Human Errors in a Syringe Factory in Urmia using PHEA

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Abstract

Background/Objectives: Studies show that 60-90% of incidents are directly caused by human errors. The objectives of this study is to determine human errors among manufacturing operators of a syringe factory. Methodology: by identifying the tasks of operators, the tasks of injection, print, assembly and packing operators were determined as important and sensitive tasks. HTA was used to analyze the tasks. Then, PHEA was used to identify the errors related to the tasks. Finally, frequency and types of tasks were determined by the software SPSS-16. Findings: in this study, 175 errors were identified in 8 major and 18 minor tasks of technical engineering, 3 major and 16 minor tasks of injection, 6 major and 7 minor tasks of printing, 4 major and 8 minor tasks of assembly, 1 major and 1 minor tasks of primary packing, 1 major and 2 minor tasks of secondary packing, 2 major and 4 minor tasks of final packing and 5 major and 31 minor tasks of operation. According to results, 103 action errors, 25 checking errors, 10 retrieval errors, 4 information errors, 15 selection errors and 18 sequence errors were identified. Applications/Improvements: PHEA can be used to analyze human errors of tasks and provide solutions to reduce those errors.

Keywords: Error Detection, Human Errors, PHEA

1. Introduction

The history of catastrophic disasters like Flex Borough (England, 1976), Teri Maul Island (America, 1979), Bopal (India, 1984), Chernobyl (Russia, 1986) shows that the role of human factor has shifted from a key element to a leader element in spite of scientific developments; so that, an error can cause a catastrophic incident1.

Since the industrial revolution, lack of interest in mental and physical abilities and limitations of users in designing and manufacturing aerospace facilities has led the military and civil weapons such as airplanes, spacecraft, etc. surpass the capabilities of their users; one of the main outcomes of this was increased rate of human errors in using, repairing and maintaining facilities2.

Studies show that 60-90% of incidents are directly caused by human errors3. A few decades ago, Heinrich studied 75000 incidents and determined the causes of those incidents as unsafe operations (88%), unsafe conditions (10%) and unpreventable factors (2%)4. Therefore, unsafe operations5 and human errors are recognized as major causes of incidents, damages and losses.

Mamagava studied fire incidents occurred in chemical industry during 1968-1980 and found that 45% of 120 incidents were related to human errors6.

Rasmosan7 studied 190 incidents occurred in chemical industries and found that human errors were caused by insufficient knowledge (34%), interface errors (32%), and instructional errors (24%).

Taj Dinan and Afshari8 studied human errors occurred in Ancoiler control room of a pipe manufacturing company and found that most errors were functional in different levels such as forgetfulness, incomplete work, and early or late work.

Gasemi et al.9 performed a study in Zagros Methanol Company in Asalloie and its different departments. They identified 222 errors including 75.5% retrieval errors, 31.97% inspectional errors, 48.62% functional errors, 0.9% selective errors, and 11.7% communicational errors.
Shah Gholi nejad et al.\textsuperscript{10} identified 2813 errors among operators of control rooms in Tehran Refinery. Out of 1331 internal errors identified by TRACERT method, majority of errors were operational (27.27\%) caused by head of the unit shift and supervisor of the department, decision making (30.21\%) caused by board man, and memory (36.6\%) caused by campus operators. Majority of external errors were communication caused by above personnel.

Human errors are controversial in medicine. Kermani et al.\textsuperscript{11} identified 231 errors caused by nurses in 65 tasks including function errors (59.3\%), inspectional errors (25.55\%), retrieval errors (4.33\%), communicational errors (2.16\%), and selective errors (18.66\%); the majority of errors were action errors and the minority of errors was communicational.

Production and preparation of medical syringes require high precision and accuracy; the smallest errors may cause hazardous outcomes for users. Transparency of syringes, visibly scaled piston, non-existing external objects and microscopic organisms are importantly effective factors in production and utilization of medical syringes.

According to Abdolmajid and Shohre\textsuperscript{12}, there were particles visible by naked eye on 46.9\% of syringes manufactured by domestic factories, while this was 3.8\% for syringes manufactured by foreign factories (p< 0.05). Moreover, the average number of particles on domestic syringes (5.1) was significantly higher than that of foreign syringes (0.1; P<0.05). Neglecting each of these cases which can be caused by human errors can lead to catastrophic incidents in pharmaceutics and medicine. This can be the most important risk factor for people who use syringes for drug injection. Therefore, increased precision and reduced error are inseparable functional factors in these industries\textsuperscript{13}.

