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The Effect of HCS on Knowledge and Safety Performance (Case study: Hazardous Chemicals in the Tehran Refinery)

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Abstract: The Hazard Communication Standard (HCS) includes inventory of hazardous chemicals, labels and other forms of warning, a material safety data sheet, and information and training program. In this paper, we seek to study the effects of HCS as a safety intervention program on the knowledge and safety performance. In addition, before and after the implementation of the HCS plan, Knowledge and unsafe behavior were determined by the questionnaire and behavior review (safety sampling method). All personnel of Tehran Refinery Laboratory (n=52) that are being exposure with chemicals participate in this study. The result showed that enhancement of the knowledge related to "chemical safety", "hazard communication methods" and "warning labels" was significant ($p<0.001$). Also result indicated after implementation the HCS unsafe act percentage decreased significantly ($p<0.0001$). Results from this study emphasize the importance of such the effective program can be useful in unsafe in the workplace with hazard chemical potentials. Therefore, results are clear evidence on improving chemical's safety performance.

Key words: Chemical Safety, Hazard Communication Standard, Unsafe Behavior, Knowledge, Safety Performance.

INTRODUCTION

About 32 million workers work with and are potentially exposed to one or more chemical hazards. There is an estimated 650,000 existing chemical products, and hundreds of new ones being introduced annually (OSHA, 2006). This poses a serious problem for exposed workers and their employers. Chemical exposure may cause or contribute to many serious health effects such as heart ailments, central nervous system, kidney and lung damage, sterility, cancer, burns, and rashes. Some chemicals may also be safety hazards and have the potential to cause fires and explosions and other serious accidents. Because of the seriousness of these safety and health problems, and because many employers and employees know little or nothing about them, the Occupational Safety and Health Administration (OSHA) issued the Hazard Communication Standard (HCS). The basic goal of the standard is to be sure employers and employees know about work hazards and how to protect themselves; this should help to reduce the incidence of chemical source illness and injuries.

Employers, therefore, must develop, implement, and maintain at the workplace a written, comprehensive hazard communication program that includes provisions for container labeling, collection and availability of Material Safety Data Sheets (MSDSs), and an employee training program. It also must contain a list of the hazardous chemicals, the means the employer will use to inform employees of the hazards of non-routine tasks (for example, the cleaning of reactor vessels), and the hazards associated with chemicals in unlabeled pipes. If the workplace has multiple employers onsite (for example, a construction site), the rule requires these employers to ensure that information regard to hazards and protective measures be made available to the other employers onsite, where appropriate. In addition, all employers must have a written hazard communication program to get hazard information to their employees through labels on containers, MSDSs, and training (OSHA, 2006).

Chemists and other scientists working in laboratories handle collectively thousands of chemicals in relatively small quantities in their experiments, procedures, and other laboratory operations. Recognition of chemical hazards, an essential component of laboratory safety, depends upon the availability of clear and accurate information about specific chemical hazards on labels and other sources, such as MSDSs.

In a study which was made with the subject of diagnosing triangular signs of warning as proposed by the country of Zimbabwe, it became clear that of total targeted individuals, who had been selected from various industries, 21% of them recognized all signs and 17% recognized some parts of the sign while the rest 62% could not recognize these signs (UNITAR, ILO and IOMC, 2001). Similar results were also obtained in other research studies.

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The study is set seven major sections; the second part presents the related works. The third part presents materials and methods. The forth part describes results. The fifth part is expressed discussions, and in the next sections, it will be present impact on industry and conclusions.

Related Works:

The Hazard Communication Standard (HCS) has been in effect in various industries and to various degrees since 1983. The purpose of the standard is to provide workers with the right to know the hazards of the chemicals they are exposed to while working, as well as the measures they can take to protect themselves. A hazardous chemical under this standard is any chemical that poses a health hazard or a physical hazard and the chemical is present in the workplace in such a manner that employees may be exposed under normal conditions of use or in a foreseeable emergency (CFR 19 10.1200 (b)(2)).

Hazard assessment and communication are an integral stage in the hierarchy of chemical assessment and decision support tools available to ensure the safe use of chemicals (Pittinger *et al.,* 2003). Like other chemical assessment tools, sound professional judgment in chemical hazard assessment is predicated upon regulatory as well as technical considerations. National and international hazard assessment and classification systems are not uniform in their source lists of hazardous chemicals, in their definitions of hazards based on key endpoints, or in their volume triggers in labeling products (Weiler, 1995). Hazard assessments of products or substances should ideally be performed by experts knowledgeable in the appropriate science(s) (Cote *et al.,* 1998).

