RESEARCH ARTICLE

• Arch Hyg Sci 2017;6(3): 250-258
• Journal Homepage: http://jhygiene.muq.ac.ir

Investigation of the Effect of Control Measures on Reduction of Risk Events in an Edible Oil Factory in Tehran, Iran

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A-R-T-I-C-L-EI-N-F-O

Article Notes:
Received: Mar. 8, 2016
Received in revised form: Jun. 8, 2017
Accepted: Jun. 21, 2017
Available Online: Jun 28, 2017

Keywords:
Risk Assessment,
Occupational Safety,
preventive measures,
Risk
Edible Oil
Iran.

A-B-S-T-R-A-C-T

Background & Aims of the Study: Identification of hazards is one of the first goals of risk analysis. Failure mode and effect analysis method (FMEA) is universally defined as efficient procedures for finding potential failures aimed to remove or decrease the risk which is related to them. This study aimed to investigate the effect of control measures on reduction of risk events in an edible oil factory in Tehran.

Methods: This cross-sectional study was conducted in an edible oil factory in Tehran, Iran. For this, a four-member team of safety engineer experts was formed. Some factory units were selected randomly. After that, in all units, probability, severity and detection probability of hazards in all processes and tasks were assessed based on FMEA method. Regarding to the RPN, some control measures were taken to reduce the risk of events. After 9 months, risk assessment was repeated; primary and secondary RPNs were compared with each other to investigate the effect of interventions.

Results: The results showed that highest and lowest probability of hazard were related to installation and can production unit, respectively. The highest and lowest severity of hazard were related to tool and can production unit, respectively. There was a significant difference between the probability of hazard in can-making and filling units, before and after the interventions. There was a significant difference between the severity of hazard in can-making, filling and neutralization units, before and after the interventions. As well, total probability, severity and RPN had a significant difference in all parts of the factory before and after the interventions.

Conclusions: According to the results of this study and the overall risk reduction caused by interventional measures, it can be concluded that, FMEA is a successful method for identifying hazards and risk control measures.

Please cite this article as: Kolahdouzi M, Halvani GH, Nazaripour Abdehgah E, Ghaljahi M, Yazdani Aval M, Abbasi M. Investigation of the effect of control measures on reduction of risk events in an edible oil factory in Tehran. Arch Hyg Sci 2017;6(3):250-258.

Background

In the edible oil production process like other industrial process, there are many risks in terms of safety, health and environment. In this industrial environment if an accident happens there will be the possibility of injury to personnel, equipment and environment. In the study of String fellow it was stated that 88 percent of industrial accidents is due to individuals' insecure performance (1). Based on ILO report, 317 million accidents happen on the work annually and around 6300 individuals' daily deaths occur due to occupational accidents or work-related diseases, subsequently economic burden of these accidents is about 4 percent of global Gross Domestic Product (2). To reduce the accident's risk level, performing risk analysis by standard methods is very useful and hazards identification is one of the first goals in the risk analysis. There are a lot of methods for hazard identification and one of them is failure mode and effect analysis (FMEA) (3). FMEA is an anticipatory instrument with a bottom-up method to recognize all potential damage of a product, process or system before they occur and have adverse effects on system or process. It records each potential failure mode, its effect, cause of failure and available and reasonable controls (4). FMEA has been used successfully to predict how a working process has failed. Many studies have shown that the technique is a powerful method to prevent accidents occurrence and it has been used frequently in high risk industries such as aerospace and nuclear power plants (5,6). Generally, FMEA is defined as a systematic process for identifying potential failures aimed to eliminate or minimize the risk associated with them (7,8). Once risks are identified and assessed by FMEA, risk-reduction measures can be introduced. The management system is served to address intolerable risks, focus on validation efforts, improve environmental condition which surrounded the dangerous installations and maximize the business value of organization (9). The more precise the safety management systems, the better safety performance of the system (10). FMEA has been used in many manufacturing industry and clinical laboratories to identifying risks and it has been used for improvement safety programs (8,11,12).

The edible oil factory is considered as one of the important industries in our country, Iran. There are no enough studies related to the identification, assessment and control of hazards in this industry. In some similar studies, while using FMEA only RPN is considered while in the present study, in addition to the analysis of risk number, other factors such as severity and probability of the accident that affect the level of risk were considered. In other word, the innovation of this study was that, in addition to identifying and evaluating risks and suggestion of control measures, these measures were implemented operationally.

