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ENVIRONMENTAL MONITORING OF OCCUPATIONAL EXPOSURE TO ORGANIC SOLVENTS IN CHEMICAL LABORATORIES

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ABSTRACT:

Introduction: The vapor of some reagents and organic solvents are the major agents of indoor pollution in chemical laboratories. Therefore students and technicians who work in these polluted places are exposed to high concentrations of these kinds of VOCs. Chloroform, dichloromethane, carbon tetrachloride are applied in laboratories as chemical solvents. Since mentioned compounds have various side effects, personal exposure of these VOCs should be monitored.

Materials and methods: In this study, personal exposure to chlorinated organic solvents in breathing zone of chemical laboratory technicians and students were monitored by diffusive personal samplers. After exposure, the chemical substances collected on sorbing cartridges were desorbed and analyzed by GC/MS.

Results: The mean values of chloroform in breathing zone of all groups were significantly greater than two other organic solvents. Moreover carbon tetrachloride had the least concentration. The mean values for exposure of chlorinated organic solvents in breathing zone of occupationally exposed groups were significantly greater than the occupationally non-exposed groups but below the 2000 ACGIH TLV. Significant differences were indicated in three studied groups monitoring for chloroform and dichloromethane ($P_{value} < 0.05$).

Conclusions: From the results of this pilot study, it seems that indoor air in chemical laboratories of universities is in the acceptable condition. It should be noted that chronic exposure to these compounds in occupational environments is justified enough to monitor the VOCs continually.

INTRODUCTION

Volatile organic compounds (VOCs) include a diversity of chemicals which are emitted from some solids or liquids. The higher concentrations of some of these compounds in indoor in comparison with outdoor are observed. Organic solvents are the major class of VOCs and are emitted from paints, wax, cleaning products, fuels, degreasing products [1]. Since health effects of VOCs in populations with high level exposure are well-known, the study of these compounds has been an important topic in occupational epidemiol-

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ogy [2-6]. Exposure of these compounds causes to irritation of eyes, nose, and nerve toxicity at low concentrations [7,8] and irritation of lower respiratory airways, asthma, and nasopharyngeal cancer, myeloid leukemia at high concentration, with long term exposure [9-13]. Monitoring of the above mentioned compounds in schools of Kardzhali, Bulgaria demonstrated the greater concentrations of these compounds in indoor environments in comparison with outdoor environments. The emission sources can be various in closed environments regarding the difference in indoor and outdoor air exchange [14]. Workers in occupational sites have been exposed to chemical point and non-point sources [15].

The vapor of some reagents and solvents in chemical laboratories containing VOCs, causes indoor pollution. Therefore students or technicians who work in these polluted places are exposed to high concentrations of these kind of VOCs [16]. Chloroform is a common solvent in chemical laboratories and also is used as a solvent for lacquers; in waxes, oils, and also as an industrial solvent in photography and dry-cleaning. According to research, the concentration range of chloroform from 0.1 to 10 μg/m^3 was detected in atmosphere and the concentrations between 1.0 to 20.0 μg/m^3 was found in indoor air (ATSDR 1997). Threshold limit value-Time weighted average limit (TLV-TWA) for chloroform is equal to 10 ppm according to American Conference of Governmental and Industrial Hygienists (ACGIH) guidelines. In addition according to National Institute of Occupational Safety and Health (NIOSH) guidelines short – term exposure limit (STEL) is equal to 2 ppm (9.78 mg/m^3) for 60 min exposure [17]. Methylene chloride or dichloromethane is another high used organic solvent in chemical laboratories and in paint and coating removal products. The short-term inhalation of this compound results to nervous system effects including decreased visual, auditory, and motor functions. According to ACGIH guidelines TLV for dichloromethane is equal to 174 mg/m^3, and based on Occupational Saftey and Health Administration Permissible Exposure Limit (OSHA PEL), it is equal to 88 mg/m^3 [18, 19].

Short-term inhalation of carbon tetrachloride which rarely is applied in organic synthesis causes headache, weakness, lethargy, nausea, and vomiting. Long-term and high level inhalation of this compound causes liver and kidney damage in human. It has been announced the number of 31 mg/m^3, and 63 mg/m^3 by ACGIH and OSHA respectively [20].