Different methods can be used for prediction and analysis of human errors in tasks. One of these methods is PETA (Predicted Human Error Analysis) presented by Ambari (1990) and Chemical Circulation Protective Center (CCPS) in 1994. In PETA, human errors are predicted for each task using a series of keywords and listed in a table called as PHEA worksheet; then, control solutions are provided for preventing errors\textsuperscript{14,15}. PHEA is used in chemical industries and repairing activities. The most important advantages of PHEA include its ease of use, systematic function, high reliability, HTA-based function, error prediction and determination of its outcomes\textsuperscript{16}.

PHEA worksheet characterizes the type and implications as well as errors by special codes. These errors include action errors (errors related to how tasks are performed), retrieval errors (errors occurred when finding the thing to be worked on), selection errors (errors occurred due to the lack of label or unsuitable coloring for identifying and selecting equipment) and information errors\textsuperscript{17}.

In PHEA, all tasks are divided into a series of minor tasks through a hierarchical process. Accordingly, all tasks are described in terms of the operations and plans (task refers to those activities which the user performs for achieving the goals of the system; work plan determines the sequence of above operations). Then, each operation is re-described in a lower level based on its sub-series. This continues until the evaluator stops\textsuperscript{18}.

Considering the sensitive role of operators working in syringe industry, the current study identified and analyzed the tasks of technical production engineer, injection operator, assembly operator, printing operator, primary packing operator, secondary packing operator, final packing operator and sterile operator hierarchically (by HTA) and identified human errors in each of the tasks by PHEA.

2. Materials and Methods

This analytical study was conducted to predict and identify human errors occurred by operators working in a syringe factory. This study identified errors related to eight jobs. Inclusion criteria included at least one year of experience and voluntarily participation. Exclusion criterion was unwillingness to participate. The study was conducted in three phases:

1) Identification and Analysis of Tasks by HTA

The tasks were identified by reviewing the literature; then, the tasks sensitive to human errors were selected for the study by interviewing supervisors and workers and reviewing the incidents occurred in the factory. The selected tasks were related to technical engineer, injection operator, assembly operator, printing operator, primary packing operator, secondary packing operator, final packing operator and sterile operator. To collect data, statements of operators were compared to the organizational documents such as job descriptions, bylaws and instructions. Then, major and minor tasks were determined and confirmed by the supervisor of the department. Finally, all major tasks were divided into minor tasks hierarchically and listed in HTA tables.
2) Prediction and Analysis of Human Errors

All human errors related to each task were identified and predicted by PHEA. According to Figure 1, PHEA was used to overview the outcomes of the incidents. In this section, action errors (A1–A10), checking errors (C1–C5), retrieval errors (R1–R4), information errors (I1–I3), selection errors (Sel1–Sel2) and sequence errors (Seq1–Seq2) were evaluated. By determining the nature of errors and their effect on the system, suitable control solutions were suggested for preventing the incidence and eliminating the outcomes of errors. Frequency and type of errors related to each major task and minor tasks were determined. Table 1 exemplifies a PHEA worksheet.

Table 1. PHEA worksheet

| Type           | Sign | Concept                                      |
|----------------|------|----------------------------------------------|
| Action error   | A1   | The action is done lately.                   |
|                | A2   | The action is done early.                    |
|                | A3   | The action is forgotten.                     |
|                | A4   | The action is done very fast.                |
|                | A5   | The action is done very slowly.              |
|                | A6   | The action is done more than enough.         |
|                | A7   | The action is done less than enough.         |
|                | A8   | The action is done partially.                |
|                | A9   | The action is done incorrectly.              |
|                | A10  | Correct action is done incorrectly on an alternative. |
| Checking error | C1   | Checking is done very lately.                |
|                | C2   | Checking is done very early.                 |
|                | C3   | Checking is done incorrectly on an alternative. |
|                | C4   | Checking is done partially.                  |
|                | C5   | Checking is forgotten.                       |
| Retrieval error| R1   | The required information is not retrieved.   |
|                | R2   | The required information is retrieved correctly. |
|                | R3   | The required information is retrieved partially. |
|                | R4   | The required information is interpreted incorrectly. |
| Information error| I1 | Information is not exchanged.                   |
|                | I2   | Information is exchanged incorrectly.         |
|                | I3   | Information is exchanged partially.           |
| Selection error| Sel1 | Selection is forgotten.                      |
|                | Sel2 | The alternative is selected incorrectly.      |

Figure 1. Identification of errors by PHEA.

3. Results

Findings of the study are presented in two parts.

