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Human error assessment in Isfahan oil refinery's work station operators using systematic human error reduction prediction approach technique

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ABSTRACT

Aims: The objective of this study was to identify operators' error in distillation units of Isfahan oil refinery.
Materials and Methods: Data were collected through task observation and interviewing with safety authorities, the unit and the shift supervisors and operators to identify and analyze critical tasks hierarchically (hierarchical task analysis). Then, human errors of each critical task were identified using systematic human error reduction prediction approach (SHERPA) technique.
Results: Analysis of the SHERPA work sheets revealed 198 human errors of which 134 (67.64%), 23 (11.61%), 11 (5.6%), 24 (12.12%), and 6 (3.03%) were action, checking, communication, retrieval, and selection errors, respectively. Critical tasks of "performance monitoring" and "communication" were the main tasks of control room operators (C.R.O's). Low occurrence probability and medium occurrence probability were estimated 64% and 36%, respectively. Furthermore, 59% of the identified errors of C.R.O's had no required recovery of which only 29% had critical consequences.
Conclusions: The results showed SHERPA technique can be used as an effective technique to detect human errors in petrochemical and oil refineries.

Key words: Human error, oil refinery, operator, systematic human error reduction prediction approach technique

INTRODUCTION

Today, sensitive systems with developed technologies are used in many industries including nuclear, chemical, military, and medical industries. Since, these systems are always in mutual interaction with humans, their potential risks of human errors are high.[1] Human errors include human performance deviation from the specified rules and duties, which go beyond the system's authorized limit and have adverse effects on the system performance.[2] Incidents such as Bhopal disaster in India showed that despite the developments and the use of automation in industries and reducing the human role in the workplace, human error can still cause human and financial disasters. The reason is that, on one hand, the human tasks in workplace is associated with increased mental-intellectual load and complexities, which

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raises the probability of the error incidence, and on the other hand, as the duties increase, the human error consequences will be more serious.[3,4] Accidents like those in Chernobyl and Three Mile Island caused the human error assessment to become an inseparable part of the studies on the process and safety of the "human-machine" systems. In this respect, many models and theories have been presented to identify and prevent human errors.[5] Keltz express that human error accounted for 60-90% of the accidents.[6] However, recent studies on the accidents showed that 88%, 10%, and 2% of the accidents were due to unsafe actions, unsafe conditions, and unknown factors, respectively.[7]

The studies on human error using different methods were about the systems in which the operator was associated with signals, indicators, and keys. Most of these systems were in chemical, nuclear, process, and rail and air transport industries.[8-12] Unfortunately, little attention was paid to human error assessment in safety parameters and risk assessment in industries in Iran. However, some studies were carried out in this regard in certain industries including, "identification and analysis of human errors by predictive human error analysis (PHEA) technique" and "reliability of the central control room in Mahshar's Emam Khomeini refinery using human error assessment and reduction technique (HEART) method."[13,14] Stanton explains that there is an ultra-organizational thread to oil and petrochemical industries where potentially hazardous materials are centralized in an area and controlled by multiple operators.[15]

The systematic human error reduction prediction approach (SHERPA) technique which deals with identification of errors on the basis of human psychological principles resulting from tasks analysis was first introduced in 1986 and completed in 1994.[16] This technique is used to predict human error, to identify and assess methods for reducing the errors based on the behaviors as was used in hazardous materials transport, gas and oil exploration, cockpit, and ticket vending machine to determine human errors.

Since, the oil refineries are among the critical industries in our country, the consequences resulting from human error will be economically, socially, and environmentally unpleasant. The objective of this study was to assess operators' error in distillation unit of Isfahan oil refinery in order to take effective actions toward the reduction of human errors through identifying and analyzing human errors and providing preventive solutions.

MATERIALS AND METHODS

In this case study, distillation unit of Isfahan oil refinery was selected among its other units due to its importance as an input unit and provider of the raw materials of other units. Data were collected through task observation and interviewing with safety authorities, the distillation unit and the shift supervisors and control room and outside operators (O.S.O's) to identify and analyze occupational tasks disposed to human errors (critical tasks) using SHERPA technique.

The technique is based on the following 8 steps:

- Hierarchical task analysis (HTA): A set of actions necessary to be done respectively to achieve a goal is shown by a Figure or table.
- Classification of tasks: Following the HTA from the bottom level, the tasks are classified into 5 categories:
    1. Action
    2. Checking
    3. Retrieval
    4. Information communication
    5. Selection.

This classification leads analysts to identify the possible errors of the operators.

