	.81	.0	.0	2.34	38.88
*F	Mean	2.7	.0	2.7	2.7	.0	.0	.0	.	.0	8.1
	Median	2.7	.0	2.7	2.7	.0	.0	0	.0	.0	8.10

*lab= laboratory/ T-74= tunnel -74/T-34= tunnel -34/ TE= tunnel entrance/F= flotation workshop

Table 3: Statistical parameters for deposition in 9 parts of the body for each job

Task	Statistic parameter	Head	Upper arms	Fore arms	Hands	Torso front	Torso back	lower body part	lower legs	Feet	Total Emission
*lab	Mean	8.1	.0	.0	24.3	.0	.0	.0	.0	.0	32.24
	Median	8.1	.0	.0	24.3	.0	.0	.	.0	.0	32.24
*T-74	Mean	7.29	.81	.81	7.29	.0	.0	.0	.0	.81	17.01
	Median	7.29	.81	.81	7.29	.0	.0	.0	.0	.81	17.01
*T-34	Mean	81.	2.7	2.7	81	2.7	2.7	2.7	2.7	2.7	180.9
	Median	81.	2.7	2.7	81	2.7	2.7	2.7	2.7	2.7	180.9
*ET	Mean	8.1	.27	.27	2.34	.27	.27	.0	.	.27	11.88
	Median	8.1	.27	.27	2.34	.27	.27	.0	.0	.27	11.88
*F	Mean	.9	.0	.0	2.7	.0	.0	.0	.0	.0	3.6
	Median	.9	.0	.0	2.7	.0	.0	.0	.0	.0	3.6

*lab= laboratory/ T-74= tunnel -74/T-34= tunnel -34/ TE= tunnel entrance/F= flotation workshop

Table 4: Statistical parameters for transfer in 9 parts of body for each job

Task	Statistic parameter	Head	Upper arms	Fore arms	Hands	Torso front	Torso back	lower body part	lower legs	Feet	Total Emission
***lab**	Mean	8.1	.0	.0	24.3	.0	.0	.0	.0	.0	32.24
	Median	8.1	.0	.0	24.3	.0	.0	.0	.0	.0	32.24
***T-74**	Mean	7.29	.81	.81	7.29	.0	.0	.0	.0	.81	17.01
	Median	7.29	.81	.81	7.29	.0	.0	.0	.0	.81	17.01
***T-34**	Mean	24.3	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	124.2
	Median	24.3	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	124.2
***ET**	Mean	8.1	.27	.27	2.34	.27	.27	.0	.0	.27	11.88
	Median	8.1	.27	.27	2.34	.27	.27	.0	.0	.27	11.88
***F**	Mean	.9	.0	.0	2.7	.0	.0	.0	.0	.0	3.6
	Median	.9	.0	.0	2.7	.0	.0	.0	.0	.0	3.6

*lab= laboratory/ T-74= tunnel -74/T-34= tunnel -34/ TE= tunnel entrance/F= flotation workshop

Table 5: Mean and median of potential dermal exposure for 9 different parts of body

Task	Statistic parameter	Head	Upper arms	Fore arms	Hands	Torso front	Torso back	lower body part	lower legs	Feet	Total Emission
***lab**	Mean	40.5	.0	24.3	72.5	.0	.0	.0	.0	.0	137.7
	Median	40.5	.0	24.3	72.5	.0	.0	.0	.0	.0	137.7
***T-74**	Mean	36.45	4.05	8.91	36.45	.0	.0	.0	.0	8.91	85.86
	Median	36.45	4.05	8.91	36.45	.0	.0	.0	.0	8.91	85.86
***T-34**	Mean	318.3	13.5	29.7	405	13.5	13.5	13.5	13.5	29.7	850.5
	Median	318.3	13.5	29.7	405	13.5	13.5	13.5	13.5	29.7	850.5
***ET**	Mean	40.5	1.35	2.97	12.15	1.35	1.35	.0	.0	2.97	59.67
	Median	40.5	1.35	2.97	12.15	1.35	1.35	.0	.0	2.97	59.67
***F**	Mean	4.5	.0	2.7	8.1	.0	.0	.0	.0	.0	15.3
	Median	4.5	.0	2.7	8.1	.0	.0	.0	.0	.0	15.3

