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Health and Safety Risk Assessment Using a Combined FMEA and JSA Method in a Manufacturing Company

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Background: Occupational accidents cause three to four times as many deaths in developing countries as industrialized countries. There are about 14,000 accidents in Iran every year, most of them involving workers in industries, To reduce these accidents, it is necessary to use risk assessment, which is a rational approach to hazard assessment and to identify hazards and potential consequences, on individuals, materials, equipment and the environment to reduce the risks of workplace accidents and consequently work-related accidents.

Methods: This study was carried out in 1998 as an analytical-applied study in a manufacturing company. The Risk Assessment process, first with the formation of the relevant team, is selected from technical and production specialists who are more familiar with the concept of safety and risk assessment and again how to perform the Risk Assessment and Identify the risks involved, using the JSA Integrated Method for the analysis of business components and associated risks and FMEA method was trained and targeted to determine system failure states as well as assign risk priority number (RPN).

Results: Risk assessment was carried out in 4 aspects, locations, equipment, main and sub-units and activities leading to the preparation of tables related to the risk assessment guide of locations, equipment, activities, RPN calculation, risk level classification and identification forms.

Conclusions: In this study, 166 hazards were identified and, through follow-up and collaboration with senior management of the organization from 38 risks of fluids production hall, 22 corrective action (57.89%), from 46 risks of solids production hall, 37 corrective action (80.43%), from 33 risks of product warehouse, 28 corrective actions (84.84%), from 30 risks of raw materials warehouse, 21 corrective actions (70%), from 19 risk of incendiary materials, 10 corrective actions (52.63%) were performed. The overall results of the study showed that the major risk in the studied units was related to the dangers of inadequate cabling and placement of people in these work situations.

key words: Safety and Health Risk Assessment, FMEA, JSA, AHA, JHA, THA, Executive Procedure, Guidelines.

Introduction

The increasing development of industries and the creation of new workplaces have increased the need to improve safety and prevent accidents [1]. Risk assessment is one of the key pillars of the HSE's health, safety and environmental management system, and its purpose is to identify evaluation and control the risk factors that affect the health and safety of employees in the industry

[2][3]. Risk assessment is a rational approach to assessing risks and identifying the potential risks and consequences for individuals, materials, equipment and the environment. In fact, it provides valuable data for decision making on risk reduction, emergency planning, acceptable risk level, inspection and maintenance policies in industrial installations and more [4]. According to the International Labor Organization, occupational accidents create the greatest human suffering and economic reparations [5]. Occupational accidents that lead to death are in developing countries 3-4 times as high as in industrialized countries, and in Iran there are about 14,000 accidents annually, most of which are for industrial workers [6]. The direct and indirect costs of accidents impose financial damages employers millions of dollars annually. As estimated by the European Agency for Occupational Safety and Health, 4.6 million accidents occur in EU member states annually, resulting in the loss of 146 million working hours. In Iran too, large sums are paid directly and indirectly due to the loss of active labor and lost working days [3, 7]. Accidents occur due to unsafe conditions or the unsafe practices of individuals and sometimes their combinations. Today, more than one hundred scientific and applied methods are available to evaluate and enhance the various aspects of accident safety and health and accident prevention. One of These methods is Job Safety Analysis (JSA) Technique (Other names for this method are: Job Hazard Analysis(JHA) or Activity Hazard Analysis(AHA) or Task-Specific Questions Hazards Analysis(THA) [4, 6, 8]. This method is very simple and is the least applicable [8], This method accurately and systematically identifies and evaluates potential risks of jobs, first, the job is broken down into stages, and then the risks of each step are identified and at the end of the calculation of the risk number, control action is presented [9, 10]. This approach is an important element in the risk management system. This technique involves analyzing key tasks in the job and identifying risks and identifying safe ways to perform those tasks [11]. The most commonly used method of risk assessment is failure mode and impact analysis, or FMEA that has been implemented in various industries [3, 12-20]. This method examines the effects of malfunctions on the system and is best utilized in the design phase [21]. This method increases the level of safety and reliability of the process level of by early detection and elimination of failures, in addition to substantially reducing the amount of potential damage [22].This method is used to assess system safety hazards, maintenance and repair activities, identify design changes, and corrective actions to reduce the effects of failure on a system [23]. In this way, risk prioritization is done by taking into multiplication the intensity, probability, and discovery that is known as the Risk Priority Number (RPN), which has been confirmed in various studies [24-30]. In a number of studies the calculation of RPN in FMEA risk assessment has been reviewed and confirmed [31-33].The calculation of the RPN makes the risk understandable and reduces it to a tolerable level [34].On the other hand, due to the increasing trend of implementation of health safety and environment system in different industries and current requirements in this field to improve the level of standards. Therefore, the present study was conducted to establish this system, based on safety performance monitoring indices using risk assessment by Innovative and integrated JSA and FMEA methods and calculate the amount of RPN.

