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ORIGINAL ARTICLE

Semi-quantitative Respiratory Health Risk Assessment of Exposure to Metalworking Fluids (Oil Mists) in an Automotive Industry

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KEYWORDS

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ABSTRACT: Metalworking fluids are used in many industries, especially those with metalworking processes. Despite their widespread use, these compounds have harmful effects on human health. Therefore, this study aimed to assess the semi-quantitative health risks of oil mists in the automotive industry. In this study, ACGIH, IARC indexes, LD50, and the risk of corrosion were used to determine the hazard rate, with the biggest index serving as the hazard rate's base. The actual exposure level was used to compute the exposure rate. Sampling and determination of oil mists were performed according to NIOSH 5026 method and using a membrane filter (37-mm). All risk rates of oil mists were in the high-risk range (H). The hazard rate level for all oil mists was equal to 4. The exposure rate for all oil mists except one of them was equal to 4. Considering the health risks identified in this study, it can be concluded that lathe workers in the automotive industries have a high risk in terms of metalworking fluids exposure.

INTRODUCTION

Today, various industries are looking for progress in all aspects of work, and their economic situation is a significant factor in this. These industries use all available material and human resources to their full potential to increase economic growth. Full-time use of available resources at total capacity is highly regarded in many industries, including metalworking processes. In metalworking processes, equipment is constantly used to increase the number of products. High efficiency in metalworking equipment is primarily linked to high cutting conditions (cutting speed and depth) and feed rate [1, 2]. Meanwhile, metalworking fluids (MWFs) were utilized to mitigate damage to the machine's equipment at the operating points, reduce wear and heat, and wash the chips, particles, and contaminants [3]. MWFs are utilized to clean metal parts, extend the useful life of cutting tools, and prevent corrosion [4].

MWFs that are crucial in the metalworking processes are also known as Cutting fluids, machining fluids, and Metalworking coolants [5, 6]. These fluids are widely used in conventional machining due to their particular applications and costs for cooling and lubricating workpieces, cleaning metal chips, and preventing rusting of tools and parts used [7-10]. Based on their structure, these

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fluids can be categorized into the three categories listed below:

1. Straight cutting fluids (mineral oil, without water)
2. Soluble cutting fluids (mineral oil emulsified in water)
3. Synthetic cutting fluids (water with soluble compounds, without mineral oil) [11]

MWFs are splashed at high or medium pressure or as a spray for the specimen [12]. Through this splashing (mainly through skin contact and respiration), these fluids can adversely affect the health of lathe operators and the environment [13]. Despite their prevalent use in machining operations, these fluids are widely regarded as one of the most severe health risks to lathe operators [14, 15]. The ingredients of these fluids may change over time, resulting in microbial, fungal, and bacterial contamination and growth [7, 12, 16]. Improper use and disposal of these fluids can worsen their destructive effects [17]. The International Agency for Research on Cancer (IARC) has assessed the risk of carcinogenicity due to exposure to semi-refined MWFs as Group A2 [18].

When these fluids are used, harmful particles known as sub-micron oil mist particles may be emitted [9]. These particles are microscale airborne oil droplets produced by fast-moving machine segments and the condensation of evaporated oil ingredients [19]. These harmful particles are produced by variables such as impaction, centrifugal force, and vaporization/compression [10]. Oil mists are released as aerosols with diameters ranging from 0.1 to 1 µm [20]. According to the recognition of the American Conference of Governmental Industrial Hygienists (ACGIH), concentrations of oil mists over 5 mg $m^{3-1}$are dangerous for employees' bodies in the workplace [21]. This agency has proposed 5 mg m^{3-1} for refined oils, but due to the suspicion that unrefined oils are carcinogenic, it has been stated that the amount of exposure to them should be controlled as much as possible [22]. These particles enter the body easily via inhalation and are then absorbed in various directions [9]. The creation and distribution of oil mists in the industrial environment cause various respiratory diseases [23]. Skin and respiratory troubles were caused by occupational exposure to these particles in those exposed [21].

