L JAST
Libya Journal Applied
For Science and
Technology
مجلة ليبيا للعلوم التطبيقية والتقنية

Volume 5.Issue1
December2018

مجلة ليبيا للعلوم التطبيقية والتقنية

Corrosion Risk Assessment Study Concerning the Libyan Oil and Gas Pipelines

Abdulbaset Frefer[1], Mahmoud Matoug[2] , Fatma Haddada[3]

Mechanical and Industrial Engineering Department, University of Tripoli [1,2]

Engineering Management Department, University of Tripoli [3]

ABSTRACT

Corrosion is a major economic and environmental deterioration phenomenon in industrial process affecting the life of process equipment and pipelines resulting in leakage, product loss, environmental pollution, and loss of life. A reduction in the number of corrosion incidents is desirable from both safety and financial standpoints

This paper aims to assess the risks of corrosion in the oil and gas pipelines in Sabratah platform and Wafaa field, which are owned by Mellitah oil and gas B.V Company, Gas division. Based on the available historical data that collected from the inspection reports, and the information gained from the experts, the researchers decided that the best techniques to apply the assessment process of corrosion in the pipelines, is the qualitative risk assessment matrix to determine the likelihood and consequences of risks in the pipelines understudy. Besides this, the AHP (quantitative technique Analytical Hierarchy) Process is implemented to identify the risk rate of the different types or corrosion.

Keywords:
Quantitative Assessment, Qualitative Assessment, Analytical Hierarchy Process (AHP), Risk Assessment Matrix (RAM), , Pipelines Corrosion
.

1. Introduction

Oil and gas Pipelines carry products (ex. crude oil, gas) are very vital and are considered the main backbone of the Libyan economy. These products are transported and distributed via pipelines that can stretch for hundreds and thousands of kilometers. Like any other engineering facility, these pipelines are facing many potential risks and problems when these products are pumped into these pipelines during production, transportation, and processing. Among these problems, were the issues of

defects, such as corrosion in the oil and gas pipelines. According to [1], defects may be

visible, hidden, as well as critical, significant and insignificant. Corrosion defects are one of the major integrity threat to oil and gas pipelines.

The rate of corrosion is expressed as an example via change of the metal loss, depth of corroded pipe surface, or formation of pitting. Oil and gas pipelines risk assessment (PRA) is the core content of the integrated management of the entire pipelines. So, it is important to employ the PRA for detecting the danger factors on the pipelines, to facilitate control and prevention of corrosion risks, as these risks can cause great deal of unwanted economic, health & safety, and environmental effects; and at the same time guarantee safe operation of the pipelines [2].

Research studies have been conducted on various topics to ensure pipeline integrity, reliability and safety, such as qualitative, semi-quantitative, and quantitative risk assessment methods [1,3-23], such as, the risk assessment matrix, the fuzzy Bayesian Belief network, the Fuzzy Petri net model, Fuzzy Logic, AHP, and F-AHP, and the combined Analytical Hierarchy Process- Fault Tree Analysis (AHP-FTA), Monte Carlo, and hazard and operability study (HAZOP).

2. Statement of the Pipelines

This paper carried out on five pipelines, which are used in transporting oil and gas at both offshore and onshore fields; namely: (i) 10” condensate, (ii) 16” oil [section A, B, C], (iii) 36” dry gas.

The historical report of the company regarding the detection of these pipelines after pigging cleaning and inspection indicates that there are several types of corrosion and other defects in each part of these pipelines, which can be summarized as: (i) Internal Metal Loss (IC), (ii) External Metal Loss (EC) , (iii) Gouge Metal Loss (GC), (iv) Dent Metal Loss (DC), (v) Pipe Mill Metal Loss (MD). All types of pipelines defects have been defined and classified in [21] and many more references were cited in [20].

3. Pipelines Risk Assessment Techniques

Among the many risk assessment techniques that have been proposed in many studies in the published literature [1,3-23] to analyze the risks, identify their causes and limiting their impacts, the researchers selected two of these techniques; namely, the Risk Assessmen Matrix (RAM) and the analytical hericury process (AHP).