Materials and Methods

This study was conducted in a manufacturing company in 1989, as risk assessment requires the use of different specialties side by side (Includes the staff of maintenance and repair units, production, quality control, engineering, research & development, production planning & materials) [20, 35-38], so the risk assessment team was formed and because of the non-random selection of specialists, the target people were selected non-random, based on their expertise, the main criterion for selecting individuals in this study is familiarity with the concept of safety and risk assessment. Therefore, the team was first taught how to conduct risk assessment and risk identification using the combined JSA and FMEA methods and the study objectives were described for them.

Aims of this study

1) Preparing daily checklists including safety of machinery, electricity, fire and ...

2) Preparing safe working guidelines

Overall Objectives of this Study

1) Identify, evaluate and control the existing hazards at workplace and provide applicable control strategies to eliminate or reduce the hazards according to the level of risk accepted by the company management.

2) Given that risk assessments in industries are often limited to remaining documentation and staff who are exposed to risks every day do not have sufficient knowledge of control measures, increased staff understanding of how to implement control measures and operational risk assessment plans.

3) Coverage of Section 4 Components of Occupational Safety and Health (OH&S management system elements) Section 1-3-4OHSAS 18001: 2007 Planning for Hazard Identification, Risk Assessment and Risk Control [39], that complies with clauses 1-1-6, 3-2-1-6-, 4-1-6 and 2-2-1-6 of ISO45001: 2018 standard [40].

Then, using the JSA method risk assessment matrix (presented in Table 1) and the decision criteria for the control measures based on the above matrix (Tables 2 and 3), the risk assessment process was initiated.

The risk assessment matrix of the JSA method derived from multiplying the probability of risk intensity is presented in Tab 1 [41].

Probability	Severity
	Disastrous (1)
Repeated(A)	A1
Likely(B)	B1
Occasionally(C)	C1
Very little(D)	D1
Unlikely(E)	E1

Table 1: Risk Assessment Matrix.

The decision criteria for control measures based on the risk assessment matrix are presented in Tables 2 and 3 [42].

Risk Criterion	Risk Classification
Unacceptable	A1-B1-C1-A2-B2-A3
Undesirable	D1-C2-D2-B3-C3
Acceptable with the need for revision	E1-E2-D3-E3-A4-B4
Minor	C4-D4-E4

Table 2: Decision Criteria for Control Measures.

Level of risk	Actions and timeframe for doing them
Minor A	No action needed.
Tolerable B	No additional control is required, protection of the source of risk is mandatory.
Medium C	Efforts to reduce and risk control are essential.
Important D	The activity must be stopped to reduce risk and prompt action taken to eliminate the risk.
Intolerable E	The activity must be stopped to reduce risk and if risk reduction is not possible, the risk source should be restricted and the device banned

Table 3: Decision Criteria for Control Measures.

Results

The risk assessment was performed in 4 aspects and as described below:

1- *Location*: A list of locations was prepared and recorded in the Location Hazard Inventory file, then each location was individually defined in the Location file and its risks were analyzed separately in the file and based on 4 parameters according to Tables 4, 6 and 7, the risk level was calculated based on the probability, severity, recurrence and the people involved.

2- *Main Equipment and Equipment*: A list of all the main equipment and devices was provided and recorded in the Equipment Hazard Inventory file, then each of the main equipment and devices was individually included in the Equipment file, The risks were separately calculated based on 4 parameters according to Tables 4, 6 and 7, the probability, severity, repetition, and risk factors involved.