According to the National Institute for Occupational Safety and Health (NIOSH), exposure to MWFs enhances the chance of cancer in some regions of the body (pancreas, rectum, larynx, scrotum, bladder, and skin) [10]. Dermatitis, respiratory problems, and higher mortality from various diseases are all risks connected with cutting fluids [6, 24].

Whereas many lathe operators have been exposed to these fluids every year and the adverse effects of these compounds [12], it is vital to take the appropriate precautions to detect and assess the risk of these compounds. To date, no studies have been performed to evaluate the health risk of oil mists. As a result, this study aimed to assess the semi-quantitative health risks of oil mists caused by MWFs in one of the automotive industries in Tehran.

MATERIALS AND METHODS

Sampling sites

This cross-sectional study was conducted in one of Tehran's automotive industries. In this automotive industry, the two main halls of machining and gear cutting were selected for research. These halls were composed of different sections. to estimate the exposure of lathe operators to oil mists in the two halls, 33 male lathe operators in the machining hall (in Nissan block machining sections, Tiba block machining, Pride cylinder head machining, and Camshaft machining) and 32 male lathe operators in the gear cutting hall (in section Shaft gear and main and secondary gears) participated. Sampling was performed for two weeks, from September 6 to September 20, 2020. In addition, demographic and job-related information was collected.

Environmental monitoring

In this study, personal sampling was performed in the respiratory area of the lathe operators. The NIOSH standard method (NIOSH 5026) was used for exposure monitoring of oil mists [25]. Personal sampling was done in time intervals with direct exposure to oil mists. Finally, a weight/time average for each lathe operator was calculated. The samples were collected by a personal sampling pump (SKC Model EX8 PC-2) at 2 L Min^{-1} flow rate with a Membrane filter with a 37-mm diameter for 8 hours.

Analytical method

Based on NIOSH 5026 analytical standard method, six standard concentrations of 5, 10, 50, 100, 200 and 250 ppm were prepared to draw the standard curve with sufficient accuracy in the range of 0.1 to 2.5 mg per sample. To recover the unknown sample, 10 ml of carbon tetrachloride was added to the samples, and the samples were placed in a shaker for 20 minutes. To analyze the samples collected in the membrane filter, The FT-IR device (Rayleigh, WQF-510A) was used at 3200-2700 nm.

Risk assessment

This study is carried out by the following steps to assess the health-related risk of lathe operators working in the automotive industry in Tehran based on a semi-quantitative chemical risk assessment conducted by Singapore's Ministry of Health and Occupational Safety (Figure 1) [26]:

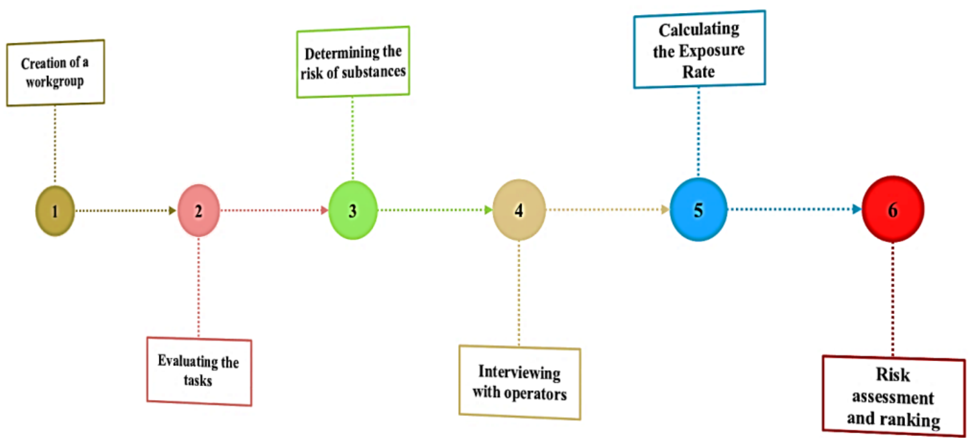

Figure 1. Risk assessment steps.