- Error identification: After the classification of tasks into behavior types, human error of each task made by the operator will be identified by the analyst according to the error taxonomy. For example; if a task belongs to the "action" category, the error modes of all action errors are considered.
- Consequence analysis: The consequences of each error on the system are taken into consideration in this step and the analyst presents a full description of the consequences of the errors identified in previous step.
- Recovery analysis: The consequences of each error are analyzed and the system potential to cover the error is determined in this step. If the system or another task covers the identified error "Has" is entered, otherwise, "Does not have" is entered.
- Ordinal probability analysis: Once the consequences and recovery potential of each error are identified, the analyst estimates the probability of the error occurrence as "low," "medium," and "high."
- Criticality analysis: If the consequence of a given error is critical with no recovery (i.e., it causes unacceptable human and financial losses), exclamation sign (!) or the word "critical" is displayed. If the error does not lead to a serious damage or the error consequence is negligible, then the word "insignificant" or nothing is displayed.
- Remedy analysis: The final step of SHERPA process is to propose error reduction solutions. These solutions are suggested to change the work system in order to prevent error occurrence.

The SHERPA technique was selected according to a comparative study on 6 human error identification methods among, which SHERPA gained the highest score of evaluated criteria (comprehensibility, accuracy, consistency, theoretical validity, practicality, and user acceptability).[17] Later studies also showed that SHERPA technique had acceptable experimental validity (test/Retest).[18-20]

RESULTS

Following the analysis of accidents and quasi-accidents, interviewing with work shift supervisors, and consulting with safety authorities of Isfahan Oil Refinery, 8 tasks, which were subject to human error (critical tasks) were identified among the staff's tasks. The number of people working in distillation unit was 18 in each shift who worked 8 h shifts.

Once the critical tasks were identified, the HTA diagram of each task was drawn in order to determine sub-tasks human errors of each task based on the technique. The result of the HTA related to the critical task of the control room's operator is shown in Figure 1. Table 1 shows the number and behavior types of the identified errors in distillation unit. Totally 198 human errors were identified of which action, checking, communication, retrieval, and selection errors comprised 134 (67.64%), 23 (11.61%), 11 (5.6%), 24 (12.12%), and 6 (3.03%), respectively.

Table 1: The type and number of the identified errors in the distillation unit using systematic human error reduction prediction approach technique

Error code	Error modes based on behavioral taxonomy	Number of identified error
A	Action errors	134
A1	Operation is done too short (quickly)/too long (slowly)	10
A2	Operation is done untimely	9
A3	Operation is done in wrong direction	6
A4	Operation is done too little/too much	8
A5	Operation is inappropriate	2
A6	Right operation is done on wrong object	12
A7	Wrong operation is done on right object	15
A8	Operation is not done (omitted)	45
A9	Operation is done incompletely	27
A10	Wrong operation is done on wrong object	0
C	Checking errors	23
C1	Checking is not done (omitted)	10
C2	Checking is done incompletely	7
C3	Right checking is done on wrong object	0
C4	Wrong checking is done on right object	2
C5	Checking is done untimely	2
C6	Wrong checking is done on wrong object	2
R	Retrieval errors	24
R1	Information are not received	4
R2	information are wrong	10
R3	information are incomplete	10
I	Information communication errors	11
I1	Information communication does not happen	4
I2	Wrong information communication happens	2
I3	Information communication happens incompletely	5
S	Selection errors	6
S1	Selection is not done (omitted)	3
S2	Wrong selection is done	3
Total		198

Table 2 shows the number of identified errors in each task and the behavior classification based on SHERPA technique. Critical tasks of "performance monitoring" and "communication" were the main tasks of control room operators (C.R.O's). The distillation unit had more than 300 thermal indicators, 30 air fans and converters, 20 pumps, and 3 furnaces with 128 burners, which were monitored by the C.R.O. The human errors associated with the task of acquiring information from the previous shift [Diagram 1], which was classified as the information communication was identified and predicted as either lack of information communication, or partial information communication. As the information communication is carried out at the end of the previous C.R.O's shift, it may not be done properly and comprehensively due to the tiredness of the operator. Thus, the probability of the error incidence was considered as medium frequency [Table 3]. Other sub-tasks of performance monitoring refer to the errors of partial information feedback and failure to get information from the indicators, which may cause risks.

On the task of communication with other operators, while the O.S.O communicates with C.R.O through speaker or telephone, O.S.O may receive ambiguous and unclear information due to the low-quality of the communicative system and also the background noise. Therefore, O.S.O either does not react, or probably takes an improper action, which can cause accidents as the former does not perform on time and the latter takes an unsafe action.

On the sub-task of recording reports related to the repairs, leakage, overload, etc., in reports book [Table 3], predicted human errors using SHERPA may be an incomplete and ambiguous recording in the book or failure in recording the reports.

