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Environmental, Health, and Safety Risk Assessment in Marun's oil Field using the FMEA Method

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Abstract

Today, the oil and gas industry is economically ranked highly on a global scale. On the other hand, it is an industry that has various effects on humans and the environment. Therefore, attention to the HSE sector in this industry is an important factor, and environmental risk assessment has become one of the most important management tools in this area. With its vast oil and gas resources, Iran is the second largest producer of OPEC (organization of the petroleum exporting countries), and all exploration, extraction, production, and exploitation stages of oil and gas have extreme environmental and ultimately adverse effects on human beings; hence one of the management factors of such projects is to enhance safety and reduce accidents and environmental damages to increase the welfare of human resources with a safe and sound environment. To identify and assess the risk of Marun's oil field, all safety, health, and environmental hazards from the year 2019 to 2020 were studied, and causal relationships between them were determined. The FMEA risk assessment index was used to assess Marun's environmental, safety, and health hazards and the effective factors.

Keywords: *Risk Assessment; Health; FMEA method; Environment; Safety.*

1. Introduction

In order to achieve its goals and help people protect themselves, their assets, and their activities against events that always endanger them, risk management uses specific sciences, principles, and criteria to organize a systematic approach so that economic individuals, entities, and institutions (industrial and commercial) can create a vision in assessing, controlling and financing damages and make plans to deal with possible future phenomena [1-3].

The importance and role of risk management in developed economies in achieving organizational goals is well known, and they benefit from their achievements, which is not the case in most developing countries. However, despite the significant losses resulting in risk management and assessment systems on the property, assets, facilities, and human resources, considerable efforts have not been made to minimize the damages, and there is no adequate financing to compensate them. This is also true in Iran [4-6].

The emergence of many prominent political, economic, military, scientific, and technological phenomena in the last century, from the Russia-Japan wars, World Wars I and II, and the Korean War, up to the advent of cars, television, computers, global warming, nuclear weapons and atomic bombs, and natural disasters such as earthquakes, hurricanes, and tornadoes, have led to new studies on their causes, effects and predictions in all areas of evolution and improvement of risk management and assessment [7-9].

1.1. Common methods in risk assessment

There are multiple ways to assess and visualize the potential risks of a project or development activity. Each method needs its own resources, and context is important in applying methods and technologies for evaluating options to have significant efficiency in evaluating specific designs. Furthermore, not all methods evaluate an environmental plan or project equally effectively. Therefore, each method has its own advantages and disadvantages [10-12].

The most common methods in risk assessment are operation and risk study methods, fault tree risk assessment, failure mode event analysis, and its effects [13].

2. Analysis of failure mode event analysis and its effects on failure modes and effects analysis

FMEA was first used in the US military. The Military Standards were published on November 9, 1949 (Defect Analysis, Related Impacts, and Significance). Following this standard, errors or defects are classified in terms of their impact on the ultimate goal and the level of safety of personnel and equipment [14-18].

The first official application of this analysis, FMEA, was in the aerospace industry in the United States. FMEA was introduced as an innovation and initiative to prevent irreparable mistakes and errors at the time; each occurrence caused huge damages and loss in capital. FMEA is an engineering technique used to identify and eliminate errors and potential problems in the system before they occur. It moves towards identifying and ranking the causes and effects associated with it. Risk prioritization is based on the probability of occurrence, severity, and detection of potential risks [19-20].

An important indicator in the FMEA is the RPN risk priority number, which is the multiplication of the probability of occurrence of an accident, the severity, and its detection (diagnosis).

$$RPN = O \times S \times D \quad (1)$$

where O is the probability of the occurrence of an environmental event: indicating the possibility of the occurrence of consequences in a certain period of time [19-21]; S is the severity of the effect: It indicates the extent of damage and loss that will occur if environmental consequences are actually realized [19-20]; D is the probability of detection: It indicates the probability of identifying the outcome or causes of the outcome [19-22].