In the first step, a working group consisting of two occupational health experts, three experienced lathe operators, and one person as a management representative was formed. Then, work processes, sampling approaches, and risk assessment methods were reviewed. In the second step, all of the tasks of the lathe operators in different areas were evaluated. The risk of oil mists was determined in the third step based on the risk of toxicity and/or carcinogenicity. This risk can be estimated in two ways:

1. Through the toxic or deleterious impacts of chemicals (Table 1 of Singapore’s semi-quantitative Risk Assessment Method)
2. In terms of acute chemical toxicity using LD50 and LC50 (Table 1A of Singapore's semi-quantitative Risk Assessment Method)

Lathe operators from different sectors were interviewed in the fourth step. During this interview, questions about working conditions and duties were asked to assess the amount, frequency, route, and length of exposure to oil mists. The Exposure Rating (ER) of the lathe operators was calculated in the fifth step. The ER can be estimated in two ways:

1. Using the Actual level of exposure

When the results of oil mist concentration measurements are accessible, the average weekly exposure can be calculated using equation 1:

$$E = \frac{F \times D \times M}{W} \quad (1)$$

Where:

E: The weekly exposure to each oil mists (ppm or mg m^{3-1})

W: The average hours worked per week (40 hours)

D: The average time of exposure to oil mists (hour)

F: The exposures frequency in a week (dimensionless)

M: The concentration of exposure to the oil mists (ppm or mg m^{3-1})

The ER can then be calculated using table 2 of Singapore's semi-quantitative Risk Assessment Method after estimating the average exposure to oil mists and the ratio of weekly exposure to permissible exposure limit (E/ PEL).

2. Using the Exposure Index (EI)

The ER can be calculated using equation 2 utilizing the Exposure Index (EI) without air monitoring results. In this case, the EI should be calculated based on an accurate assessment of the working conditions.

$$ER = [EI_1 \times EI_2 \times \ldots \times EI_n]^{\frac{1}{n}} \qquad (2)$$

Where:

n: The number of exposure factors used

The EI is calculated according to a rating from one to five according to Singapore's semi-quantitative Risk Assessment Method. In the sixth step, the risk is assessed using equation 3 and ranked according to Figure 2.

$$RR = \sqrt{HR \times ER} \qquad (3)$$

Where:

RR: Risk Rate

HR: Hazard Rating

ER: Exposure Rating

Risk Prioritization Matrix

5	4	3	2	1	HR / ER
2.2	2	1.7	1.4	1	1
3.2	2.8	2.4	2	1.4	2
3.9	3.5	3	2.4	1.7	3
4.5	4	3.5	2.8	2	4
5	4.5	3.9	3.2	2.2	5

Risk Level
Negligible
Low
Medium
High
Very High

Figure 2. Risk Prioritization Matrix According to Hazard and Exposure Rate of Every Chemical Substance.

In this research, carcinogenic ACGIH, IARC indexes, LD50, and the risk of corrosion, were used to determine the hazard rate. The actual exposure level was used to compute the ER according to the measurement and availability of oil mist concentrations. In the final step, the risk of oil mists was calculated and ranked according to equation 3 and Figure 2.

RESULTS

Table 1 provides some information about the two halls studied. Also, in Table 2, the exposure rate of lathe operators with different oil mists is presented in different sections of the two halls studied. Figure 3 compares The 8 hours of time-weighted average (C_{TWA}) of oil mists.

Table 1. Workplace Environment Information.