3.1. The Risk Assessment Matrix (RAM)

The Risk Assessment Matrix (also known as Likelihood Impact Matrix), is one of the commonly used quantitative and qualitative techniques for risk assessment [20]. It is also considered to be one of the most useful and effective screening techniques that has the capability and potential to discriminate reliability between very high and very low risks [20-21]. Risk ranking is based on a matrix whose axes are the ranks of likelihood and impacts. The combination of ranks of impacts and likelihood creates risk rank [21].

A common technique used for risk ranking utilizes risk matrices; these are typically 4x4 or 5x5 matrices. These matrices are having event consequences along one axis and event frequency along the other [22-23]. Each block on the risk matrix represents some level of risk and blocks presenting similar risk are often grouped together into one of four or five risk regions [24]. RAM calculations are very simple considering that likelihood and impact of an event is assigned a random basis to the total, which can be a particular classification [20]. RAM also collates information on risks, likelihoods, impacts and mitigating actions. It involves rating each risk against two dimensions likelihood and impact [22]. Eq (1) describes the two basic variables of the matrix which are the rates of risk that can be identified.

Risk = likelihood × Impact **Eq (1)**

In this section, the steps followed in applying the Risk Assessment Matrix to assess the riskiness of offshore and onshore fields are discussed.

3.1.2. Likelihood Definitions

In this paper; a (5×4) matrix has carried out to assess corrosion risks and to obtain risks' rates in offshore (Sabratah Platform) and onshore (Wafaa desert) fields. Based on the chances of occurrence of the risks, each risk should fall into one of four categories [22]:

a. Rare Likelihood: the risk might occur once every year.
b. Unlikely Likelihood: the risk might occur once every six months.
c. Likely Likelihood: the risk might occur less frequently than once in every three months
d. Almost Certain Likelihood: the risk might occur less frequently than once in one month.

The likelihood attributes a weight of "Almost Certain", "Likely", "Unlikely", and "Rare" values as shown in Table 1.

Table 1: Risk Likelihood Descriptors.

Likelihood	Weight	Likelihood of occurrence
Rare	1	1 time every year
Unlikely	2	1 time every 6 months
Likely	3	1 time every 3 months
Almost Certain	4	1 time every 1 month

3.1.3. Impact Definitions

The 'Impact's aspect of risk assessment involves considering what the potential impact of the risk would be on the pipelines [22], each risk should fall into one of five categories:

a. Catastrophic Risks: The possibility that pipelines will suffer very huge losses.
b. Critical Risks: Which can cause large effects that lead to destruction and delaying or stopping the process, this one needs to be solved as soon possible.
c. Moderate Risks: This means that there is a significant potential for a dangerous effect that needs to be controlled.

d. Marginal Risks: Any risks that can cause just a minor impact on the process, still these, must be addressed and monitored in time.

e. Negligible Risks: These risks do not pose any significant threat and which can be left unmediated without any fear.

The Impact attributes were given weights of “Catastrophic”, “Critical”, “Moderate”, “Marginal” and “Negligible " values as shown in Table 2.

Table 2: Impact Scale.

Rating	
5	Catastrophic
4	Critical
3	Moderate
2	Marginal
1	Negligible

After setting the rates of the risks, the Risk Matrix may be constructed as shown in Table 3. This table shows the level of risks and their classification. In some cases it may be enough merely to rank risks against each other to determine relative prioritization. All ‘red’ risks should be treated as high priority.

Table 3: Levels of Risks, and their Classification.

Value of rate	1 to 4	5 to 9	10 to 14	15 to 20
Classification	Low	Medium	High	Huge

3.2. The Classical Analytical Hierarchy Process

The theory of AHP is based on the fact that the elements of the problem can be arranged within a separate group, each of which has a specific hierarchical level within the overall hierarchical structure, each level affects directly the above level; therefore, the bottom level is affected too.

3.2.1. Hierarchical Structuring of the Problem

The assessment is decomposed into a hierarchy consisted of the problem (goal), then the criteria, followed by sub-criteria and alternatives in lower levels. At the core of the hierarchy is the goal of the problem being studied and analyzed. The leaf nodes are the alternatives to be compared.

3.2.2. Priority Analysis

The AHP calculates the priorities between the elements of the hierarchy and collecting the opinions, to obtain a set of the overall priorities, and to check the stability of these opinions to draw a final decision based on the results of this process.