Aims of the study:

Therefore, this study was done in order to investigate the effect of some control measures on reduction of events in an edible oil factory in Tehran in 2014.

Materials & Methods

Methods

This analytical-descriptive study conducted in an edible oil factory in Tehran in 2014. Among several active units in the factory, some of them were selected randomly and FMEA method was conducted for risk assessment. This study was carried out by a team consisting of researchers, Health, Safety and environment (HSE) experts, production engineer, experienced foreman and one of the skilled workers. In all units, probability rate, severity rate and detection probability in all processes and tasks were assessed based on FMEA method. Regarding to the RPN, some control measures were taken to reduce the risk of events. Interventions were conducted for 9 months and risk assessment was repeated; also, primary and secondary RPNs were compared with each other to investigate the effect of interventions.

System description

After visiting and assessing various parts of selected units, probability, severity and detection probability of hazards were recorded in FMEA standard worksheets (13). Also, the risk of each hazard was obtained and control measures were expressed. Tables of the severity, risk probability and risk number required before and after the control measures are presented separately.

Identification of Hazards

Identifying hazards in selected units (including cans' production, filling, tools' production, neutralization and installation units), identifying worker's duties and the ways they do that, identifying current instructions and regulations in the factory, observing documentations related to recorded accidents was conducted by factory inspection and interview with the workers and their supervisors.

RPN Methodology

The RPN is a mathematical production of the probability, severity and detection. The RPN is applied to recognize the most dangerous failure mode and doing corrective action. Decision making about hazard is based on RPN score and crisis level. RPN score is according to the fact that hazards with upper risk urgency have priority for evaluating and resource allocation. The expert team should focus on failure modes with higher RPN. RPN is attained by multiplying three elements of severity, probability of occurrence and detection possibility. It is obtained according to below equation (5,14,15);

$$RPN = Occurrence \times Severity \times detection$$

Determination of the Severity Rate

Severity is related to the importance of the impact of a potential failure mode. Severity rate of the risk is considered just in case of effect seriousness. Decreasing the severity is achievable only by the process change and altering the way of executing activities. The higher the severity rate, the worse the effects of hazard.

Determination of the Probability of Occurrence

Probability of occurrence expresses the likelihood that a risk will occur. Probability is a number between 1 and 5; number 1 indicating that the probability of situation is very low and 5 showing that it is very high probable (16).

Risk Matrix

A risk matrix describes the different levels of risk. It is a product of the combination of the effect of probability and severity categories (17).

Interventional Measures

Implementation of corrective actions such as guarding, replacement of tools and equipment, use of earthing system in all understudied units, use of personal protective (PPE), regular inspection of equipment, limitation of dangers by changing the distances between personnel and equipment, installing warning symbols such as auditory or visual warning alarms, labeling such as installing emergency call numbers on the boards, providing special instructions and safety education programs for workers, monitoring and improving the lighting system were conducted for nine months. Safety training was carried out based on daily Tool Box Meeting.

Statistical Analysis

For deceptive and analytical analysis, SPSS 23 was used. The Wilcoxon Signed Ranks Test and paired sample T test were used to compare the mean of severity and probability of hazard in each unit. The Tests of Within-Subjects Effects was used to compare above mentioned two factors between all units before and after the control measures; also, the Tukey's range test was used to more investigation. In order to obtain a clearer effect of the interventions on the risk parameters, unit's type was considered as a confounding factor in this model. To verify the accuracy of the results of the repeated measures model, Levene's test of homogeneity of variances, Mauchly's sphericity test and Q-Q plot for normality of residuals were used. The marginal homogeneity test was used to study the effects of interventions. Test of within subjects was conducted to study the difference of RPN among all units in factory before and after the interventions.

Results

The results showed that the highest probability of hazards was related to installation unit. The probability of hazard in this unit was 4.5 and 3.25 before and after the intervention, respectively. The lowest rate of this parameter was related to cans production unit and the probability of occurrence before and after the intervention was 3.6 and 2.8, respectively. The results of the comparison of severity rate among units showed that tools production had the highest severity rate before the intervention (4.75) and it was reduced (to 3) after interventions. The lowest severity rate among unit was related to cans production unit with score 4.07 before the interventions and it was reduced to 2.42 after interventions. Comparison of probability and severity of hazard among units before and after the interventions is presented in figure 1 and figure 2, respectively.

