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ORIGINAL ARTICLE

Evaluation of Control of Substances Hazard to Health (COSHH) Essentials Model by Measuring Occupational Exposure in a Chemical Production Industry

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KEYWORDS

COSHH Essentials;
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ABSTRACT: Control of Substances Hazard to Health (COSHH) Essentials is a simple, user-friendly matrix that provides risk-control solutions. Considering a large number of small enterprises under 25 workers in Iran and the lack of a suitable control banding tool, the COSHH Essentials can be considered an appropriate option. The purpose of the present experimental semi qualitative study was to evaluate the validity of the COSHH Essentials tool. Six processes were selected from a chemical products industry, including the production of silicone glue, polishing, PVC glue, Grease, Twin glue filling, and quality control. Amorphous silica and toluene concentrations were monitored using NIOSH 0600 and NIOSH 1501 in the ambient air of operators. The predicted exposure range (PER) was obtained by combining the control strategies available at the sampling time with exposure predictor (EP) bands in the COSHH Essentials, then compared to silica and toluene concentrations in the air.All exposure data were within the PER for amorphous silica dust and lower or within the PER for toluene. Compared to the acceptable concentration range in hazard bands, the threshold limit value (TLV) for respirable dust is within the acceptable concentration range, while toluene TLV exceeded it. COSHH Essentials is a conservative and safe tool, especially in liquids. Due to its simplicity, employers and health center experts can use the COSHH tool successfully for small enterprises or as a screening tool before a comprehensive risk assessment.

INTRODUCTION

Occupational diseases related to chemical exposure are one of the world's most important health problems[1]. The United Kingdom Health and Safety Executive (HSE) has estimated that 13,000 deaths occur each year, primarily to chemicals or dust [2]. More than 140 million chemical compounds have been registered with the International Chemical Abstracts Society, and approximately 10,000 new substances are recorded yearly, complicating the health risks associated with chemical substances [3]. Therefore, it is necessary to assess exposure risk to chemicals and

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implement the most appropriate control measures to protect the workers [4]. The traditional approach used for such assessments is the quantitative measurement of the concentration of chemicals in the air and comparison with the occupational exposure limit (OEL) established by organizations such as the American Conference of Governmental Industrial Hygienists (ACGIH) [5]. Given a large number of compounds, however, OELs are only supplied for a small fraction of chemicals (less than 5%) [6].

In a comprehensive risk assessment, it is not practical to perform quantitative exposure measurements for chemicals that lack an OEL [7, 8]. According to the European Commission, small and medium enterprises (SMEs) are classified into three categories: micro (less than 10 workers), small (less than 50 workers), and medium (less than 250 workers) [9]. They constitute a significant portion of the working population and frequently face challenges in obtaining specialized occupational health and safety consultations [5, 7].

Due to these limitations, OEL and threshold limit value (TLV)-based assessment methodologies cannot completely meet the actual needs of the workplace. Consequently, in the first half of the 1990s, new alternative approaches were utilized in evaluating and managing chemical risks based on qualitative and semi-quantitative criteria, and various international models inspired by the Control Bonding (CB) approach were developed [7, 10]. In the absence of exposure and toxicological data, CB strategies provide simplified methods for restricting worker exposure to workplace components [11]. In this strategy, the risk band is derived from the combination of the hazard band and exposure band [10].

The pharmaceutical industry was the first to use the CB technique, categorizing pharmaceutical agents into five risk bands based on their intrinsic toxicological and pharmacological characteristics [12]. Then, the British Health and Safety Executive (HSE) extended the CB technique to examine employee exposure in small and medium-sized enterprises, introducing the Control of Substances Hazardous to Health (COSHH) Essentials tool[13]. COSHH Essentials is a global chemical management solution that has been extensively adopted and used in both paper-based and web-based (online) [14, 15]. This tool employs warning labels and straightforward ways to predict exposure and implement control measures [14]. Health hazard bands defined by H-statements, exposure bands based on dustiness or volatility of chemicals and the quantity of chemicals utilized, and a stratified control approach to presenting adequate control are the components of the COSHH Essentials [16].