3.2.3. Identification Priorities

Priority setting is represented by making binary comparisons between elements in the second level of the hierarchy with values ranging from (1 to 9) as shown in Table 4.

Table 4: Saaty’ Scale for Quantitative Comparison of Alternatives [5].

P.L	E.S	E.T.M.S	M.S	M.T.S.S	S.S	S.T.V.S.S	V.S.S	V.S.T.E.S	E.S
N.V	1	2	3	4	5	6	7	8	9

Abbreviations in this table mean: P.L=Preference Level, N.V=Numerical Value, E.S=Equally Serious, E.T.M.S= Equally to Moderately Serious, M.S=Moderately Serious, M.T.S.S=Moderately to Strongly Serious, S.S=Strongly Serious, S.T.V.S.S=Strongly to Very Strongly Serious, V.S.S=Very Strongly Serious, V.S.T.E.S=Very Strongly to Extremely Serious, E.S=Extremely Serious.

3.2.4. Estimating Priorities

To estimate the priorities in an approximate way; (i) sum of the values in each column should be calculated; (ii) each value should be divided by the summation of the column that allows meaningful comparisons between elements; (iii) the mean of the rows should be calculated by summation of the values in each row and divided by the number of elements in that row [11-13,23].

3.2.5. Consistency Verification

When the matrix is steady, the normalized summation for each row shows how much each element is dominated by the other relative elements [25-26]. If the rules are contradictory, this value known as (Consistency Ratio) will be greater than 10% [24].

3.2.6. Estimating the Consistency Ratio

The consistency ratio is calculated as shown in Eq (2) and is required to be less than 0.1 for acceptable consistency [20,26-29].

$$CR = CI/RI \qquad \text{Eq (2)}$$

Where: CR= Consistency Ratio; RI= Random Index; CI= Consistency Index

4. Results and Discussion

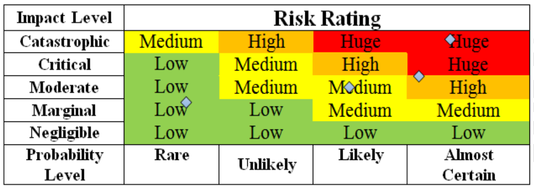
For RAM in offshore field's pipelines as presented in Tables 5 and 6, show the highest risk rate given to (IC). These results are completely consistent with the results achieved by applying the AHP technique. RAM indicates that the (IC) rating value is (19.104%) and pose a greater impact on the pipeline failure.

Table 5: Offshore Fields Risks' Likelihood and Impacts.

Risk Factor	Impact	Likelihood	Risk%
GC	0.97	1.63	1.5811
IC	4.8	3.98	19.104
EC	4.6	2.7	12.42
DC	4.1	2.7	11.07

The external metal loss (EC) has a significant rating value in offshore field's pipelines equal to (12.42%), which place this type in the orange zone. External metal loss has increased due to the pipeline presence in an aggressive environment (water). DC has higher rating value than GC, as shown in Table 5. However, such defects' events should not be ignored during future monitoring of the pipelines.

Table 6: Risk Matrix Table for Offshore Fields.



Impact Level	Risk Rating			
Catastrophic	Medium	High	Huge	Huge
Critical	Low	Medium	High	Huge
Moderate	Low	Medium	Medium	High
Marginal	Low	Low	Medium	Medium
Negligible	Low	Low	Low	Low
Probability Level	Rare	Unlikely	Likely	Almost Certain

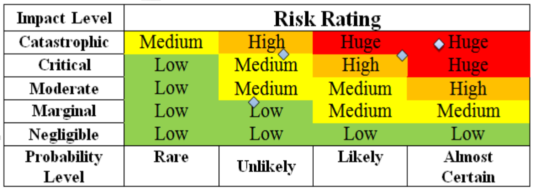
In the case of onshore fields, the situation may vary a little, because of the change in the surrounded conditions; Table 7 shows the combination weight of risks' Impact and Likelihood in onshore fields.

Table 7: Onshore Fields Risks' Likelihood and Impacts.

