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The evaluation of safety behaviors in a gas treatment company in Iran

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Abstract

The study aims to evaluate the workers' safety behavior in an Iranian gas treatment company. The methodology was based on the safety behavior sampling (SBS) technique. After specifying the unsafe behaviors and with reference to the results of a pilot study, a sample of 3248 was determined, with a sampling accuracy of 5% and confidence level of 95%.

The results indicated that 26.7% of workers' behaviors were unsafe. The most important unsafe behaviors were awkward postures in working hours with 13.1% of total unsafe behaviors. The results also notified a significant relationship between age and job experience on unsafe behaviors ($p<0.001$). The relationship between unsafe behaviors and previous accidents records was also significant ($p<0.005$). The ultimate findings of the study showed that a considerable number of workers' behaviors were unsafe, which is one of the main antecedents of industrial accidents. Considering catastrophic consequences of accidents in gas treatment industry, the results emphasize on diminishing unsafe behaviors and recommend applying behavior-based safety principles.

Keywords: Accidents; Gas treatment; Safety behavior sampling; Unsafe acts; Unsafe condition; Workplace

1. Introduction

Although the development of science and technology has already decreased the number of employees in industries, there has been a developing trend in terms of employees' importance in workplaces (Lund & Aaro, 2004). Controlling a large number of different and critical operations is the duty of human beings in modern industries. It is usually assumed that making errors is one of the main contributors to catastrophic disasters likelihood (Haslam, 2002). Disastrous accidents like Chernobyl, Three Mile Island and Boopall are all examples of these kinds (Azadeh, 2000) (Table 1).

Due to the catastrophic consequences of such accidents, human beings always try to take controlling measures and reduce the potential risks (Kjellén, 2000). Before the 1930s safety specialists followed the prevention approaches by using physical methods such as machine guarding, house keeping and inspection programs (Reason, 1997). Until that time it was believed that the main causes of industrial accidents were unsafe conditions and physical hazards such as heavy equipment, trenches, mechanical explosions, ionizing radiation, flammability, corrosion, reactivity, fast moving vehicles, steep grades, uneven surfaces, etc. It was in the early years of 1930s when the concept of unsafe acts and their role in causing industrial accidents were introduced (Reason, 1997) and the theory of "human beings as the first antecedents (trigger reason) of accidents by doing unsafe acts" was propounded by Heinrich in his book "prevention of industrial accidents" (Kannapin, Pawlik, & Zinn, 1998). Heinrich (1995) stated that roughly 88% of all accidents were caused by human errors. Drew estimated that 80–90% of the accidents were caused by human errors (Bahr, 1997). In addition, Reynard and Billings came to this conclusion that human's unsafe acts

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Table 1
The causes of some major accidents

Name of accident	Causes of accident/failure				
	Managerial error	Human factor	Inadequate interface design	Safety issues	Inadequate system design
Chernobyl nuclear power plant accident (1986)	*	*	*	*	*
TMI nuclear power plant accident (1979)	*	*	*	*	*
Bhopal chemical processing plant accident (1983)	*	*	*	*	*
Aloha airlines accident (1988)		*	*		*
US telephone network accident in Chicago suburb (1988)					*
Thirty major accidents in chemical plants (1985–1989)	*	*			
NASA's space shuttle explosion (1986)	*				*
Proctor& Gamble Tylenol (1982)	*	*			*
US public phone network outage (1991)	*	*	*		*

caused 70–90% of the accidents (Bahr, 1997). This drew psychologists and safety specialists' attention to unsafe acts as the most probable cause of frequent accidents happening in industries. In order to diminish the likelihood of such accidents, this group of specialists emphasized the behavior of employees using behavior science techniques (Varonen & Mattila, 2002). Social psychologists recognize "attitude" as the most important factor to predict employees' behaviors. In other words, these efforts led to initiation and development of the "behavioral-based safety" approach.