COSHH Essentials assigns a chemical to a health hazard band based on toxicological categorization using European Union (EU) risk phrases (R-phrases) or hazard statements (H-statements) found on Safety Data Sheets (SDS). The quantity utilized, dustiness for solids or vapor pressure for liquids determine exposure potential. COSHH Essentials determines a predicted exposure range (PER) and recommends a control program based on the substance's hazard [17]. The sensitivity of the proposed control bands is the primary challenge in making and using this tool. Poorly predicted control bands may lead to high costs and work-related illnesses [18]. To this point, the validity of this tool has been examined in a variety of research; however, conflicting findings have been reported [15, 19, 20].

Today, the support of CB by organizations such as the American Industrial Hygiene Association (AIHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and others has resulted in the widespread adoption of CB by SMEs in developed and developing countries [21, 22]. More than 14 million Iranians are recruited by more than 5 million SMEs [23]. More than 98% of industries and 80% of the workers are small enterprises [24]. Companies with at least 25 employees are required by Iran Labor Law to monitor and measure exposure to chemical agents; however, quantitative and qualitative assessments of chemical exposure are neither mandated nor implemented in companies with less than 25 employees.

The HSE tool is a simple, user-friendly matrix that offers recommendations for controlling risk exposure. The employer with little or no occupational hygiene expertise may perform the hazard assessment method if properly trained [25]. Considering a large number of small enterprises under 25 people in Iran and the lack of a suitable CB tool to assess and control of chemicals exposure risk, the COSHH Essentials can be considered an appropriate option. According to our knowledge, no study has investigated the validity of this tool in Iran. The purpose of the present experimental semi qualitative study was to evaluate the validity of the COSHH Essentials tool.

MATERIALS AND METHODS

Process description

This research was carried out at a chemical products manufacturing in Tehran. The factory included three shifts and key operations the production line of grease, silicone glue, Polyvinyl Chloride (PVC) glue, polishing compound, twin glue filling, printing, packing, coding, and sub-processes of quality control and maintenance.

Considering the information necessary for quantitative and qualitative assessment, we examined the feasibility of performing the research in procedures. Operations in which the utilized chemicals could not be quantified using current standard methods such as OSHA and NIOSH analytical methods were eliminated. Six processes were selected, including the production of silicone glue, polishing, PVC glue, Grease, Twin glue filling, and quality control. For evaluation, amorphous silica and toluene were chosen as solid and liquid samples, respectively, and their concentrations in the ambient air of operators were monitored. Amorphous silica was introduced and blended as a raw material in one of the production steps, and toluene was used to clean devices and containers at the end of the procedures. Other information necessary, such as the quantity of material utilized, dustiness and volatility, and the operating temperature, was also collected.

Quantitative measurement of exposure

According to the NIOSH 0600 method [26], amorphous silica was monitored and reported as respirable dust. After calibrating the personal sampling pump (SKC, USA) and weighing the sample and blank filters, a 5-m PVC membrane was assembled in the filter cassettes. Silicon glue, polishing, PVC glue, and grease operation productions were sampled for eight hours at a flow rate of 2.2 L/min. In each procedure, samples were collected three times on different days. After sampling, the weight of the filters was determined using a balance, and the concentration was calculated.

Toluene concentrations in ambient air were also determined using the NIOSH 1501 method [26]. Operators from the polishing, silicone glue, quality control, and twin glue filling operations were chosen. Sampling using activated charcoal absorbent tubes and a personal sampling pump (SKC-USA) at a flow rate of 0.2 L min^{-1} for 8 h was performed on three separate days. Following sampling, the samplers were caped with plastic caps and packed securely for shipment, then the samples were transferred to the mineral processing research center for analysis using a Agilent gas chromatography-flame ionization detector (GC-FID) with BP5 colume.