Generally, low occurrence probability and medium occurrence probability of human error in C.R.O were estimated 64% and 36%, respectively. Furthermore, 59% of the identified errors of C.R.O were not covered, of which only 29% had critical consequences.

DISCUSSIONS

The results showed that SHERPA technique which is used in other industries (nuclear power) was an appropriate method for predicting human errors in a refinery's distillation unit as it identified and classified the operators' human errors and revealed latent defects and deficiencies of the system properly. A study in 2005 on the identification of human error in cockpit using SHERPA, HUMAN HAZOP, and HEIST methods also found SHERPA as a better method than the other two in identification and classification of human errors and latent errors and suggested the technique for assessing human errors in human-machine systems.[21] Another study using SHERPA to predict design-induced error on the cockpit found validity and stability of the method as 0.7 and 0.9,

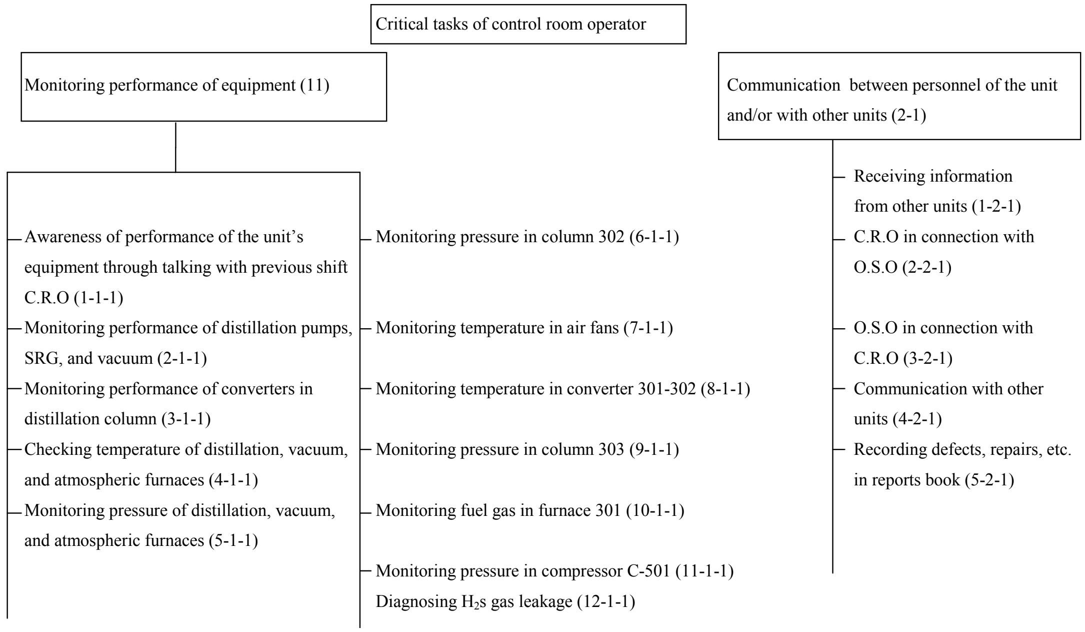

Figure 1: Analysis of the tasks of control room operator using hierarchical task analysis method in distillation unit of Isfahan Oil Refinery

Table 2: Critical tasks and the type and number of their identified errors

Task No	Task name	Action	Checking	Retrieval	Information communication	Selection	Total number of identified errors
1	Monitoring equipment performance	0	2	21	0	0	25
2	Communication and exchange of information with colleagues	2	0	3	6	0	11
3	Setting up and shutting the pump 101	47	2	0	0	0	49
4	Occurrence of emergencies and stopping the entire unit	12	0	0	0	0	12
5	Setting up and shutting the compressor 101	13	0	0	0	2	15
6	Setting up distillation furnaces	18	4	0	0	0	22
7	Routine tasks	14	10	0	0	2	26
8	The process of working license	28	5	0	3	2	38