This study has been conducted in the operational department of a gas treatment company, which is located in the south of Iran, in 2005. The purpose of this investigation was to specify the type and proportion of unsafe acts in employees' behaviors. Furthermore, the relationship between unsafe behaviors and employees' demographic characteristics such as age, education, job experience, previous accidents records and marriage status was examined. It is also worth mentioning that in this research, an unsafe act is defined as a behavior that is committed without considering safety rules, regulation, standards and specified criteria in system, which can affect the system safety level (Fuller, 2005).

2. Materials and methods

Safety behavior sampling (SBS) technique was employed to conduct this study. SBS is a technique of measuring unsafe acts and is based on the laws of probability (Armitage & Conner, 2001; Cox, Jones, & Rycraft, 2004).

If we are dealing with a process that can be only in two states, safe and unsafe, the total probability is 1% or 100%. In a multi-activity study each observation is in a binary state for each activity considered.

In terms of probabilities, we can express the relationship as

$$p + q = 1,$$

where p is the probability of a single observation in one state, say S for safe act, and $q = (1-p)$ the probability of no observations in state S.

For "n" observations,

$$(p + q)^n = 1,$$

where n is the number of observations in the sample.

The distribution of probabilities resulting from the binomial expansion follows the binomial distribution. The mean of the distribution is "np" and the standard deviation of the distribution is $\sqrt{np(1-p)}$. As "n" becomes large the distribution becomes almost continuous and takes as the properties of normal distribution. When "n" is large and neither "p" nor "q" is close to zero, the mean and standard deviation are obtained by

$$\text{Sample mean} = \frac{np}{n} = p,$$

$$\text{Sample standard deviation} = \frac{\sqrt{np(1-p)}}{n} = \sqrt{\frac{p(1-p)}{n}}.$$

This sampling technique has demonstrable usefulness in evaluating unsafe behavior (Harvey & Roger, 1984). Here, it is assumed that the percent of time a worker working safely/behaving safely can be determined.

In order to obtain a complete and accurate picture of safe/unsafe acts performed by the worker, it is necessary to continuously observe the worker and record data related to unsafe acts (Cooper, 1994). Note that a sufficiently large sample must be obtained for representative results (Gherardi & Nicolini, 2002). For a large number of observations, the resulting distribution approaches the shape of a normal curve.

After specifying the unsafe behaviors, a list of unsafe acts was collected. This list has been organized based on unsafe acts list, which has been proposed by National Safety Council (NSC), and consists of previous accidents records, including disabling injuries, recordable injuries and first aid cases, interviews with the managers and experts of the department and the review of the related documents. The obtained list was adjusted on the basis of present conditions such as type and nature of work, reviews of accidents reports, present cultural conditions and a number of related factors. After specifying the unsafe acts, a number of necessary observations of workers' behaviors were carried out in order to determine the proportion of their unsafe acts.

The number of observations required is based on data collected during the pilot study, the degree of accuracy required and the given level of confidence.

Two terms are recorded during the pilot study:

1. Total number of observations made (N_1).
2. Number of observations in which unsafe behavior was observed (N_2).

Thus, the proportion of unsafe behavior is

$$P = \frac{N_2}{N_1}.$$

If 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, then the total number of required safety behavior observations is derived from (Raouf & Dhillon, 1994)

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

For a given level of confidence K, the value of K is read from the standardized normal tables. For 95% confidence, K is approximated as 2, and for 99% confidence, K is taken as 3.

Confidence level means that the conclusions will be representative of the true population 95% of the time. Accuracy may be interpreted as the tolerance limit of the observations that fall within a desired confidence level. Five percent accuracy with 95% confidence level is the combination often used in SBS. This means that 95% of the time within 5% accuracy limit, the conclusion drawn on the basis of SBS will be representative of the actual population (Stead, Tagg, MacKintosh, & Fadie, 2005).

After conducting a pilot study the proportion of unsafe acts was estimated to be about 33%. 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 3248.