The HCS covering the manufacturing sector was published on November 25, 1983 and since then, has been tested in many court actions that slowed or even prevented its introduction into some sectors of the workplace. Because of the actions, the Occupational Safety and Health Administration (OSHA) were actually ordered by the court of appeals to expand the scope of HCS enforcement. Further court action prevented OSHA from enforcing the standard in the construction industry and the requirements for providing Material Safety Data Sheets (MSDS) on multiemployer worksites. As of March 17, 1989, the HCS has been fully enforceable in all SIC's and as a result of a Supreme Court decision, all provisions of the rule are now in effect for all industrial segments (U.S. Department of Labor, 1990).

Karapantsios *et al.,* (2007) suggest that the traditional teaching of safe handling and hazard labeling is inadequate, and there is a need for more effective teaching methods to improve the Knowledge of labeling and the safe handling of chemical substances.

The HCS requires each employer to fully inform their employees of the hazards of the chemicals that exist in the workplace. This is accomplished by developing a written program, establishing a labeling system, providing employee training, and compiling material safety data sheets for those chemicals that have been determined to be hazardous.

Numerous researchers have described the warning process as a communication consisting of several information-processing stages (Schwartz and Driver, 1983; McGuire, 1980). In particular, Lehto and Miller (1986) describe the warning process as a sequence of eight stages: (1) exposure to the warning stimulus, (2) attention and active processing of the warning stimulus, (3) comprehension and agreement with the warning message, (4) retaining the message in memory, (5) retrieval of the message at the time it is relevant, (6) deciding to respond consistently with the message, (7) performing the response, and (8) adequacy of the response for preventing accidents. This model implies that the effectiveness of a warning sign or label can never be greater than the probability of successfully completing any single step in the sequence. Recent research has confirmed such implications of this model. For example, Otsubo (1988) observed in an experimental study of warning labels designed to convince people to wear gloves while using a circular saw that 74% of the subjects noticed the warning, 52% said they read it, and 38% were observed to comply. For a jigsaw, 54% of the subjects noticed the warning, 25% read it, and 13% complied.

OSHA has been charged with the responsibility for ensuring that safety and health standards are enforced in the workplace. The HCS has ranked at the top of the list of most frequently cited OSHA standards for a number of years (Weinstock, 1992, 1993). From October 1, 1993 to September 30, 1994, for example, 42,377 inspections were conducted by OSHA. Failure to have a written program (1910.1200(E)(l)) in a general industry location topped the list of most frequently cited violations with 4,728 citations. Other HCS violations included failing to have a written program in the construction industry (1926.59(E)(1)) with 3,458 violations, and failing to train employees with 3,834 violations (1910.1200(H)) (U.S. Department of Labor - Office of Data Management, 1994).

Safety management practices not only improve working conditions but also positively influence employees' attitudes and behaviors with regard to safety, thereby reducing accidents in workplace. Safety training was identified as the most important safety management practice that predicts safety knowledge, safety motivation, safety compliance and safety participation (Vinodkumar and Bhasi, 2010).

In the current study, safety behaviors were taken as safety performance indicator. Safety compliance and safety participations are two kinds of safety behaviors. Safety compliance refers to activities employees need to do in order to maintain workplace safety. When employees do not obey the procedures and rules, their behaviors are labeled “unsafe activities”. Thus, unsafe activities and safety compliance behaviors are two ends of one dimension (Neal and Griffin, 2000 as cited in Jiang, Yu, Yongjuan Li and Feng Li, 2010).

This study has been conducted in the laboratory department of a big refinery in Iran. The purpose of this investigation was to evaluating effectiveness of implementation of the HCS on enhancing knowledge and safety performance level of laboratory staffs.

MATERIAL AND METHODS

Scope and Procedure:

In this paper, general methodology is entailed **(a)** pre survey using a knowledge questionnaire and safety behavior sampling method **(b)** implementation of the HCS and **(c)** post survey using a knowledge questionnaire and safety behavior sampling method. At the present study, field study has been comprised of various laboratory units including quality control (QC), storage of chemicals, analysis, special, gases, research activities, water and steam, refining, recycling, and sour water units. All personnel (n=52) that are being exposure with chemicals and are being staff in Tehran Refinery, participate in this survey.