The risk factor with high RPN should be considered with caution. The main purpose of risk management is to maintain the risk at an acceptable level and alter unacceptable risks to an acceptable level [14].

3. Settings

Marun Field is an oil field located in the Khuzestan province of Iran and is the second-largest oil field in Iran. The field was discovered in 1963, owned by the state-owned National Iranian Oil Company (NIOC2), and operated by the National Iranian South Oil Company (NISOC) [4].

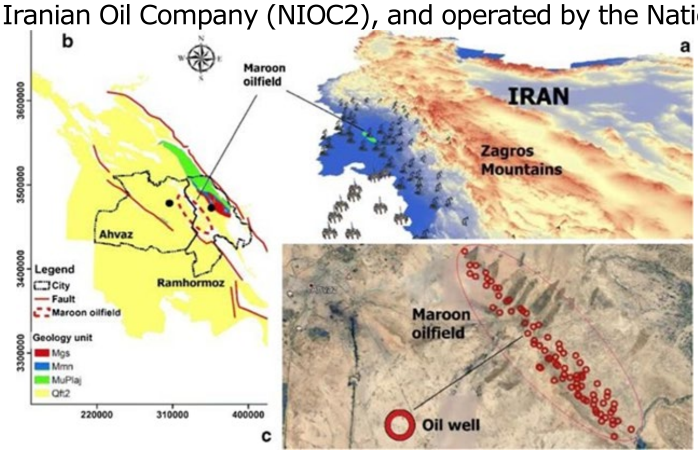

Figure 1. Location of Marun [23]

The Marun field contains estimated recoverable oil reserves of 22 billion barrels, making it the world's sixth biggest onshore oil field in the world.5 Marun is currently producing approximately 520,000 barrels per day (83,000 m^3/d) of crude oil daily. It is the second biggest producing oil field in Iran, after Ahvaz Field [4].

The super-giant Marun field has long been one of Iran's most prolific oil fields. It reached a peak of 1.34 million b/d in 1976, and although it has since declined, it remains in the top three producing fields alongside Ahvaz Field and Gachsaran Field [4]. The smaller Kupal and Shadegan oil fields are located north and south of Marun. The Marun field was brought on stream in 1966, and its production gradually increased to more than one million barrels of oil daily in

1972 [4]. It consists of two oil reservoirs and one gas reservoir named Asmari, Bangestan, and Khami [22-24].

4. FMEA objectives

FMEA is an inductive method (specific to the general approach) and has two major goals:

1- Identifying important defects that have reliability, accessibility, and maintainability and affect the safety of the system in general.

2- Determining the effects of failure modes in the components of a system on different functions of the same system [23-24].

5. Steps

5.1. Data collection

The device or location where risk assessment is performed must be identified thoroughly, and activities and processes should be examined carefully. The characteristics of the region, processes, and the environment were also studied in this study.

5.2. Definition of the scale of severity, occurrence, and detection

Table 1. Effect severity of risks

Effect	Degree of effect	Definition/examples of effect severity
No effect	1	No occurrence of negative environmental hazards and effects
Insignificant	2	The risk to staff and the environment is not significant
Partial	3	Poses a risk to staff and the environment
Low	4	Hazards cause inconvenience to staff and environmental elements / significant effect
Average	5	Effects of risk on the environment lead to visitation from health officers and cessation of work
High	6	Hazards cause significant and irreparable damage and pollution to the environment
Very high	7	Hazards in the environment should be cleaned, treated, etc.
Serious	8	Hazards in the environment lead to the destruction of some elements of the environment or pollution.
Critical	9	Hazard in the environment leads to the loss of vast resources in the environment or creates a great deal of pollution.
Catastrophic	10	Hazards in the environment are such that they affect natural resources, animals, plants and humans, as well as neighbors and neighboring workshops.