3.1 HTA Results

HTA identified 8 major and 18 minor tasks for technical engineer, 3 major and 16 minor tasks for injection operator, 6 major and 7 minor tasks for printing operator, 4 major and 8 minor tasks for assembly operator, 1 major and 1 minor task for primitive packing operator, 1 major and 2 minor tasks for secondary packing operator, 2 major and 4 minor tasks for final packing operator, and 5 major and 31 minor tasks for sterile operator. In total, 175 errors were identified for 30 major and 53 minor tasks (Figure 2).

Figure 2. An example of HTA for tasks of electrical engineer.

3.2 PHEA Results

The identified errors included 103 action errors (58.85%), 25 checking errors (14.28%), 10 retrieval errors (5.71%), 4 information errors (2.28%), 15 selection errors (8.657%),
and 18 sequence errors (10.28). Therefore, action errors and information errors were the most and the least occurred errors in the syringe factory, respectively (Figure 3 and Table 2).

![Figure 3. The number of errors.](image)

According to Figure 4, the highest number of action errors (36.95%) was related to sterile operator and the lowest number of action errors (0.95%) occurred by primary packing operator.

![Figure 4. Action errors related to tasks.](image)

### 3.3 Error Identification

For technical engineer, the highest number of errors (22.22%) was related to action error occurred when replacing the injection mold (B) incorrectly (A9).

For injection operator, the highest number of errors (40%) was related to action error occurred when performing a correct action on an incorrect alternative (A10).

For printing operator, the highest number of errors (40%) was related to action error occurred when replacing the mold.

For assembly operator, the highest number of errors (37.5%) was related to action error occurred when controlling syringes and filling the silicon tank partially (A8).

| Type          | Sign | Concept                                    | No. | %   |
|---------------|------|--------------------------------------------|-----|-----|
| Action error  | A1   | The action is done lately.                 | 1   | 0.75|
|               | A2   | The action is done early.                  | 1   | 0.75|
|               | A3   | The action is forgotten.                   | 35  | 20  |
|               | A4   | The action is done very fast.              | -   | 0   |
|               | A5   | The action is done very slowly.            | -   | 0   |
|               | A6   | The action is done more than enough.       | 2   | 1.14|
|               | A7   | The action is done less than enough.       | -   | 0   |
|               | A8   | The action is done partially.              | 23  | 13.14|
|               | A9   | The action is done incorrectly.            | 23  | 13.14|
|               | A10  | Correct action is done incorrectly.        | 18  | 10.28|
| Checking error| C1   | Checking is done very lately.              | 1   | 0.57|
|               | C2   | Checking is done very early.               | 11  | 6.28|
|               | C3   | Checking is done incorrectly on an alternative. | 2 | 1.14|
|               | C4   | Checking is done partially.               | 8   | 4.57|
|               | C5   | Checking is forgotten.                     | 3   | 1.71|

For printing operator, the highest number of errors (40%) was related to action error occurred when replacing the mold.
For primary packing operator, half of the errors were related to action errors occurred by the operator when forgetting (A3) to pack the parts (syringe or needle) and the other half was related to sequence errors occurred when interrupting the correct sequence of packing and the need for repeating the packing process (Seq2).

For secondary packing operator, the highest number of error was related to action errors due to forgetfulness (A3) in controlling the packages which may occur because of distraction or fatigue. It is noteworthy that the improperly packed syringes may be exposed to ethylene oxide gas used for disinfection during sterilization and infected by this toxic gas.

For final packing operator, the highest number of errors was related to action error occurred during final control when performing the action incorrectly (A9). Improperly packed syringes may be infected during sterilization.

Accordingly, the number of action errors was higher than other errors. Most of the errors occurred by the sterile operator when setting the sterile tank. The errors related to forgetfulness (A3), partialness (A8) and incorrectness (A9) were the most important errors resulting in failure to perform the task completely and correctly. For example, packing will be done impartially when the technical engineer forgets to replace the packing films in the machine. This will expose the syringes to ethylene oxide gas, which is very toxic and carcinogenic, and infect the syringes.