Hall	Ventilation		Amount of material consumed per week	Hall volume	Ventilation rate	Exposure time (hr)
	General	Local	(L week^{-1})	(m^3)	M^3 min^{-1}	
Nissan block machining		■	208	34560	8640	6.5
Tiba block machining			208			6.5
Pride cylinder head machining and Camshaft machining		■	520			6.5
Shaft gear	■	■	7979	32832	8208	6.5
main and secondary gears	■	■	7979			6.5

Table 2. Estimated values of average concentrations, weekly exposure rate, E/PEL ratio, exposure rate, and risk assessed for oil mists by type of mists and their used locations.

Mist type	The main hall	Sub-hall	number of samples	Average concentration (mg m$^{3-1}$)	E (mg m$^{3-1}$)	E/PEL	ER	RR
8402-ZetCut	Machining hall	Nissan block machining section	11	9.72863 ± 3.552	6.4224	1.2844	4	4
8402-ZetCut		Tiba block machining section	8	9.92335 ± 3.710	6.5509	1.3101	4	4
8402-ZetCut		Camshaft machining	8	9.52247 ± 0	6.2863	1.2572	4	4
SARAD		Pride cylinder head machining	7	7.80455 ± 2.643	5.1522	1.0304	4	4
Rock water		Camshaft machining	8	7.69362 ± 3.045	5.0789	1.0157	4	4
8402-ZetCut	Gear cutting hall	Shaft gear	11	6.99369 ± 3.552	4.61692	0.9233	3	3.5
8402-ZetCut		Main gear	8	7.99675 ± 0.480	5.2791	1.0558	4	4
8402-ZetCut		Secondary gear	5	9.7037 ± 0.611	6.4059	1.2811	4	4
Oil		Secondary gear	5	9.83032 ± 1.078	6.4895	1.2979	4	4
Oil		Main gear	8	9.9688 ± 2.00	6.5809	1.3161	4	4
Oil		Shaft gear	11	10.18318 ± 0.885	6.7224	1.3444	4	4
Rock water		Main gear	8	11.59036 ± 0	7.6514	1.5302	4	4

Abbreviations: E=The weekly exposure; E/PEL=The ratio of weekly exposure to permissible exposure limit; ER=Exposure Rating; RR=Risk Rate.

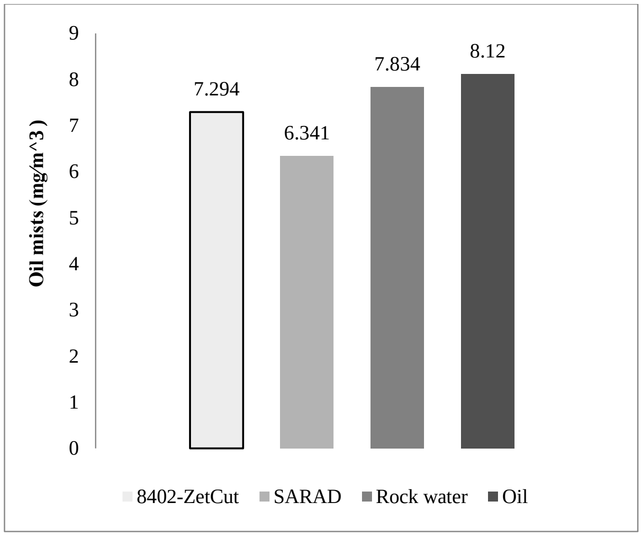

Figure 3. The 8-hours, time-weighted-average concentration of oil mists (mg m^{3-1})

According to Table 1, the highest consumption of cutting fluids was related to the gear cutting hall with 15958 liters per week. Also, the status of the ventilation system of the machining hall was worse than that of the gear hall. According to Table 2, the average concentration of oil mists was 6.993 –11.590 mg m^{3-1}. The highest average concentrations of rock water, 8402-ZetCut, and Oil mist were observed in the main gear, Tiba block, and Shaft gear, respectively. SARAD mist was used only in Pride cylinder head machining. The average exposure concentration of lathing workers to SARAD mist was 7.80455 ± 2.643 mg m^{3-1}. This table also presents the weekly exposure to concentration (E) of oil mists based on Equation 1. The highest rate of E was related to rock water mist in the main gear section. According to Figure 3, the C_{TWA} of oil mists was in the range of 8.12 to 6.34 mg m^{3-1}. The highest C_{TWA} was for Oil mist.