COSHH Essentials tool

In the first step of the COSHH Essentials technique, chemicals are assigned to one of the hazard bands A-E based on the toxicological profile and H-statement provided on the safety data sheet (SDS). The least hazardous substances and chemicals not containing the H-statement are classified in A, while the most hazardous are listed as E. The acceptable concentration range for dust and vapors has been defined in each hazard band (Table S1). The combination of the material's physical properties and the quantity utilized yields four exposure predictor (EP) bands. Dustiness is the most important physical characteristic, which the user subjectively describes in the COSHH Essentials. The important characteristic of liquids is volatility, and the user must know the boiling point and the process temperature. The quantity of a material used was categorized as small (grams or milliliters), medium (kilograms or liters), or large (tonnes or cubic meters). Based on the substance's boiling point for liquids and particle size for solids, the volatility and dustiness were also classified as small, medium, or large. In the paper-based COSHH Essentials, the predicted exposure range (PER) is obtained by combining the control strategies available at sampling time with Eps (Table S2) [27]. Control strategies cannot be included in the online version. Hence PER is not an output of the online version. The calculated PER was then compared to the measured exposure to silica and toluene to assess its validity.

RESULTS

Table 1 displays the results of monitoring amorphous silica and toluene exposure in various procedures. Comparing the measurement findings to the ACGIH TLV reveals that in all procedures, the operator's exposure exceeds the TLV of 3 mg m^{-3} for Amorphous Silica. Nevertheless, the only exposures over the TLV of 20 ppm for toluene were in polishing compound production and quality control stations.

Table 1. the concentrations of amorphous silica and toluene in various procedures (n=3).

Amorphous Silica		Toluene	
Procedure	**Concentrations (mg m^{-3})**	**Procedure**	**Concentrations (ppm)**
Silicon glue production	5.6 ± 1.5	**Silicon glue production**	1.7 ± 9
polishing compound production	5 ± 1.2	**polishing compound production**	146 ± 12
PVC glue production	6.2 ± 2	**Twin glue filling**	2 ± 0.5
Grease production	5.8 ± 0.8	**Quality Control**	62.5 ± 7

Evaluation of COSHH Essentials

The required data, such as the quantity, boiling point, dustiness, operation temperature, and existing controls, were collected (Table 2). Based on the H-statement in the material safety data sheet, amorphous silica was classified in hazard band A with an acceptable exposure range of 1 to 10 mg m^{-3}, and toluene classified in hazard band C with an acceptable exposure range of 0.5 to 5 ppm. Then the exposure band and REL were determined (Table 3). Detailed process specifications are included in the table.

Table 2. Basic process specifications

Chemical	Procedure	Quantity	Particle size	Boiling point	Operating temperature	Controls
Amorphous Silica	Silicon glue production	200 Kg	Fine solid and light particle	-	-	General ventilation
	polishing compound production	100 Kg	Fine solid and light particle	-	-	General ventilation
	PVC glue production	100 Kg	Fine solid and light particle	-	-	General ventilation
	Grease production	200 Kg	Fine solid and light particle	-	-	General ventilation
Toluene	Silicon glue production	0.5 L	-	110.6	ambient temperature	General ventilation
	polishing compound production	20 L	-	110.6	ambient temperature	General ventilation
	Twin glue filling	2 L	-	110.6	ambient temperature	General ventilation
	Quality Control	2 L	-	110.6	ambient temperature	General ventilation

Table 3. exposure predictor and predicted exposure ranges for various processes

Chemical	Procedure	Dustiness	Volatility	exposure predictor (EP) bands	Predicted exposures (PER)
Amorphous Silica	Silicon glue production	High	-	EP3	1-10 (mg m^{-3})
	polishing compound production	High	-	EP3	1-10 (mg m^{-3})
	PVC glue production	High	-	EP3	1-10 (mg m^{-3})
	Grease production	High	-	EP3	1-10 (mg m^{-3})
Toluene	Silicon glue production	-	Medium	EP2	5-50 (ppm)
	polishing compound production	-	Medium	EP3	50-500 (ppm)
	Twin glue filling	-	Medium	EP3	50-500 (ppm)
	Quality Control	-	Medium	EP3	50-500 (ppm)