Risk Factor	Impact	Likeli Hood	Risk
GC	4.5	3.2	14.4
IC	4.87	3.86	18.7982
EC	2.51	3.62	9.0862
DC	2.24	1.97	4.4128

In Table 8 different zones are defined, corresponding to different levels of corrosion risks. Where the (IC) was located in the red zone, which means that it had a high rating value of (18.7982%). This type should be prioritized to reduce the likelihood and consequences of corrosion risks. The gouge metal loss (GC) defect appeared almost at the borderline with a high rating value of (14.4%), which places it in the orange zone. The external metal loss has been ranked with a rating value of (9.0862%) and placed in the yellow zone with a medium risk rate. Finally, dent metal loss (DC) defect was ranked as the lowest type of metal loss defect's risks in the green zone with a rating value of (4.4128%).

Table 8: Risk Matrix Table for Onshore Fields.



Impact Level	Risk Rating			
Catastrophic	Medium	High	Huge	Huge
Critical	Low	Medium	High	Huge
Moderate	Low	Medium	Medium	High
Marginal	Low	Low	Medium	Medium
Negligible	Low	Low	Low	Low
Probability Level	Rare	Unlikely	Likely	Almost Certain

Although that the risk assessment in this study was based on two well-known and different techniques; namely, RAM and AHP, the results were very close, as in 10", 16" and 36" pipelines. This means that the results of the Risk Assessment Matrix (RAM) were verified by using the AHP technique.

For AHP**,** it is clear as shown in Table 9 that the uniform corrosion of internal metal loss (IC) in general presides the assessment process and obtains the highest risk rate among the rest of the types, followed by the external metal loss (EC)

Table 9: Summary of Assessment Results for the Pipeline

	GC	DC	EC	IC	MD
10" Pipe	-	-	0.214862915	0.785137085	-
16"-Sec. A Pipe	0.4668	-	-	-	0.5331
16"-Sec. B Pipe	0.1132	0.1276	-	0.7591	-
16"-Sec. C Pipe	-	0.095758	0.253525	0.58893	0.061786
36" Dry Pipe	-	-	-	0.869692	0.130308

5. Conclusions

In this study, the researchers have investigated the subject of risk assessment in oil and gas pipelines in offshore and onshore fields. Two risk assessment techniques have been used in this study; namely, the risk assessment matrix (likelihood and impact matrix) and AHP techniques for assessing the corrosion risks in oil and gas pipelines, based on the theoretical study results of oil and gas pipeline risk assessment. Risk assessment results of RAM are completely consistent with the results achieved by applying the AHP technique.

Risk matrix is very effective and simple technique in making and improving risk decisions in the pipelines understudy. It can help facilities gain insight into the relative risks of different scenarios that can be addressed in a specific area.

The analysis of the risk assessment results as was discussed elsewhere indicates that there is a range from convergent to divergent. Results showed that these pipelines are subject to damage due to high-risk rates of some types of corrosion and other defects.

The risk assessment matrix was designed using offshore and onshore field' data. In the offshore field, the results showed that the internal metal loss (IC) got the highest risk rate, then it was followed by the external metal loss (EC), which showed an increase due to the changing of the conditions' nature that surrounding the pipelines. In the onshore fields, gouge metal loss (GC) was ranked as the second most dangerous type after the internal metal loss, and dent metal loss (DC) recorded a lower risk rate than the gouge metal loss in this case.

From analysis of the results achieved, the AHP has been introduced and applied in assessing the corrosion risks of constructing. three consequences criteria; namely, Economic Effects, Health-Safety Effects, and Environmental Effects, which were used in this study to compare results, and to determine the severity of corrosion risks [22]. Based on the AHP results, the Internal Metal Loss showed the highest risk rate compared with the other types of corrosion. Although External Metal Loss in pipelines showed relatively low risk values, this may not exclude this type from being monitored regularly in the future.

All pipelines, including the 10" condensate pipeline (Except 16" oil pipeline section A) and by using the classical AHP, the type of corrosion that should receive all the attention is the (IC) (0.7851). However; in the 16" oil pipeline section A, the defect of (MD) with value of (0.5331) was more significant than the other (GC) defect.

Risk rates significant to these pipelines are identified and incorporated in this assessment. Decision maker might find the AHP useful to support inspection process in these pipelines.

Assessment techniques allow for corrosion risks to be assessed besides the inspections process, which can help inspectors focus on the risks' types that have higher influence on pipelines failure and limit the unnecessary delaying or stopping in the operations.