### 4. Discussion and Conclusion

Findings show that action errors and communication errors were the most and the least occurred errors, respectively. The errors related to forgetfulness (A3), partialness (A8) and incorrectness (A9) were the most important action errors resulting in failure to perform the task completely and correctly. For example, packing will be done impartially when the technical engineer forgets to replace the packing films in the machine. This will expose the syringes to ethylene oxide gas, which is very toxic and carcinogenic, and infect the syringes. This is consistent with Taj Dinan and Afshari who studied human errors occurred in Ancoiler control room in a pipe manufacturing company. They found that most potential and occurred errors were action errors in different levels such as forgetfulness, partialness, lateness or earliness. This is also consistent with Jahangiri et al. who reported the most important reasons of errors as forgetfulness and partialness. Gasemi et al. conducted a study in Zagros Methanol Company and showed that the third highest error occurred (48.62%) was related to action. In this industry, information retrieve is a common task; thus, retrieval errors are more common in this industry and require eliminating the weaknesses identified in system and controlling human errors effectively. While in a syringe factory, the product itself, not information, is handled; thus, only 5.71% of errors are retrieval.

Literature clearly highlights the role of human factor in occurrence of incidents. Hence, it is vital to identify the errors caused by human in different workplaces. Although human errors cannot be eliminated entirely, different techniques can be used to identify and evaluate those
errors and provide preventive solutions including engineering and managerial controls by analyzing the errors. In this regard, it is recommended to use skilled workers, provide and update instructions, prevent unqualified workers from entering to hazardous units such as sterile room, hold training courses for operators, eliminate distractions and use colors for better recognition of valves and regulating switches.

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6. References

1. Brauer RL. Safety and health for engineers. John Wiley and Sons: New Jersey, 2006.
2. Seraji J, Vatani J. Identification and control of human error: Necessary for Aerospace Industry. Article aviation medicine. 2011 Nov; 134–42.
3. Salminen S, Tallberg T. Human errors in fatal and serious occupational accidents in Finland. 1996; 39(7):980–88.
4. Santamaria Ramiro JM, Brana Aisa PA. Risk analysis and reduction in the chemical process industry. Springer: Netherlands, 1998.
5. Mohammad Fam I, Golmohammadi R. Evaluation of safety behavior among coach drivers in Hamadan. Journal of Research in Medical Sciences. 2004; 5(4):251–60.
6. Meshkati MR. Reviewing the occupational accidents of Iran In 2002, Safety at shores Conference, Tehran, Iran, 2003 Feb.
7. Haji Hosseini AR, Jafari MJ. Factors influencing human errors during work permit issuance by the electric power transmission network operators. Indian Journal of Science and Technology. 2012; 5(8):3169–73.
8. Tajdinar S, Afshari D. Ahwaz Pipe Mills Ankvylr machine control room to investigate human errors using SHERPA and HET in 2011. Iran Occupational Health. 2011; 10(3):56–67.
9. Gasemi M, Seraji J. Compared to control and reduce the risk of human error correction technique in the control room Petrochemical SHERPA. Iran Occupational Health. Autumn. 2010; 8(3):14–22.
10. Shah Gholi Nejad N, Jafari MJ et al. Structure of human errors in tasks of operators Working in the Control room of an oil refinery unit. Indian Journal of Science and Technology. 2012; 5(2):2065–70.
11. Kermani A, mazlumiya A et al. Identification and evaluation of human error related to the duties of a nurse in the emergency department of a hospital in the city of Semnan. Journal of Occupational Medicine Specialist. 2010; 4(4):98–108 [Persian]
12. Cheraghali AM, Agasyan S, Amir soleimany K. Comparative evaluation of disposable syringes in for the presence particles visible to the naked eye, University of Medical Sciences BAQYATALLAH. 2003; 8(6(36)):417–20.
13. Lees FP. Loss Prevention in the Process Industries. Butter Worth-Haineman: UK, 2005.
14. Hidemitsu H, Iwaki T, Embery D. Study on the Methodology for Predicting and Preventing Errors to Improve Reliability of Maintenance Task in Nuclear Power Plant. INSS Journal. 2001.
15. Mostia WL. Human error in instrumentation systems. Available from: http://www.controlglobal.com/articles/2006/140/, Date accessed: 09/11/2002.
16. Brazier A, Richardson P, Embery D. Human factor Assessment of safety critical tasks R. 2000; 8–11.
17. Adl J, Seraj JN, Jahangiri M. Seraj Identification and Analysis of Human Errors by PHEA Technique in Isomax Unit of an Oil Refinery. Journal of Petroleum Research. 2006; 15(52):54–62.
18. Stanton N, Salmon P et al. Human Factors Design and Evaluation Methods Review. Defense Technology Center. 2004.
19. Jahangiri M, Adl J. Identify and analyze human errors are predictable licensing process works in Tehran Refinery. Fourth National Congress of Occupational Health hamadan. 2004; 63–9.