*lab= laboratory/ T-74= tunnel -74/T-34= tunnel -34/ TE= tunnel entrance/F= flotation workshop

Table 6: Mean and median values of actual dermal exposure for 9 different parts of body

Task	Statistic parameter	Head	Upper arms	Fore arms	Hands	Torso front	Torso back	lower body part	lower legs	Feet	Total Emission
***lab**	Mean	12.15	.0	7.29	65.61	.0	.0	.0	.0	.0	85.5
	Median	12.15	.00	7.29	65.61	.00	.0	.0	.0	.0	85.5
***T-74**	Mean	10.93	.405	2.673	295.24	.0	.0	.0	.0	.2673	309.53
	Median	10.93	.405	2.673	295.24	.0	.0	.0	.0	.2673	309.53
***T-34**	Mean	104.49	1.35	8.91	1093.5	1.35	13.5	13.5	13.5	.891	1214.5
	Median	104.4	1.35	8.91	1093.5	1.35	13.5	13.5	13.5	.891	1214.5
***ET**	Mean	12.15	.135	.891	98.415	.135	.135	.0	.0	.0891	111.95
	Median	12.15	.135	.891	98.415	.135	.135	.0	.0	.0891	111.95
***F**	Mean	1.3	.0	.81	21.87	.0	.0	.0	.0	.0	24.068
	Median	1.3	.0	.81	21.87	.0	.0	.0	.0	.0	24.03

*lab= laboratory/ T-74= tunnel -74/T-34= tunnel -34/ TE= tunnel entrance/F= flotation workshop

Ranking of total potential and actual dermal exposure in 5 states (low, moderate, high, very high, extremely high) were shown in Table 7.

Table7: Ranking of actual dermal exposure

Rank rate	Number	Percent
Low	7	15.2
Moderate	2	4.3
High	6	13.0
Very high	17	37.0
Extremely high	14	30.4

DISCUSSION

In this paper, a semi-quantitative method for assessing skin exposure(DREAM) has been used [12] and values to exposure variables determined according to an approach described by Cherrie *et al.* [5].Due to the lack of articles that have been studied in this field and the lack of relevant articles as well as the discrepancy between the evaluations of other articles in the present study, there are few sources to study this study.

In this research as can be seen in Table 3, the highest average of emission in the laboratory job is for head (24), Forearms (24) and Hands (24).In fact, in the other parts of the body emission factor was not important to lead exposure in this section.In 34th floor, the highest value was for the head (21.87) and then forearms and feet (7.29)because when pushing a wagon, some soil is spilt on the shoes and chest and head of these people. In the drill job (74th tunnel), the highest average of emission is related to the hands because most of the exposure is by contact with the shovel. In tunnel bumps (tunnel entry) most exposures in emission were for the head because they do not use a helmet or other head protection equipment's. In the flotation area, exposure with emission is lowest, because the job is in an open area and the person's exposure to the pollutant is minimal. The estimated exposure in deposition state for different mine jobs have been shown in Table4. In the lab, the highest average exposure estimate was for hands (24.3) is head (8.1), and the rest of the body has no exposure. On the 34th and 74th floor, the most exposure estimate is for the head and arms (7.29).The most exposure estimate concerning deposition in the entrance to the tunnel is to head (8.1). In the flotation, the estimated exposure was to the hands (2.7) and head (0.9), and the rest of the parts were almost unexposed. The exposure estimate for transfer in the various mine jobs is shown in table5.