Table 2. Probability of risk occurrence

Effect	Degree of effect	Possibility of occurrence
Never	1	The occurrence of hazard is unlikely/ one in 10 years.
Possible	2	The amount of hazard occurrence is scarce/ one in every 5 to10 years.
Insignificant	3	The amount of hazard occurrence is very low/one in every 3 to 5 years.
Partial	4	Possible risks or events / one in every 1 to 3 years.
Very few	5	Possibility of multiple risks /occasional failure/ one event per year.
Low	6	The number of failures is low/one event every 6 months toa year.
Average	7	Failures occur on average/one event every 3 to 6 months.
High	8	Probability of significant risks / one event every month.
Very high	9	Probability of occurrence is very high / one event every week.
Certain	10	The occurrence of danger is certain / History has shown that danger has always existed/ more than one event per day.

Table 3. Probability of detecting (diagnosis) hazards

Effect	Degree of effect	Definition/examples of detection probability
Certain	1	Potential hazards are almost certainly detected with existing controls.
Excessive	2	Process hazards are detected by indicator systems and potential hazards are alerted.
A lot	3	The risk is identified and controlled through laboratory measurements and tests.
High	4	Hazards are identified and discovered through tracking and auditing the current situation/ observation control/ daily monitoring.
Average	5	Relative risk control and identification through the staff's scientific and experimental skills.
Low	6	Potential hazards are identified through random visitations and available guidelines.
Few	7	Methods used to identify and control the hazard are completely experimental with usage of reliable equipment; in terms of accuracy and precision.
Very few	8	Identification and control of danger, according to the Supervisor of Safety, Health and Environment report. Completely experimental without the use of special equipment.
Partial	9	Unlikely detection of risk with existing controls.
Unknown	10	Has no control or, if present, is unable to detect potential danger.

- Identifying potential process risks, problems, and improvement costs.
- Identifying the consequences of failure to subsequent processes, operations, customers and government regulations. The effects of any hazard are potential effects that endanger the safety of individuals. Danger effects such as fire, poisoning, fractures, etc.
- Identifying the root causes of potential hazards.
- First level method / method for detecting / preventing process failure.
- Severity: Importance of rank in potential risk.
- Occurrence rating: Frequency estimation for potential causes of failure.
- Detection rating: The probability of detecting the specific causes of failure.
- RPN calculation: the result of three inputs (severity, occurrence and detection) [5,21-22].

Table 4. Multiplications and the final results of RPN

		Severity									
	No.	1	2	3	4	5	6	7	8	9	10
Probability	1	1	4	9	16	25	36	49	64	81	100
	2	2	8	18	32	50	72	98	128	162	200
	3	3	12	27	48	75	108	147	192	243	300
	4	4	16	36	64	100	144	176	256	324	400
	5	5	20	45	80	125	180	245	320	405	500
	6	6	24	54	96	150	216	294	386	486	600
	7	7	28	63	112	175	252	343	448	547	700
	8	8	32	72	128	200	288	392	512	684	800
	9	9	36	81	144	225	324	441	586	729	900
	10	10	40	90	160	250	360	490	640	810	1000
	No.	1	2	3	4	5	6	7	8	9	10
		Detection									

6. Results and discussion

To assess the present study's environmental risk, health, and safety, studies were conducted on the current situation in the field in the form of checklists and interviews. Then, using the results obtained from the current situation, risks were identified and analyzed according to three dimensions: effect severity, probability of occurrence, and probability of detection. Finally, the results were evaluated using the results of the analysis.

6.1. Definition of levels

Level 1: Low risk, where all three RPN factors are less than 6 or the RPN number is low, and no precautionary measures are required.

Level 2: The critical level where a maximum of one of the three factors of the RPN is higher than 6, but the RPN number is low. In this case, it is necessary to take preventive measures.

Level 9: A supercritical level in which at least two of the three factors of the RPN are greater than 6, and the RPN number is also high. Clearly, this level requires immediate preventive measures [25].