SBS needs to be done randomly. This is achieved when each period of the workday is equally selected as the observation period. So in the next stage the observations are done randomly. This means that both observed workers (64 workers of operational department) and frequency of observations (in the period of 8 h from 7 to 15) were selected randomly.

Since the behavior of human beings might change from time to time, the observation duration has a vital role in accuracy of the results. This duration should be as short as possible to observe and specify the behaviors. In this research the average of each duration was 2 s.

To perform 3248 observations, a nine-digit code was entitled to each worker. The digits were defined as given below:

1. The first three digits: employees' personal code.
2. The next two digits: the day of observing a behavior.
3. The next two digits: the hour a behavior was observed.
4. The last two digits: the minute a behavior was observed.

The observations were carried out randomly by the researcher while the subjects were not aware of the fact that they were being observed.

In order to recognize the relationship between the employees' demographic characteristics and unsafe behaviors, the mentioned variables such as age, work experience, education, previous accidents records and marriage status were collected through interviews and a special questionnaire. In each questionnaire, there were questions about age, education, job experience and previous accidents records. Having been chosen randomly, subjects were questioned by the researcher and their answers were recorded.

It is worth noting that the collected data were analyzed with SPSS and was tested by Exact Fisher test and logistic regression.

3. Results

A total of 3248 observations were conducted in this study. From these observations, 868 were unsafe. Therefore, the proportion of unsafe acts was 26.7%. Among unsafe acts, the awkward posture in working hours was allocated itself as the largest proportion (13.1%) of the unsafe acts. Inappropriate use of personal protective equipments (PPEs) and dangerous driving with 12.8% and 10.1% of all unsafe acts stood in the second and third grade. Employees from 18 to 25 were the most dominant and frequent age group among observed subjects. They made up 30.9% of all sampled population. On the other

Table 2
Frequencies of individual according to age

Age groups	No.	%
18–25	1004	30.9
26–35	954	29.4
36–45	1004	30.9
46–55	237	7.3
>55	49	1.5
Total	3248	100

hand, subjects above 55 had the lowest frequency with 1.5%. The results and frequencies of age groups are given in Table 2.

Considering marriage, 63.6% of the employees were married and rest of them were single. Moreover, regarding the education, the employees with educational degrees made the largest proportion 66.2%. The employees with primary education allocated themselves to the least proportion with 4.4% (Table 3).

According to Table 4 among the observed employees, 23.6% of them had experienced the previous accidents. The results also signified that the work experience of the workers varied from 1 to 18 years, and among them, those whose work experience was less than 1 year formed the most proportion of the observed employees with 42.6%.

Referring to the results, for 63.1% of the employees, the number of unsafe behaviors was higher than 50%. There was a significant relationship between the number of unsafe behaviors and previous accidents records ($p<0.05$). A logistic regression model was used to evaluate the effect of age and work experience on unsafe act. The results are given in Table 5.

Table 3
Frequencies of individual according to education

Education	No.	%
Primary school	143	4.4
Junior high school	240	7.4
High school	2150	66.2
Academic	715	22
Total	3248	100

Table 4
Frequencies of individual according to work experience

Work experience (year)	No.	%
<1	1384	42.6
1–5	383	11.8
6–10	718	22.1
>11	763	23.5
Total	3248	100

Table 5
Result of logistic regression model

Variable	β	SD	Wald	df	Significant level	R	exp(β)
Work experience	−0.43	0.0865	0.247	1	0.0292	−0.2500	0.9579
Age	−0.1144	0.0489	5.4884	1	0.0191	−0.1919	0.8919
Constant	2.1654	1.6777	1.666	1	0.1968		

As one can see from Table 5, the relations between age and work experience on the number of unsafe behaviors are statistically significant ($p<0.05$). The results showed an inverse relationship between the unsafe behaviors with age and also for work experience. This means that, as the employees get older, the number of unsafe behaviors is reduced. This result is consistent with the vast majority of previous studies (Kim, Reicks, & Sjoberg, 2003).