Intervention Design:

The intervention was based on the Hazard Communication regulation, otherwise known in the United States as "Right-to-Know" (OSHA 29 CFR 1910.1200, 2006) requires the development of a written program that addresses the worker's right to know: a) What the HCS is and what it requires, b) What chemicals in the workplace are hazardous and what those hazards are, c) How and where to obtain information about hazardous chemicals and how to use this information to ensure personal health and safety, and d) What the employer is doing to ensure compliance with the Hazard Communication Standard. In order to these worker's rights, in all segments of the laboratory, the written program includes procedures used by the laboratory to determine chemical hazards, to employ labels and other forms of warning, to make available health and safety information regarding hazardous chemicals, and to conduct personnel training. The training program has been comprised of two parts: the first part of general training program was held during 22 days, include detailed information regarding the concept of hazard warning signs, contents of the material's safety data sheet, safe working with hazard materials such as corrosive materials, oxidative materials, reacting materials, inflammable and explosive materials and the selection, proper use, and maintenance of personal protective clothing and equipment. The second part of a training program was held during two months for each site or workplace in such a way that hazards alarmed by labels and other data extracted from special material safety data sheet using the face to face method. In addition, other training aids, such as training films, were used for a period of eight hours. In the same direction, personnel were trained, as the self-learning way, through writing plan, labels of containers and MSDSs continuously within seven months to post survey time. It has been tried to control and monitor study filed during this period.

Knowledge Measurement:

Safety knowledge is measured before and after seven months by a self-administrated questionnaire. Basic demographic question includes age, education and work history.

A pilot questionnaire entitled ‘‘a study on the knowledge of chemical safety” was mailed to 25 experts from chemical laboratory, and the academic fields for reviewing. Comments from 17 experts were received, and the questionnaire was modified subsequently. Contents of the questionnaire are divided into three major parts: (1) ten multiple-choice questions regarding the chemical safety (2) judging of personnel’ perception of labels of chemical. Seventeen multiple-choice questions of the global harmonization system (GHS) with pictograms are designed for correct perception (Peterson, Mokhtar, Chang and Krueger, 2010). (3) Ten multiple-choice questions are designed regarding the HCS requirements and elements. Participants get 1 point for correctly answering a question and 0 point for incorrectly answering it. The internal consistency of the questionnaire is evaluated by the Cronbach's alpha. Results show that the questionnaire was internally consistent in the present study (α=0.89).

Safety Behavior Sampling:

Safety behavior sampling (SBS) technique was employed to conduct this study. A list of unsafe acts is collected. This list has been organized based on the unsafe act's list, which has been proposed by Griffin and Neal (2000). The obtained list was adjusted based on present conditions such as type and nature of work, reviews of accident's reports, present cultural conditions and a number of related factors. The number of observations required is based on data collected during the pilot study. The proportion of unsafe behavior is shown in eq.1.

$$P = \frac{N_1}{N_2} \qquad (1)$$

Where N1 is the total number of observations made, N2 Number of observations in which unsafe behavior is observed and P proportion of unsafe acts. Then the total number of required safety behavior observations is derived from eq.2.

$$N = \left(\frac{K}{S}\right)^2 / P(1 - P) \qquad (2)$$

Where S is the desired accuracy, N the total number of observations required and K the value obtained from Standardized normal tables for a given level of confidence (Nouri, Azadeh and Mohammad Fam, 2008). After conducting a pilot study the proportion of unsafe behaviors was estimated to be about 25%. Considering that 5% accuracy with 95% confidence level is the combination, which is often used in SBS, the total number of observations was estimated to be 4800. Therefore, unsafe behavior proportion is measured by the SBS before and after seven months. The researcher carries out the observations randomly while the subjects were not aware of the fact that they were being observed.

Statistic Analysis:

At first, it was analyzed descriptive statistics of the demographic variables. Cronbach's Alpha test was used for internal consistency of the three determinants of knowledge (chemical safety, perception of chemical signs, HCS requirements). Paired t-test was used to test the hypotheses and to compare the total knowledge scores and unsafe behavior proportions in the per-post survey. All the statistic analyses were done using SPSS-15 software.