Tools production unit

Regarding this, sample size was very small (n=4) in tools production unit, the median was used as a criterion to measure and describe the severity and probability rate, as well, the Wilcoxon Signed Ranks Test was used to compare the mean of severity and probability of hazard in this unit. The results showed that (table 1), there was no statistical significant difference between probability and severity rate before and after the interventions (alpha=0.1).

Can production unit

Considering this, sample size (n=33) was more than 25 in the can production unit. The mean was used as a criterion to measure and describe the severity and probability rate and also, the Paired Samples Test was used to compare the mean of severity and probability of hazard in this unit. The results showed that (table 1), there was a statistical significant difference between probability and severity rates before and after the interventions ($p_{-value} < 0.001$).

Neutralization unit

As the reason was above mentioned for tools production unit, the median was used as a criterion to measure and describe the severity and probability rate, as well, the Wilcoxon Signed Ranks Test was used to compare the mean of severity and probability of hazard in this unit. The results showed that (table 1), there was a statistical significant difference between severity rate before and after the interventions ($p_{-value}=0.05$). There was no statistical significant difference between probability rate before and after the interventions.

Can filling unit

The results of the Paired Samples Test showed that (table 1), there was a statistical significant difference between probability and severity rates before and after the interventions ($p_{-value} <0.001$).

Installation unit

The results of the Wilcoxon test (table 2) showed that there was no statistical significant difference between probability rate before and after the interventions ($p_{-value} = 0.059$).

The Tests of Within-Subjects Effects was used to compare the mean of probability and severity between all units before and after the control measures. The results of the test (table 2) showed that there was a statistical significant difference between the mean of probability and severity before and after the interventions in all units ($p_{-value} <0.001$). These results are depicted in table 2.

The Tukey's range test was used to more investigation. The results showed that, the probability of hazard in each unit was different with others. The results (fig. 3) showed that, the probability of hazard in installation unit with can production unit was significantly different ($p_{-value}=0.031$).

The test of Within-Subjects Effects was used to compare above mentioned two factors between all units before and after the control measures. The results showed that (fig. 4), there was a statistical significant difference between the mean severity and probability rates before and after the interventions (p_{-value} <0.001). It was also clear that there was no significant difference related to mean severity rate between different units (p_{-value}=0.333).

The Marginal Homogeneity Test was used to clarify the effect of intervention corrective measures on risk levels. The result showed that there was a significant difference between marginal distribution for before and after the intervention (p_{-value} <0.001). Considering these results, risk levels were categorized in three levels including acceptable, relatively acceptable (with modifications) and unacceptable. The later was categorized to three categories including low, average and high unacceptable risk levels. Before the implementation of control measures, low unacceptable risk level was 15.07% and relatively acceptable and acceptable risk levels were 45.21% and 39.73%, respectively. After the implementation of control measures, the amounts of low unacceptable risk level and relatively acceptable risk level were reduced to 2.77% and 5.56%, respectively. While, the amount of acceptable risk level was increased to 91.67%. The results showed the positive effect of control measures on the risk level in the factory which is provided in fig. 5.

The Test of Within-Subjects Effects was used to compare the mean RPN before and after the control measures in all units. The results showed that (fig. 6), RPN was significantly different between before and after the interventions (p_{-value} <0.001). The results showed that (fig. 6), there was no significant difference between mean RPN in different units (p_{-value}=0.077).

Table 1) comparison of the mean of probability and severity and detection scores before and after the interventions.

	Unite	mean of severity/probability score before the intervention	mean of severity/ probability score after the intervention	p_{-value}
Severity	Tools production	4.75	3	0.06
	Can production	4.07	2.42	0.001
	Neutralization	4.4	2.8	0.038
	Can filling	4.18	2.75	0.001
	Installation	4.25	2.75	0.063
Probability	Tools production	3.75	3.25	0.157
	Can production	3.57	2.8	0.001
	Neutralization	3.8	3	0.05
	Can filling	3.84	3.21	0.001
	Installation	4.5	3.25	0.05
Detection	Tools production	3.25	3.25	1
	Can production	3.12	2.85	0.01
	Neutralization	3.2	3	1
	Can filling	3.33	3.33	1
	Installation	2.75	2.75	1

Table 2) descriptive and statistical analysis of probability and severity rate before and after the interventions.