4. Discussion and conclusions

The results of current research in gas treatment company indicated that a large number of employees' behaviors were unsafe (26.7%), which seems to be quite less than the results of previous studies. The rates of unsafe behaviors in other researches in a foundry and a metal working company in Iran were 59.2% and 27%, respectively (Azadeh, 2000).

The consequences of unsafe behaviors depend on different factors such as the nature of the tasks and the type of industry. From safety specialists' point of view, the gas treatment company is a critical workplace due to its high complexity, low flexibility and high vulnerability toward accidents (Kjellén, 1998). Although in the studied treatment company the proportion of unsafe behaviors is approximately low, the risk of such behaviors is unacceptable due to their serious consequences (Kjellén, 1998). Thus the aforementioned proportion of 26.7%, as a marginal value in a gas treatment company, is considered unacceptable.

The most frequent and important behavior was awkward posture in working hours with a rate of 13.1% of all unsafe acts. The evidence is growing that such inappropriate postures are the most important risk factors of inducing work related musculoskeletal disorders (Sheeran & Silverman, 2003), which are considered as the major cause of occupational health problems in developing countries. The expenses of the musculoskeletal disorders are estimated to be $\frac{1}{13}$% of the government budget in 2000 in Iran (Choobineh, 2004). In order to prevent and control these disorders, the evaluation of employees' working postures and specifying the basic risk factors are necessary. To accomplish that, different methods of posture analysis can be employed, among which Rapid Upper Limb Assessment (RULA), Ovako Working Posture Analyzing System (OWAS), Quick Exposure Check (QEC), Rapid Entire Body Assessment (REBA), Hand–Arm-Movement Analysis (HAMA), etc. are worth mentioning (Kristensen, 2000).

Further studies using QEC method revealed that the most important reason for employees to behave unsafely was the lack of anthropometric considerations in work station design. Having measured anthropometric dimensions, equipment and tools dimensions such as height, length and width of tables, chairs, controls, etc. were redesigned to eliminate unsafe behaviors.

The second frequent unsafe behavior was inappropriate use of PPEs with a rate of 12.8%. Inappropriate uses of

PPEs have always been one of the basic factors in accidents. The use of inappropriate clothes and garments was reported as one of the six basic triggers of accidents from 1994 to 2003 in Iran (Arshi, 2006). Plenty of reasons can be mentioned for inappropriate use of PPEs such as lack of workers' knowledge about workplace hazards and PPEs, ignoring workers' opinions in selecting and purchasing PPEs and insufficient supervision in terms of using PPEs properly (Sheeran & Silverman, 2003).

Modern safety approaches lay a great emphasis on identifying and controlling the hazards by administrative and engineering practices. According to this, controlling methods that directly depend on workers' level of acceptance and participation (such as using of PPEs) are not in top priorities and should be taken as the last resort (Sheeran & Silverman, 2003). An important and effective factor for PPE programs to be successful is employees' acceptance and participation (Sheeran & Silverman, 2003). Without considering this issue, it is almost obvious that, in spite of all plans, policies or measures, the PPE programs not only cannot be successful but also they can have some undesirable results. Some factors that might influence employees' acceptance are their frequent participation in selecting proper equipment, conducting training and retraining programs on maintaining, cleaning and using PPEs. A complementary study in company notified that 79.8% of the workers believe that the use of safety equipment in workplace is necessary, meanwhile 33.9% of them had developed this opinion that the PPEs are mainly uncomfortable and 32% of them believed old, worn-out and expired PPEs were not substituted with new ones regularly (Arshi, 2006).

In summary the main reasons related to high frequency of unsafe behavior occurrence in terms of PPE uses are:

- Selecting PPEs without considering task safety analysis, employees' characteristics and present hazards.
- Lack of appropriate training about hazards communication.
- Insufficient participation of personnel in PPE programs.

Dangerous driving was the other frequent unsafe behavior. The road traffic accident is the most important cause of death in Iran. It is reported that 70–80% of road traffic accidents are caused by driver's unsafe acts (Caird & Kline, 2004). It is therefore incumbent on drivers to take part in road accident controlling programs.