According to the carcinogenicity indices of ACGIH and IARC and LD50 of oil mists, the HR level was 4. ER values were also calculated according to Table 2 of the Singapore semi-quantitative risk assessment method. The Risk Rate (RR) of oil mists was calculated according to equation 3 and was included in this table. All RRs of oil mists were in the high-risk range. Therefore, to reduce the risks of oil mists, suggestions were made to control and minimize the hazards to the allowable level.

DISCUSSION

Given that no study has been conducted to assess the risk of exposure to metalworking fluids, this study aimed to assess the semi-quantitative respiratory health risks of oil mists (MWFs) in one of the automotive industries in Tehran.

Two main halls of machining and gear cutting and four oil veils of mists were selected for the study. The C_{TWA} of oil mists in the two main halls was in the range of 8.12 to 6.34 mg m^{3-1}. All evaluated C_{TWA} values for oil mists were above the allowable level provided by Occupational Safety and Health Administration (OSHA), ACGIH, and NIOSH (> 5 mg m^{3-1}). The highest E value was related to the main gear section, and the lowest was related to the shaft gear section. In contrast to the findings of this study, Workers' exposure to oil mists in 44 sites out of 25 machining factories was less than the allowable limits provided by NIOSH, OSHA, and ACGIH (0.02 to 0.89 mg m^{3-1}) [27]. In addition, Verma et al. conducted a cross-sectional investigation in four workplaces with machining processes and found that exposure to MWFs in the air ranged from 0.04 to 3.84 mg m^{3-1} [4]. Furthermore, According to the findings of a cross-sectional study conducted by Park et al. in an Automotive Ring Manufacturing Plant in Korea, 82.4 percent of grinding and manufacturing workers sampled were exposed to MWF mists at levels greater than 0.2 mg m^{3-1}[28]. Various reasons such as the amount and manner of MWFs consumption and inadequate working conditions such as poor ventilation of the halls and the proximity of the halls to each other might be the factors that have caused the exposure of lathe operators to be higher than the allowable exposure limit.

Health risk assessment of oil mists revealed that all oil mists are in the high-risk group. The high average concentration of oil mists has been one of the main reasons for placing all oil mists in the group with high health risks for lathe operators. Despite the low weekly consumption of MWFs in the machining hall, the average concentration of oil mists in this hall was as high as in the gear cutting hall. The high average concentration of oil mists can happen due to poor ventilation and the proximity of this hall to the gear cutting hall, which has caused this hall to be in the high-risk group. Therefore, the harmful nature of the ingredients of oil mists and the exposure to the high average concentration of oil mists were among the main reasons for placing these compounds in the high health risk group.

Several chemicals have been evaluated for health risk due to their detrimental effects on workers' health [29-31], while no studies have been performed to evaluate the health risks of oil mists. Oil mists have adverse effects on human health due to several harmful substances in their structure. [32]. Therefore, the risk assessment of oil mists was performed according to the Singapore semi-quantitative risk assessment method. Finally, to reduce the exposure of lathe operators, recommendations such as checking the parameters of the ventilation system, and redesigning and using ventilation systems in some parts of the factory are recommended as necessary to reduce these risks.

CONCLUSIONS

Exposure to various types of oil mist, including the mist evaluated in this study, has adverse effects on the health of people exposed to them, including lathe operators. In this study, C_{TWA} values for different types of oil mists were higher than the allowable limits provided by ACGIH. In addition, according to the HR and ER values obtained for different types of oil mists in the Singapore semi-quantitative health risk assessment method, all oil mists were placed in the high-risk group. Therefore, appropriate control measures must be taken. It is also recommended for all researchers to do more research in this field in different industries.

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Conflict of interest

The authors declare that there is no conflict of interest.

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