In this study, personal exposure to organic solvents, including chloroform, tetrachloride, and dichloromethane, was measured in laboratory technicians and students who were working on their thesis. To our knowledge, there is no report about environmental monitoring of occupational exposure to organic solvents in chemical laboratories.

MATERIALS AND METHODS

Study population

The study population includes 40 healthy and nonsmoker male technicians of chemical laboratories in some universities of Tehran, Iran and also 40 students who worked in mentioned laboratories. All of subjects were between 20-43 (mean 29) years old and were requested to wear plastic gloves in their shift work in order to protect dermal exposure to chemical compounds. In addition, 40 non-exposed men from same universities were selected as the reference group.

Analysis process

Radiello passive samplers were installed on clothes of technicians and students with 10 cm distance from their face while their working. Chemical compounds collected by cartridge, were desorbed by 2 ml of benzene free CS_2 for about 30 min , then 1,2-dichloromethane-d4 was added as the internal standard to solution. Analysis was performed by GC-MS (Agilent 6890) equipped with a 5973 mass selective detector quadrupole mass spectrometer. An HP-1 MS column) 60m; 0.25 mm i.d; 0.25 mm film thickness) was ap-

plied. Temperature conditions for the monitoring instrument were as follow:

Injector temperature: 250 ° C; initial oven temperature: 40 ° C (hold for 10 min), increased to 90 ° C at a rate of 10 ° C 1/min, hold for 3 min, then to 120° C at 20° C , hold 2 min, then to 160 ° C at 30° C 1/min, (final temperature 2 min hold). The inlet was operated in splitless mode. The acquisition mode was SIM. Limit of quantification (LOQ) was 1 µg/L for all the analytes. Air concentration (µg/m^3) was calculated by Eq. (1):

$$\text{Conc.}(\mu g/m^3) = \frac{m(\mu g)*1000}{Q\left(\frac{L}{\min}\right)*t(\min)} \quad (1)$$

Where 'm 'shows mass of analytes determined in desorbing solvent

'Q 'means uptake rate of substances (75 mL/min for chloroform; 59 mL/min for carbon tetrachloride; 90 mL/min for dichloromethane)

"t" shows exposure time [21]

Statistics

The mean value of environmental measurements among three groups (40 laboratory technicians, and 40 students and 40 occupationally non-exposed persons) were analyzed and since the data distribution was not normal; the analysis was carried out by means of two statistical procedures: analysis of variance (one way ANOVA) followed by scheff's post hoc test and Kruskal-Wallis test. Results were expressed as mean ± S.E and 95% confidence intervals. The level of significance was set to 0.05 and $P_{values} > 0.05$ were assumed to be nonsignificant.

RESULTS AND DISCUSSION

Chlorinated organic solvents are found in solvent-based paints, maintenance and cleaning products, heating and air conditioning plants [22]. These solvents are used for extraction and purification of many organic synthetic compound, antibiotics, vitamins, alkaloids and also is found in floor polishes, artificial silk manufacturing, resins, greases, waxes, oils, photography industrial solvents and dry cleaning [17]. Chemical technicians and students are exposed to organic solvents. Many research over the health effects of chlorinated organic solvents have declared some problems such as system sclerosis [23], autoimmune diseases, neurological symptoms [24], etc. Therefore in present study personal exposure to chlorinated organic solvents in breathing zone of chemical laboratory technicians and students were monitored by diffusive personal samplers because they were small, silent, and easy to handle and did not need any calibration. The occupationally exposed groups and non-exposed group were monitored for chlorinated organic solvent exposure during their shift work. In order to prevent dermal exposure risk, the study groups were requested to wear plastic gloves while working with chlorinated organic solvents, so no significant skin exposure occurred during the study.

Table 1 shows the results of environmental measurements (mg/m^3) in the three groups of laboratory technicians, students who work in the same laboratories and occupationally non-exposed persons during a day shift.