6.2. Results of environmental, safety, and health risk assessment using the FMEA method

Table 5. Environmental risk assessment of Marun's oil field using the FMEA method

No.	Unexpected events	Consequences	Probability of occurrence	Effect severity	Probability of detection	Degree of risk	Level of risk
1	Oil spills in soil	Pollution, groundwater	8	1	4	32	Critical
2	Oil spills in seawater	Water pollution and endangerment of aquatic organisms and seabirds	7	1	3	21	Critical
3	Amount of oil drainage and treatment to soil	Soil contamination, adverse effects on plant	7	8	3	168	Supercritical
4	Oil drainage rate to seawater	Water pollution, adverse effects on aquatic life	7	8	1	56	Critical
5	Factories' disposable oil effluents	Water and soil contamination, harm to living organisms	7	10	3	210	Supercritical
6	Single round effluent	Sewage production, water pollution	5	9	3	135	Critical
7	Production of industrial garbage	Solid waste increase	3	9	2	54	Critical
8	Waste production	Increased solid waste	5	9	3	135	Critical
9	Burned gas	Air pollution	9	10	7	630	Supercritical
10	Contaminated soil as a result of oil discharge	Soil Pollution, adverse effects on plants	7	4	3	84	Critical
11	Uprooted trees	Damage to green space and landscape	2	1	1	2	Low risk

Table 6. Safety risk assessment of Marun's oil field using the FMEA method

No.	Unexpected events	Consequences	Probability of occurrence	Effect severity	Probability of detection	Degree of risk	Level of risk
1	Number of fatal events	Endangering the health of people	10	5	1	50	Critical
2	Number of cases causing disability	Employees' disability	8	4	2	64	Critical
3	Number of cases leading to a job change or work restriction	Inability to perform work	8	1	6	48	Supercritical
4	Number of motor accidents	Life-threatening events to employees, injuries to installations, low air, and water pollution	10	1	2	20	Critical
5	Number of industrial fires	Endangering employees' lives, producing	9	1	4	36	Supercritical
6	Number of pseudo-reports	Life-threatening accidents and installation hazards	6	7	8	336	Critical

Table 7. Health risk assessment of Marun's oil field using the FMEA method

No.	Unexpected events	Consequences	Probability of occurrence	Effect severity	Probability of detection	Degree of risk	Level of risk
1	Number of non-emergency outpatient visits	Endangering the health of people	5	10	1	50	Critical
2	Number of hospitalizations	Loss of working hours and reduced performance	7	8	6	336	Supercritical
3	Going to the emergency room due to industrial accidents	Danger to the health of employees and causing disability	7	6	1	42	Critical
4	Number of visits due to high blood pressure and high blood sugar	Danger to health	5	1	3	15	Low risk
5	Number of visits to medical centers	Loss of working hours and reduced performance	7	10	7	490	Supercritical

According to the FMEA method, the results showed that about 38% of the hazards are classified as supercritical, 53% critical, and 9% low risk. Most of the supercritical low-risk states are in the health sector. According to the results and further studies of the risks reported in the supercritical and critical categories, frequency of occurrence plays a very important role, and taking corrective measures in this direction effectively reduces multiple risks.

It can be acknowledged that before allocating the resources of an organization to focus on the development and improvement of error detection, it is essential that managers and officials take caution in reducing the likelihood of errors and minimizing their impact. On the other hand, allocating financial credit to increase workplace safety is a type of future investment.

Not paying attention to this investment will have, without a doubt, unfortunate consequences for any organization (whether in terms of manpower, finances, or social), and the organization may be forced to bear more costs at a later point in time.