RESULTS AND DISCUSSIONS

Demographics:

Fig. 1 shows age distribution of studied participants. Participants' age group from 31 to 40 years was the highest age group percentage (40%) while Participants' age group between 51 and 60 years allocated the lowest percentage (15%).

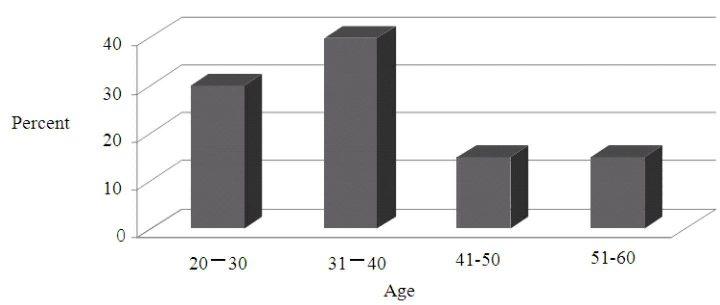

Fig. 1: Distribution of participants according to age.

According to fig. 2, Participants' work history group from one to 10 years was the highest work history group percentage (50%) while the lowest work history group belongs to 21 to 30 years (10%). Furthermore, fig. 3 shows that of all participants, 35, 30 and 35 percent hold BS, diploma and below-diploma degrees respectively.

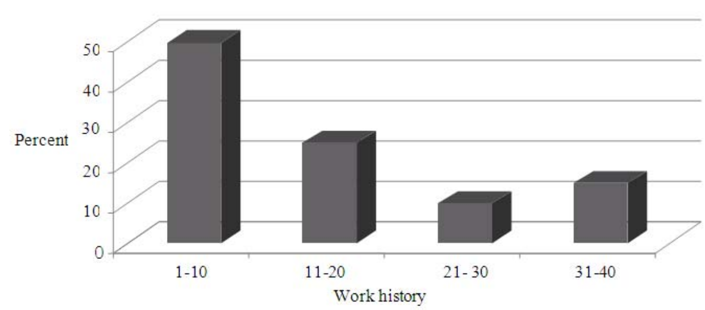

Fig. 2: distribution of participants according to work history.

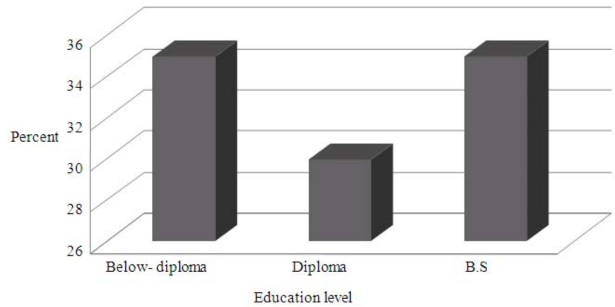

Fig. 3: distribution of participants according to education.

Knowledge:

Table 1 shows the mean and standard deviation of Participants' knowledge on chemical safety, warning labels and hazard communication methods before and after intervention and result of paired t-test.

Table 1: Statistical analysis of participants' knowledge before and after intervention.

	Time	Mean	SD	P-Value
Chemical safety	Before	36%	14%	0.0001
	After	88%	12%	
Warning label	Before	29%	22%	0.0001
	After	80%	16%	
Hazard communication methods	Before	25%	11%	0.001
	After	79%	17%	

The mean and standard deviation of knowledge level on chemical safety before and after intervention showed 46%±14% and 88%±12% respectively. Paired t-test showed the significant differences before and after intervention (P=0.0001). For warning labels, the mean and standard deviation of participants' knowledge before and after intervention was 29%±22% and 80±16% respectively. The result of paired t-test showed the significant differences (P=0.0001). Finally, the mean and standard deviation of participants' knowledge on hazard communication methods before and after intervention showed 25%±11% and 79%±16% respectively. The result of paired t-test shows a significant difference before and after intervention (P=0.001).

Safety Behavior:

Table 2 shows the mean and standard deviation of participants' unsafe proportion on chemical safety, warning labels and hazard communication methods before and after intervention and result of paired t-test.

Table 2: Statistical analysis of participants' unsafe proportion before and after intervention.