3- *Auxiliary equipment and devices*: A list of all auxiliary equipment and devices was provided and recorded in the auxiliary Hazard Inventory file, then each auxiliary equipment was individually included in the auxiliary file, The risks were separately calculated based on 4 parameters according to Tables 4, 6 and 7, the probability, severity, repetition, and risk factors involved.

Risk preference number or RPN was used to determine the risk of failure in each of the three areas. The RPN is the result of multiplying the four risk factors of probability, repetition, severity, and the people involved.

4- *Task*: A list of all activities was first compiled and recorded in the Task Hazard Inventory, then each activity was individually included in the Task file. The risks were analyzed separately by the description of the activity written in the file and based on 2 parameters according to Tables 5, 6 and 7, the probability and severity, the level of risk were calculated.

JSA method was used to identify and analyze the hazards in the activities and the RPN was calculated from the probability and intensity multiplication. The Equipment and Location Risk Assessment Guide is presented in Table 4 and the Activity Risk Assessment Guide in Table 5.

Probability	Repetition	Severity	People involved
impossible	0	Low / Rare	0.1
Almost impossible	0.5	yearly	0.2
medium	1	monthly	1
Likely	5	Weekly	1.5
Very likely	10	Daily	2.5
Forever	15	Hour	4
		always	5

Table 4: Equipment and locations risk assessment guide.

Severity
Low loss
medium
Harmful
Probability
Very unlikely
Unlikely
Likely

Table 5: Risk Assessment Guide for Activities.

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The calculated RPN numbers were calculated according to Table 6.

Risk	Minor / insignificant	very little	Low	medium	Much	very much	Infinitely many
RPN	0-1	1-5	5-10	10-50	50-100	100-500	500-1000

Table 6: Calculates the RPN.

The control measures required to prevent accidents and illnesses caused by hazardous workplace environments were determined and implemented according to Table 7 according to the type of risk and risk level (figure 1) (figure 2).

Risk	Minor / insignificant	very little	Low	medium	Much	very much	Infinitely many
Time to do	Acceptable	Less than a year	Less than 3 months	Less than a month	Less than a week	Less than a day	Quickly

Table 7: Risk Level Classification.

Figure 1: Frequency distribution of identified risks in different halls.

Figure 2: Number of corrective actions taken.

Discussion

In this study, 166 hazards were identified, and through follow-up and collaboration with senior management of the organization from 38 hazards of liquid production hall, 22 hazards of corrective actions (57.89%), from 46 hazards of solids production hall, 37 corrective actions (80.43%), from 33 hazards product warehouse, 28 corrective actions (84.84%), from 30 hazards of raw materials warehouses 21 corrective actions (70%), from 19 hazards of flammable materials 10 corrective actions (52.63%) were performed. The levels of risks obtained are presented in Charts 1 and 2, respectively.

The outputs from the risk assessment carried out are as follows:

a. Control measures needed to prevent accidents and illnesses caused by workplace harmful factors.

b. Develop working guidelines to increase employee awareness.

c. Reduce staff exposure to hazardous factors in the workplace by defining workflow.

d. Define the hours of work and overtime in different parts, especially the difficult parts.

e. Safety training for managers, bosses, supervisors and workers to improve work performance and identify and understand workplace hazards.

f. Preparation of HSE Action Map for control measures.

g. Preparation of guidelines and regulations for allocating the number and types of personal protective equipment to the personnel of the target units.

h. Developing safety and hygiene and information discipline rules and regulations at the organization level for implementation by all staff.

Due to the combination of the JSA and FMEA risk assessment methods and the basic characteristic of the JSA method that provides detailed job analysis that identifies and assesses work hazards as a result of the staffing process [43].Then, with FMEA method and RPN risk priority calculation, risk assessment was more accurate. Comparison of the risk level results showed that the major risk in the studied units was related to the dangers of inadequate cabling and placement of people in these work situations, which is consistent with similar studies [44]. The results of this study showed that educating workers will greatly reduce risk and is consistent with similar studies [38, 45, 46].The simultaneous use of training and work instructions, which is one of the outcomes and outputs of the Risk Assessment Operational Program (b, e and g), is one of the most important ways of controlling and reducing risks and enhancing staff safety knowledge and is consistent with similar studies [47-52].

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