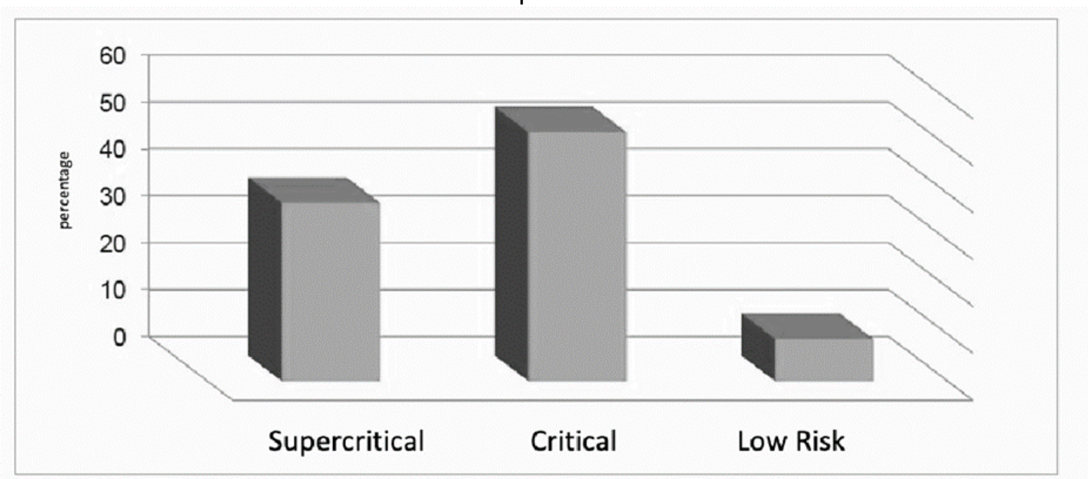

Figure 2. Comparison of risk levels in Marun's oil field

7. Conclusions

Risk management and assessment may seem very costly and time-consuming at first glance, but in the long run, it reduces remedial costs by lowering the number of potential accidents. Risk management can lead the situation toward environmental protection and preventive measures by providing appropriate solutions according to the conditions of any organization. Risk management should be prioritized based on each organization's experiences, knowledge, and needs to reduce potential risks to a minimum using effective methods. Accordingly, providing logical and targeted solutions to reduce risk management requires accurate knowledge of the organization's current situation as well as its risks. Therefore, identifying and assessing risk is extremely important in prioritizing and providing the correct solution for remedial and preventive measures. The purpose of this study is to assess the potential risks of Marun's oil field and determine its most dangerous risks. The offshore oil field's environmental, safety and health risks (Marun) is accomplished using the FMEA method.

The results of the FMEA method also showed that most risks in this region are critical and supercritical, respectively. According to the FMEA method, this field, even an industrial one, is highly risky and dangerous. Remedial measures in the environment and reducing potential environmental hazards can be the most effective remedial actions in this region. Also, corrective measures in health and safety have a greater ability to reduce risk.

Conflict of interest

The authors declare they have no competing financial interests.

References

[1] Allahviranloo T, Saneifard R. Defuzzification method for ranking fuzzy numbers based on center of gravity. Iranina Journal of Fuzzy Systems, 2012;9(6): 57-67

[2] Shahrekordi AP, Behnood M, Hosseinian A, Mozaffari S, Sheikhzakariaee SJ. A sensitivity analysis for the effective parameters disparity on pressure and pressure derivative of well-testing in a horizontal well. Petroleum and Coal, 2019; 61(4): 749-756.

[3] Tamiru AT, Rade BK, Taye EB, Azene ZN, Merid MW, Muluneh AG, Kassa GM, Yenit MK, Taddese AA, Gelaye KA, Geberu DM, Tilahun SY, Mekonnen HS, Azagew AW, Webneh CA, Belay GM, Assimamaw NT, Agegnehu CD, Azale T, Andualem Z, Dagne H, Gashaye KT, Kabito GG, Mekonnen TH, Daba S, Azanaw J, Adane T, Alemayehu M. Community Level of COVID-19 Information Exposure and Influencing Factors in Northwest Ethiopia. Risk Manag Healthc Policy, 2020; 17;13:2635-2644. doi: 10.2147/RMHP.S280346.