Variable		Average±SD	p-value
Severity	S1	4.2±0.81	0.001
	S2	2.65±0.58	
Probability	P1	3.8±0.72	0.001
	P2	3.06±0.65	

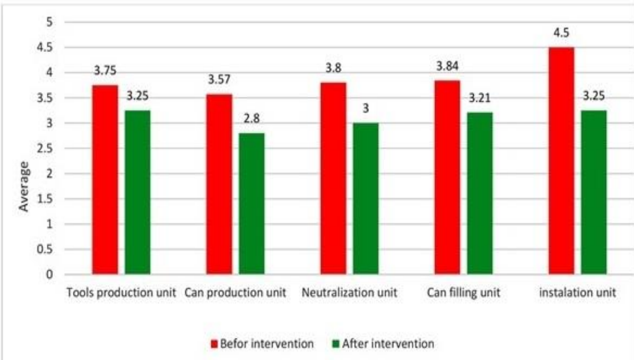

Figure 1) Comparison of probability of hazard in the units before and after the interventions.

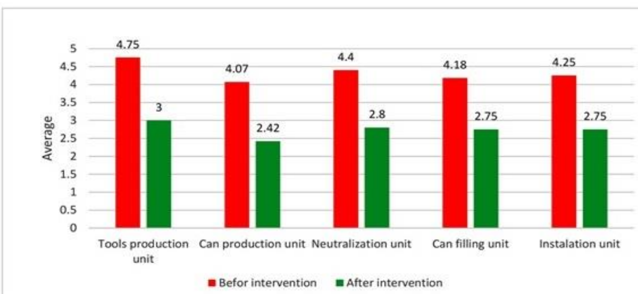

Figure 2) Comparison of severity of hazard among the units before and after the interventions.

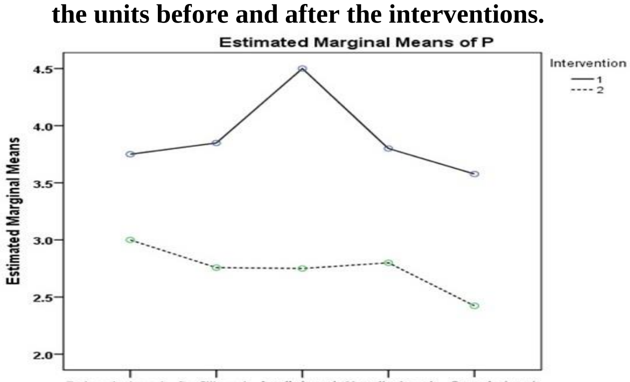

Figure 3) Comparison of mean score of probability rate in all the units before and after the interventions.

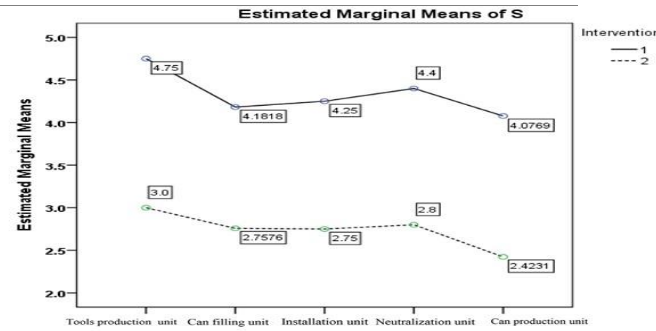

Figure 4) Comparison of mean severity rate before and after the interventions in all the units.

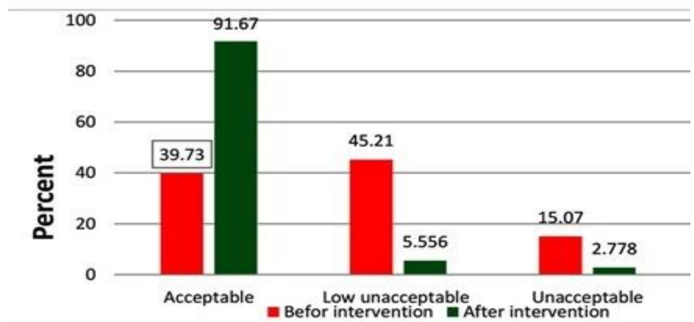

Figure 5) Frequency of risk levels before and after the interventions.