in the lab, the highest average exposure estimate was for hands (24.3).On the 34th floor, the highest estimate of exposure is for the head and hands(7.29)also, on the 74th floor, the highest value was to head(24.3) and the other parts of the body have had equal levels of exposure. In the entrance to the tunnel, the most exposed area was head (8.1), and in the flotation, hands exposure was more important. Comparison of Tables 4 and 5 indicated that the estimated values for deposition and transition are very similar to each other. Non-parametric test of Friedman also shows a significant relationship between the components of each of the formulas of deposition and transition (p-value <0.001). It can be well understood that the role of sedimentation of lead on the surface of the skin and transfer of it on the skin is very close together. Table 6 is about the potential dermal exposure values and as shown in Fig. 1, this parameter is a combination of emission, Deposition and Transfer. For laboratory job, the highest estimates of exposure were for the hands (72.5), forearm (24.3) and head (40.5). For workers in the 34th class, the greatest amount of exposure was found for the head and arms (36.45), then the forearm (29.7), the legs (8.91) and the arms (4.05) were involved. On the 74th floor, the most potential dermal exposure was for the head (318.3), arms (405), then the legs and forearms (29.7) and for the entrance tunnel, these value was 40.5 for head and 12.5 for arms. In the flotation plant, the greatest amount of potential dermal exposure was estimated for the hands (8.1), head (4.5) and forearm (2.7). Table 7 shows the Actual dermal exposure for a different part of the body. As shown in Fig. 1, the actual exposure of the skin is extracted from the potential dermal exposure. In the lab, the highest values are for the hands (65.61) head (12.15) and forearm (7.29). In the34th and 74th tunnel, estimation of skin exposure was 295.245 and 1093.5 for the hands and 10.94 and 104.49 for head respectively. At the entrance to the mine tunnel, the hands (98.41) had the highest Actual dermal exposure that followed by the head (12.15) and forearm (0.891). In the flotation area, the hands (21.87), head (1.3) and forearms (0.81) have been showing the highest scores of estimations.

In general, little research has been done on the DREAM model and in none of these, skin exposure to lead and determining the effect of the parameters of the DREAM was not investigated, therefore, the present manuscript has an innovation. B. Baharuddin *et al.* show that the dermal exposure of respondents that used manually operated spraying equipment was found to be moderate to high while respondents using motorized sprayers came under the very low to moderate exposure category. No respondents using either type of spraying equipment fell in the very high exposure category [27].

In the study, the divisions are divided into five categories, from low to extremely high, as you can see in Table 8. In Actual skin exposure, the most estimated values are very high and the lowest is moderate.

In a study by Luis E. Blanco *et al*., Dermal Exposure Ranking Method (DERM) was developed to estimates skin exposure in two transport factors. The transport factor in 3 transfer, deposition, and emission categories is under the DREAM definitions [28].Camilo Lesmes Fabian *et al.* in one research, investigate on dermal exposure assessment to pesticides in agricultural systems in developing countries and DREAM was found to be an appropriate model [29].

CONCLUSION

DREAM is a flexible model that can be used for dermal exposure characterization for all kinds of scenario and because of its hierarchical structure, it takes on average 15–30 min only to assess exposure for one person carrying out one task(30). According to the present study, the DREAM is a simple and inexpensive model which is well suited to investigate exposure to lead in the mine, however, there are still some important determinants that can improve the accuracy. In addition to the benefits of this mode, DREAM, like many of the other developed models, has some limitations. Since limited knowledge's available on dermal exposure determinants, the data to developing of the model is based on hypothetical assumptions. This model assesses exposure at a task level and the observer determining which activities comprise tasks. According to the results of this study, it is suggested that exposed workers should use hand protection and other personal protective equipment's, as well as how to use it correctly. Because the greatest exposures in three modes were for hands

ETHICAL ISSUES

Ethical issues including plagiarism double publication and/or submission, redundancy, etc. have been completely observed by the authors.

CONFLICT OF INTEREST

The authors have declared that no competing interest exists.

AUTHORS' CONTRIBUTIONS

All authors equally participated in drafting, revising and approving of the manuscript.

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