Table 1. The results of environmental measurements (mg/m^3) in the three groups

Compound / Group	Chloroform		Carbon Tetrachloride		Dichloromethane	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Employees	3.48±1.7	1.25-7.45	0.25±0	0.25	0.70±0.6	0.25-3.62
Technicians	15.9±4.5	7-27	0.25±0	0.25-0.250	2.7±1.9	0.25-10
Students	33±8.9	18-56	0.37±0.4	0.25-2	4.8±2.9	0.95-11
P_{value}	< 0.001		> 0.05		0.001	
TLV	10 ppm ; 50 mg/m^3(ACGIH) 50 ppm (OSHA) 2 ppm (NIOSH)		5 ppm; 31 mg/m^3 (ACGIH)		50 ppm; 174 mg/m^3 (ACGIH)	

As it can be seen in Table 1 the mean value for exposure of chlorinated organic solvents in breathing zone of occupationally exposed groups were significantly greater than the occupationally non-exposed groups but below the 2000 ACGIH TLV (TWA) [25]. Chloroform was found to be the most abundant component, followed by dichloromethane in breathing zone of all groups. Since chloroform is the common solvent which is used in chemical lab in Iran, airborne chloroform usually exists at higher concentrations compared to other compounds.

The concentration of carbon tetrachloride detected in breathing zone of occupationally exposed groups was significantly lower than permitted standard concentration, maybe because of general awareness about carbon tetrachloride serious side effects on health and being more cautious in working with carbon tetrachloride. Airborne chlorinated organic solvents levels of chemical laboratory were similar to the ones related to other jobs which have occupational exposure to chlorinated organic solvents asserted in the literature [26, 27]

Time weighted average of environmental concentration (in the breathing zone) (C_{env}) of all target solvents in all groups were lower than specific TLV. The mean value of environmental measurements in laboratory technicians and students were significantly greater than the occupationally non-exposed group. High levels of exposure are more marked among students who work directly with different solvents. Chlorinated organic solvents have been widely used in many chemical laboratories in worldwide; in organic synthesis and analysis procedure as reagents and solvents.

Results indicated significant differences in three studied groups monitoring for chloroform and dichloromethane ($P_{value}< 0.05$), but there were not observed these differences in groups monitoring for carbon tetrachloride, ($P_{value} >0.05$). It was assumed that carbon tetrachloride was not a common solvent in chemical laboratories because of its proved carcinogenic effects; therefore the exposure concentration of this solvent was not considerable. As the results indicated, a significant difference was observed in environmental measurements of job categories ($P_{value}<0.05$ by ANOVA and Kruskal–Wallis test). The exposure levels detected in this study was less than those were obtained for workers who work in paint factory and footwear factory [28]; whereas exposure level was much more than levels which are reported for American bus drivers [25]. As a comparison among occupational exposure of solvents in breathing air of different careers, the measured ranges of chlorinated organic solvents in these laboratories were obtained significantly lower than the range of solvents applying in dry-cleanings [29]. For justification of this outcome, it is assumed that technicians and students working in laboratories are more aware of solvents side effects compared to workers in dry-cleanings. Another study in a medical school laboratory showed lower occupational exposure of formaldehyde, which is another kind of VOCs, compared to OSHA's limit regarding the ventilation systems were On [30]. So it was supposed that good and efficient ventilation systems are necessary for these kinds of workplaces.

CONCLUSIONS

Because of serious health adverse effects of organic solvent, monitoring of these compounds in occupational environments is necessary. Therefore, the concentrations of organic solvents in breathing air of occupationally study groups were monitored and the results were compared to permissible limit. Concentrations of all selected organic solvents in exposed and non-exposed groups were lower than specific TLV. It was hypothesized that chloroform was applied more than the other mentioned solvents, besides people were informed about carcinogenesis of carbon tetrachloride and preferred to apply alternative solvents. From the results of this pilot study, it seems that indoor air in chemical laboratories of universities is in the acceptable condition. It should be noted that chronic exposure to these compounds in occupational environments is jus-

tified enough to monitor the VOCs continually.

Regarding the study on occupational exposure of formaldehyde [33], in order to reduce solvents vapors exposure in indoor environment a good and efficient ventilation system is recommended.

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COMPETING INTERESTS

The authors declare that they have no conflicts of interest.

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ETHICAL CONSIDERATIONS

The authors state that they have no ethical considerations**.**

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