DISCUSSION

Examining the comparability of amorphous silica dust data indicated that all exposure concentrations were within the PEL. However, toluene measured exposure values for the twin glue filling process and silicone glue production were lower than the PER, and exposure values for the quality control and polishing compound production were within the PER. The toluene usage was almost the same in the quality control and twin glue filling operations; the dimensions of the twin glue filling workshop are much greater than those of the quality control department (laboratory), resulting in the improved ventilation of the toluene vapor and, therefore, a lower concentration. Comparing the TLVs for toluene and amorphous silica to the acceptable concentration ranges in hazard bands indicated that the TLV for respirable dust falls within the acceptable concentration range. Nonetheless, toluene TLV exceeded it. These results illustrate the usefulness and reliability of COSHH Essentials for qualitative risk assessment. The TLV and the measured concentration of amorphous silica dust were within the PER and acceptable concentration range, and the results were quite consistent. Two processes had toluene concentrations below the PER for liquids, and the TLV was also greater than the acceptable exposure range. Thus, it is feasible to conclude that COSHH Essentials is more conservative and safer in the case of liquids. Other studies have also indicated that the COSHH Essentials is intended to estimate exposure [28] conservatively; our results are consistent with previous studies.

PER often overestimates exposure. In 97% of the cases, the degree of exposure was either correct or overestimated in Kimbrough's analyses [17]. Tisher et al. observed a good agreement between measurements of solid materials (powder, dust) and predicted ranges. However, the situation was somewhat different for liquids. When organic solvents were used in liter, exposure levels were within the predicted range or even lower. However, exposure levels measured in milliliters exceeded the predicted ranges [15]. The model was also validated using data collected at 12 Japanese oil industry workplaces, and a good agreement was established [29]. Li et al. investigated the COSHH Essentials in the printing industry using short-term and full-shift measurements and monitoring the concentration of five chemical solvents in the mixture. They found that the model functions effectively under short-term exposure.

Furthermore, a more accurate exposure prediction is made when low chemicals are used. Long-term exposure resulted in a moderate to poor relationship between TWA and PER measurement outcomes [19]. Long-term measurement, however, demonstrates great agreement in our investigation.

On the other hand, Jones and Nicas analyzed the control measures supplied by the COSHH Essentials using air monitoring data from NIOSH Health Hazard Evaluations and Control Technology Assessments to discover under-controlled and over-controlled errors. Under-controlled errors are instances in which airborne chemical concentrations exceed the upper limit of the exposure band in the presence of control technologies. In contrast, over-controlled errors are instances in which airborne chemical concentrations are within or below the exposure range without control technologies. Jones and Nicas disagreed with the model and suggested that it be subjected to a thorough assessment before being implemented beyond the United Kingdom [20].

We could not evaluate all chemicals utilized in the selected industry due to the scope of our inquiry. The OEL and OSHA or NIOSH Analytical Methods were not established for several existing chemicals. It was not possible to quantify the chemicals used in various processes. Due to this, amorphous silica and toluene were included in this evaluation, which is one of the limitations of the research. Due to the limited number of tasks and chemicals investigated, this study should be seen as a pilot and exploratory research comparing COSHH Essentials to real air exposure data. Therefore, consideration should be used when extending these results to other substances and occupations. In studies that evaluated the method's validity on a larger scale, COSHH Essentials was described as a straightforward and user-friendly tool [15, 17].

CONCLUSIONS

In this study, the validity of the COSHH Essentials technique was investigated by measuring the concentration of chemicals and comparing the results to the PER attained by COSHH. The results revealed the conservatism of COSHH Essentials' evaluations. Due to its simplicity, employers and health center experts can use the COSHH tool successfully for small enterprises or as a screening tool before a comprehensive risk assessment. However, it should be noted that the diversity of activities and chemicals used in this study was limited. Consequently, it is suggested that a more comprehensive study be undertaken in many industries, including various jobs and solid and liquid chemicals of broad concentrations with different volatilities.

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Conflict of interest

The authors declare no conflict of interest

Compliance with ethical guidelines

This research does not contain any studies with human participants or animals performed by any of the authors

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