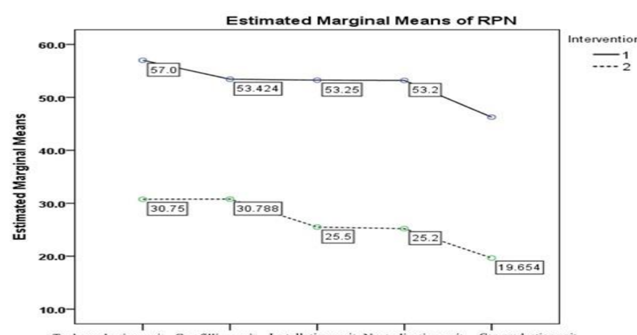

Figure 6) Comparison of risk levels before and after the control measures in all the units.

Discussion

The present study was conducted to identification and assessment of potential risks in an edible oil factory based on FMEA method and study the effects of corrective actions on the risk levels. The results showed that, there was a significant correlation between severity and probability rates before and after the corrective actions. These results are in line with other studies (10). There seems to be several reasons for this consistency. It is clear that, for example, implementation of the corrective measures, based on output of risk assessment process can leads to reduction of risks and also reduction of probable losses caused by these risks. The results of another study such as Pareek et.al (18) showed that the highest risk score was related to installation unit. The similar results observed in the present study. Thus, there are instantaneously several risk factors and dangerous conditions such as material and equipment for lubrication, welding, electric tools and splurge caused by repair of equipment which lead to potential risks in this unit. Moreover, physical conditions in this unit including inappropriate lighting, noise annoyance generated by equipment and also gases or vapors released from different material, can cause high probability of hazard in installation unit.

It should be noted that, involving the managers in the risk assessment process and considering their points of view in regard to control measures will facilitate implementation of the measures. The results of the present study showed that, if the proposed interventions by researchers take into account economic and physical considerations of the workplace, it will convince the manager to accept the implementation of interventions. For instance, such corrective measures and actions, such as on time maintenance and inspection, requiring workers to follow the instruction in tasks and implementation of safety management system will minimize the potential risks by reducing the probability and severity of consequences of hazards in an industry.

In the present study several corrective measures were taken. Some of the interventions were included guarding, replacement of tools and equipment, use of personal protective equipment (PPE), limitation of hazards by changing the distances between personnel and equipment, installing warning symbols such as auditory or visual warning alarms and providing special instructions and educations. A significant reduction of risk level in the studied units was observed after implementation of the interventions. Bonfant et.al (17). showed a significant reduction in risk level after implemented some corrective measures of a hospital in Italy. It should be noted that, some of interventions, such as using specific operational instructions and providing educational courses for new personnel in their study were similar to our interventions in the present study.

In another study conducted in Department of Pediatrics of a hospital in Italy, Lago et.al (16). using FMEA showed that, the highest faults in prescription of drugs were related to calculate the dose and amount of prescribed drugs. They had provided some corrective measures such as defining specific instructions for physicians and nurses in the hospital. Lago et.al observed that the risks level is reduced after the intervention. It can be concluded that, interventional corrective measures can lead to reducing the risk level in different industries and organizations. In another study by Intra et al in 2016 (19), the authors showed that some corrective measures including staff training can lead to the reduction in risk level. These results are in consistent with the results of present study.

Based on the results of this study, according to the overall risk reduction caused by interventional measures, it can be concluded that, FMEA is a successful method for the identification and control of risks.

It must be considered that, implementation of a proactive program to reduction of hazards risk level in industries is considerable. One of the most important elements to prevent the occurrence of accidents in industries is following an appropriate safety programs. In a good safety program, in addition to the assignment of personnel duties in detail, it can improve the level of responsibility in all of the top managers, headman, supervisors and contractors. To reach this goal, applying some comprehensive risk assessment methods is necessary to monitor and evaluate all jobs, equipment, machinery and behavior of personnel in the workplace.

There were several limitations in our study. We were allowed to study only 5 of 12 units. There was also insufficient fund to carry out further interventions. Thus, the risk level could be more reduced because we were forced to ignore some better measures.

Conclusion

Based on the results of this study, according to the overall risk reduction achieved by interventional measures, it can be concluded that, FMEA is a successful method for identifying hazards and risk control measures. As well as, interventional measures like those which mentioned above in the material and method section can be effective in minimizing the risk in edible oil factory.

Footnotes

Acknowledgement:

This article is extracted from Master's Thesis. The authors would like to acknowledge the financial support of Yazd Shahid Sadoughi University of Medical Sciences. As well, the authors would like to appreciate all honorable participants and the entire staff of the oil factory for their gracious cooperation.

Conflict of Interest:

The authors declared no conflict of interest.

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