The future workshop method was employed to increase the rate of drivers' participation. The workshop was carried out for 5 days and necessary training was given. Then, two of the recommended solutions by drivers (including reforming maintenance systems of vehicles and shift working system) were made operational. The rate of unsafe acts decreased after 6 months from 10.1% to 8.6%.

To decrease driver's unsafe behaviors, implementation of award systems and periodic and regular training were recommended.

It is concluded that 36% of all unsafe behaviors in this gas treatment company consist of awkward postures in working hours, inappropriate use of PPEs and dangerous driving. With more attention to the antecedents, the number of unsafe behaviors can be reduced resulting in a more efficient accident prevention system.

Having studied the relationship among different variables and the number of unsafe acts these results were obtained:

- The relationship between the number of unsafe acts and the previous accidents records is significant. It signifies that the frequency of unsafe acts among workers, who have experienced previous accidents, is more than the others. This result of current study confirms the concept of accident proneness theory that some employees a natural ability or tendency in causing accidents (Blasco, Prieto, & Cornejo, 2003).
- There is an inverse relationship between unsafe behaviors and age. As employees grow older the proportion of unsafe behaviors is reduced. It might be related to the higher work experience and workmanship level and the fact that older employees are usually more skillful.

It is a general view that adolescents are more likely to take risks than middle-aged and older people. This opinion is supported by results from traffic studies, which have shown that young drivers tend to drive faster, follow with shorter headways and not wear seat belts as often as older drivers (Evans & Wasielewski, 1983; Jonah, 1986).

Accidents tend to accumulate on new inexperienced workers (Root & Hoefer, 1979; Siskind, 1982). For example, the risk of a woodworker having an accident on his/her first day on the job can be as much as 50 times higher than that of a worker with 1 year's work experience (Larsson, 1988). The accident risk generally decreases as work experience increases (Butani, 1988; Saari & Lahtela, 1981).

There was also a significant relationship between work experience and previous accidents. This implies the fact that the more work experience people have, the more accidents they might have experienced. No considerable relationship was found between unsafe behaviors and marital status ($p>0.05$).

In order to improve safety behavior of workers, a comprehensive program must be introduced. This could be composed of implementation of appropriate safety management systems, identify and correct unsafe conditions such as temperature or humidity extremes, unguarded equipment, uncovered floor openings, safety training programs, lecture series, etc. (Alexander, Barham, & Black, 2002; Reason, 1990; Roberts, 2004). The SBS study may be conducted on a weekly basis during and upon the completion of the program. The safety behavior control chart for each period following the beginning of the program will show if a significant improvement in unsafe behavior has been achieved. Modification of the program or its components may be carried out as long as the unsafe behavior is being reduced.

Once the minimum number of unsafe behavior has been achieved (i.e. p), the behavior sampling study may be repeated and the obtained data plotted on the control chart to assure that the frequency of unsafe behaviors remains at the desired minimum level.

5. Suggestions

Considering the results, the following items are suggested:

1. Employing task risk analysis methods to screen and determine risky jobs in order to perform ergonomic evaluations and appropriate interventions.
2. Setting and implementing an executive system to accomplish PPE programs successfully. Such programs mainly include appropriate selecting, maintenance and cleaning of PPEs.
3. Design and implementation of accident proneness tests before employment in order to recognize and screen employees with higher natural tendencies in causing accidents. This might prevent such employees from doing critical (safety concerned) jobs.
4. Planning and conducting safety training programs on the basis of behavioral-based safety in gas treatment company in order to improve unsafe behaviors and change false safety attitudes consequently.
5. Design and implementation of punishment and award system considering employees' patterns of behaviors.
6. Periodic evaluation of workers' behaviors in order to provide proper inputs for interventions and measuring their effectiveness.
7. Implementation of a risk management system to determine the risk of unsafe behaviors and presenting suitable engineering and administrative controlling methods.

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