	Time	Mean	SD	P-Value
Unsafe proportion	Before	23.6	5.49	0.0001
	After	18.15	6.18	

As it is observed at table 2, the mean and standard deviation of unsafe behavior's proportion before intervention showed 23.60 and 5.49 respectively, while the rate of which after seven months showed 18.15 and 6.18. The result of statistical test showed the significant differences before and after intervention (P=0.0001).

Discussion:

In the evaluation of the HCS, there was no strong evidence to suggest that the program was effective in enhancing knowledge and safety performance in companies participating in the program. The purpose of this investigation was to evaluating effectiveness of implementation of the HCS as a safety intervention program on enhancing knowledge and safety performance level of laboratory staffs. The result of pre-study showed that the knowledge level of staffs about the chemical safety and hazard communication methods was low and the warning labels are poorly understood (participants obtained 29% correct). Nevertheless, Standards Organization (ISO, 2001) suggested that effective symbols have been arbitrarily defined as those which are correctly interpreted by 85% or more of the evaluated population. The research findings were indicated that knowledge of safety before intervention has been 46% with standard deviation 14% and Knowledge of safety after intervention has been increased to 88% with standard deviation 12%. Knowledge of the warning labels before intervention has been 29% with standard deviation 22% and Knowledge of the warning labels after intervention has been increased to 80% with standard deviation 16%. Knowledge of the HCS before intervention has been 25% with standard deviation 11% and Knowledge of the HCS after intervention has been increased to 79% with standard deviation 16%. The results of this study are similar to prior studies. Su and Hsu (2008) stated that taking training courses in hazard communication is the most imperative factor. Wogalter, McKenna, and Allison (1985) found that training led to a significant increase in pictorial comprehension. Therefore, the current results clearly demonstrate the benefits of using the HCS to improve processing of warning labels and other hazard communication tools such as MSDS.

One strength of the study, compared with previous researches, is the use of the SBS technique. This sampling technique has demonstrable usefulness in evaluating unsafe behavior (Harvey and Roger, 1984). Whereas in the previous researches, usually, safe or unsafe behavior data were collected via the use of self-report methods and may be biased. Always, there was a concern about long term effectiveness of safety training on knowledge level and safety behaviors. Wang and Chi (2003) indicated that comprehension of most hazard symbol labels immediately increased after having received training, but there was a significant decline in comprehension performance after one month. In the current study this concern was investigated and the result showed that the HCS have long term effectiveness after seven-month duration. This issue is another strength of the present study.

However, the study was limited in some important respects. A first limitation was the fact that the study implemented in a field study with almost high graduated staffs (65% with academic education). A second limitation was the issue that there were no disparate samples with different job context to examine the relationships among different factors.

To overcome some of the limitations of the present study it would be useful for future research to examine the relationships found in the present study using disparate samples as well as ones in which the job context is different (e.g., nature of the work, equipment usage). This would allow for an examination of the generalize ability of the present findings. In addition, it would be important for subsequent research to collect data on actual employee performance data, including accident/injury records, in order to gain a more precise assessment of the HCS implementation in the workplaces. Such future studies would aid in overcoming some of the limitations of the present study.

Impact on Industry:

While the American National Standards Institute (ANSI, 2000) recommends that training be employed to improve comprehension of labels and other chemical hazard communication, little studies are provided as to the type of training that should be used. Results from this study emphasize the importance of such the effective program can be useful in unsafe behavior and accident reduction in the workplace with hazard chemical potentials. While there may be challenges in implementing and becoming comfortable with a new system, these results suggest that the HCS will be effective in helping identify chemicals by hazard classes and categories. It will be up to the chemical manufacturers and suppliers to identify the hazard classes and categories for each chemical they produce.

Conclusions:

In this paper, we review the HCS includes inventory of hazardous chemicals, labels and other forms of warning, a data sheet of material safety, and information and training program, and studies the effects of HCS as a safety intervention program on the Knowledge and safety performance. In addition, before and after the implementation of the HCS plan, Knowledge and unsafe behavior were determined by the questionnaire and behavior review (safety sampling method). The results indicated that the HCS is supported as an effective program with a significant increase in the chemical safety knowledge and significant reduction in unsafe behaviors in the laboratory workplaces. In conclusion, the results from this study emphasize the importance of the effective programs that can be useful in unsafe behavior in the workplace with hazard chemical potentials.

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