[4] Mozaffari S, Hosseinian A, Shahrekordi AP, Sheikhzakariaee SJ, Mansouri MJ. Functional Analysis of Performance of Artificial Neural Networks (MPL) and (RBF) in predicting seismicity of tubes related to offshore drilling in one of Iran's oilfields. Petroleum and Coal, 2020; 62(3): 975- 993.
[5] Polinkevych O, Khovrak I, Trynchuk V, Klapkiv Y, Volynets I. Business risk management in times of crises and pandemics. Montenegrin Journal of Economics, 2021;17(3): 99-110.
[6] Hemphill TA, Kelley KJ. Artificial intelligence and the fifth phase of political risk management: An application to regulatory expropriation. Thunderbird International Business Review.
[7 Margan SK. Commercial Insurers Facing a Perfect Storm. Bimaquest, 2021; 21(1).
[8] Wysokińśka-Senkus A, Górna J. (2021). Towards sustainable development: risk management for organizational security. Entrepreneurship and Sustainability, 2021; 8(3): 527.
[9] Richter A, Wilson TC. Covid-19: implications for insurer risk management and the insurability of pandemic risk. The Geneva risk and insurance review, 2020; 45(2): 171-199.
[10] Kaplan AD, Cruit J, Endsley M, Beers SM, Sawyer BD, Hancock PA. The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. Human factors, 2021; 63(4): 706-726.
[11] Patel SK, Ritt CL, Deshmukh A, Wang Z, Qin M, Epsztein R, Elimelech M. The relative insignificance of advanced materials in enhancing the energy efficiency of desalination technologies. Energy & Environmental Science, 2020; 13(6): 1694-1710.
[12] Qureshi MI, Khan N, Qayyum S, Malik S, Hishan SS, Ramayah T. Classifications of sustainable manufacturing practices in ASEAN region: A systematic review and bibliometric analysis of the past decade of research. Sustainability, 2020; 12(21): 8950.
[13] Bueno S, Salmeron JL. Fuzzy modeling enterprise resource planning tool selection. Computer Standards & Interfaces, 2008; 30(3): 137-147.
[14] Karsak EK, Ozogul CO. 2009, An Integrated Decision Making approach for ERP System Selection. Expert Systems with Applications, 2009; 36: 660-667.
[15] Fakhrava, H. Application of Failure Modes and Effects Analysis in the Engineering Design Process. arXiv preprint arXiv: 2021; 2101.05444.
[16] Wang S, Li Z, He X, Sheng K, Zhou J, Wu W. Safety Argument Pattern Language of Safety-Critical Software. In 2020 7th International Conference on Dependable Systems and Their Applications (DSA) (pp. 459-467). IEEE.
[17] Wu Z, Liu W, Nie W. Literature review and prospect of the development and application of FMEA in manufacturing industry. International Journal of Advanced Manufacturing Technology, 2021; 1-28.
[18] Macedonia RN. FMEA for TCal: Risk Analysis in Compliance to EN ISO/IEC 17025: 2017 Requirements.
[19] Aven T. Safety is the antonym of risk for some perspective of risk. J Safety Sci; 2014; 47: 925-939.
[20] Oboni F, Oboni CH. Mankind, Risks and Planning. In Convergent Leadership- Divergent Exposures (pp. 19-51). Springer 2021.
[21] Shang SS, Lyv WF, and Luo LJ. Improved Grey FMEA Evaluation with Interval Uncertain Linguistic Variables and TOPSIS. Engineering Letters, 2021; 29(2).
[22] Shen M, Zeng Z, Song B, Yi H, Hu T, Zhang Y, Xiao R. Neglected microplastics pollution in global COVID-19: disposable surgical masks. Science of The Total Environment, 2021; 790: 148130.
[23] Tootkaboni MG, Ebadati N, Naderi A. 3D simulation of a giant oilfield in calcareous formations and scrutiny study of the interaction of the calculated parameters (Asmari formation in Maroon oilfield, Iran). Arabian Journal of Geosciences, 2021; 14(9): 1-11.
[24] Sun S, Tu J, Li C. Research on Reliability Demonstration of Naval Gun Weapon System. In Journal of Physics: Conference Series. 2021; 1961(1): 012067.
[25] Eduljee GH. Trends in risk assessment and risk management. Science of the Total Environment,2020; 249(1-3): 13-23.

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