respectively.[22] Furthermore, a study in 1996 on prediction of the human errors in using ticket vending machine by two experts also showed the values of 0.8 and 0.9 for the stability and validity of the method, respectively.[19] All these studies acknowledged that SHERPA method had a high-efficiency for prediction and control of the human errors in designing and evaluating human-machine systems. Eight critical tasks were identified for the distillation unit of Isfahan Refinery, which conformed to another study which identified 10 critical tasks for the Isomax unit.[13] The identified errors in the present study belonged to the Action category with high- probability of occurrence, which was consistent to the previous studies conducted in this regard in Iran.[13,23] It was also found error taxonomy and instructions were effective when using this technique. As the most of identified errors were forgetting to do the tasks (eliminating some instruction items) [Table 1], it seemed that establishment of an appropriate cultural context for doing the tasks based on the instructions was a strategy to eliminate or reduce this kind of error. The control room of petrochemical systems can be considered as the heart of the refinery units. In this study, performance monitoring in control room was identified as a process disposed to human error, which confirmed previous errors.[13,14] Human errors in these tasks were always critical and of special importance, since the required recovery may not occur in time. This was also the cause of the accident in Texas, since, within 11 min before the explosion, the operator had to recognize 275 alarms and perform necessary reactions, which were not carried out due to lack of time.[13,23,24] Furthermore, incomplete and unclear or failure of recording in reports book were expected as human errors, which could be dealt with using an executive and codified method for recording reports and informing workers of its importance. One of the root causes of the explosion in ISOM unit of BP Company's Refinery in Texas in 2005 was the incomplete and short recording of the overload in the column, which was written incompletely by the previous shift operator and resulted in unrecoverable human and financial losses.[24] A proper communication reduces the probability of human errors. Therefore, communication systems play

Table 3: Systematic human error reduction prediction approach work sheet about tasks of control room operator of distillation unit in Isfahan oil refinery

Error code	Task name	Code of the identified error	Cover	Probability of the error occurrence	Error consequence
1-1-1	Awareness of performance of the unit's equipment through talking with previous shift C.R.O	I3/I2	Does not have	Middle	Negligible-low
2-1-1	Monitoring performance of distillation pumps, SRG, and vacuum	R2/R3	Has	Low	Negligible-low
3-1-1	Monitoring performance of converters in distillation column	R2/R3	Does not have	Low	Critical
4-1-1	Checking temperature of distillation, vacuum, and atmospheric (it is one part of distillation unit) furnaces	R2/R3/R1	Has	Low	Critical
5-1-1	Monitoring pressure of distillation, vacuum, and atmospheric furnaces	R2/R3	Has	Low	Critical
6-1-1	Monitoring pressure in column 302	R2/R3	Does not have	Middle	Negligible-low
7-1-1	Monitoring temperature in air fans	R2/R3	Does not have	Low	Critical
8-1-1	Monitoring temperature in converter 301-302	R2/R3	Does not have	Low	Negligible-low
9-1-1	Monitoring pressure in column 303	R2/R3	Does not have	Low	Critical
10-1-1	Monitoring fuel gas in furnace 301	R2/R3	Does not have	Middle	Critical
11-1-1	Monitoring pressure in compressor C-501	R2/R3	Does not have	Low	Negligible-low
12-1-1	Diagnosing H_2s gas leakage	C1/C5	Has	Low	Critical
1-2-1	Receiving information from other units	R2/R3	Does not have	Low	Critical
2-2-1	C.R.O in connection with O.S.O	I1/I2/I3	Has	Middle	Critical
3-2-1	O.S.O in connection with C.R.O	I2/I3	Has	Middle	Critical
4-2-1	Communication with other units	R2/R3	Does not have	Low	Critical
5-2-1	Recording defects, repairs, etc., in reports book	A8/A9	Has	Middle	Critical

O.S.O: Out side operator; C.R.O: Control room operator

an important role in this regard. As the communication equipment of this unit was old and had technical defects, it caused unclear communication between operators (especially between C.R.O and O.S.O). Moreover, background noise in the site disrupted the communication. This was the reason of the accident in Shell Oil Company in the US in 1997,[25] and the quasi-accidents in this refinery were due to the incomplete reports. Since, such communication system also exists in other units of refinery based on previous studies,[13,24] it is recommended to use modern communication technology like using cordless phones attached to the O.S.O's helmet and soundproofing the rooms in order to control background noise.

Although, system covers to control human error were evaluated and some solutions were presented to increase system reliability in this study, further studies are suggested on the system through fault tree analysis (FTA), since, the distillation unit was built more than 30 years ago, which may result in deficiency of precision tool systems that SHERPA technique is not able to evaluate. Furthermore, the results of this study showed that SHERPA technique identified only the behavioral mode of error and does not provide any information about the environmental conditions affecting error. This weakness of the technique was also expressed in previous studies.[18,21,22] Moreover, studies have shown that the cause of human error is multifaceted and the factors such as job complexities, managerial-organizational, personal, and designing factors are effective in this regard.[14,23] In order to identify these factors, HEART and THERP techniques are recommended to evaluate human reliability. Generally, SHERPA technique can be an effective method for identification of human errors in oil and petrochemical refineries and consequently, prediction of probable risks arising from human error and making reasonable decisions. This technique also presents practical control solutions suitable for the identified error and can help to promote safety, prevent the accidents, and increase reliability of the system by reducing human errors. However, further studies are suggested to identify the roots of human errors, environmental and organizational factors, etc., using methods which evaluate human errors in order to quantify human reliability.

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