References

[1] GOST 15467, Quality Management. Basic Concepts. Terms and Definitions, IPK Izd-Vo Standartov, Moscow, 2009.

[2] H. Dong, L. Wei, Hang, W. Lixin, and Q. Wang, "A Study on Oil Pipeline Risk Assessment Technique Based On Fuzzy Analytic Hierarchy Process", The Open Petroleum Engineering Journal, pp. 125-129, 2014.

[3] A. Frefer, "Corrosion Risk Assessment Study Onshore Field". MSc Thesis, Engineering Management Department, University of Tripoli : Tripoli, Libya, 2008.

[4] G. Kabir, R. Sadiq, and S. Tesfamariam, "A Fuzzy Bayesian Belief Network for Safety Assessment of Oil and Gas Pipelines", Structure and Infrastructure Engineering Journal, vo. 12, no 8, pp. 874–889, 2016.

[5] Z. Tan, J. Li, Z. Wu, J. Zheng, and W. He, "An Evaluation of Maintenance Strategy Using Risk Based Inspection". Safety Science, vol. 49, pp. 852–860, 2011.

[6] Y. Guo, X. Meng, D. Wang, T. Meng, S. Liu, and R. He, "Comprehensive Risk Evaluation Of Long-Distance Oil And Gas Transportation Pipelines Using A Fuzzy Petri Net Model", Journal of Natural Gas Science and Engineering, vol. 33, pp. 18-29, 2016.

[7] A. Hasan, "Security of Cross-Country Oil and Gas Pipelines: A Risk-Based Model", Journal of Pipeline Systems Engineering and Practice, volL.7, no. 3, 2016.

[8] O. Shabarchin and S. Tesfamariam, “Internal Corrosion Hazard Assessment of Oil & Gas Pipelines Using Bayesian Belief Network Model”, Journal of Loss Prevention in the Process Industries, vol. 40, pp. 479-495, 2016.

[9] Q. Zhou, W. Wu, D. Liu, K. Li, and Q. Qia, “Estimation of Corrosion Failure Likelihood of Oil and Gas Pipeline Based On Fuzzy Logic Approach”, Engineering Failure Analysis, vol. 70, pp. 48-55, 2016.

[10] C. Briggs, “Risk Assessment in the Upstream Crude Oil Supply Chain: Leveraging Analytic Hierarchy Process”, Doctoral Dissertation, Transportation and Logistics, University of Agriculture and Applied Sciences, 2010.

[11] I. Roux, “Applying the Analytic Hierarchy Process to Oil Sands Environmental Compliance Risk Management”, Doctoral Dissertation, College of Management and Technology, Walden University, 2014.

[12] A. Balogun, A. Matori, and A. Hamid-Mosaku, “A fuzzy multi-criteria decision support system for evaluating subsea oil pipeline routing criteria in East Malaysia”, Environmental Earth Sciences, vol. 74, pp. 4875-4884,2015.

[13] S. Tesfamariam and R. Sadiq, “Risk-Based Environmental Decision-Making Using Fuzzy Analytic Hierarchy Process (F-AHP)”, Stochastic Environmental Research and Risk Assessment, vol. 21, pp. 35-50, 2006.

[14] P. Dey, “Analytic Hierarchy Process Analyzes Risk of Operating Cross-Country Petroleum Pipelines in India”, Natural Hazards Review, vol. 4, no. 4, pp.213-221, 2003.

[15] Y. Bai, L. Lv, and T. Wang, “The Application of the Semi-Quantitative Risk Assessment Method to Urban Natural Gas Pipelines”, Journal of Engineering Science and Technology, pp. 74-77,2013.

[16] I. Bertuccio and M. Moraleda, “Risk Assessment of Corrosion in Oil and Gas Pipelines Using Fuzzy Logic”, Corrosion Engineering, Science, and Technology, vol. 47, no. 7, pp. 553-558, 2012.

[17] A. Dawotola, P.H. van Gelder, and J. Vrijling, “Risk Assessment Of Petroleum Pipelines Using A Combined Analytical Hierarchy Process - Fault Tree Analysis (AHP-FTA)”, Proceedings of the Seventh International Probabilistic Workshop, pp. 491-501, 2009.

[18] S. Mubin and G. Mubin, “Risk Analysis for Construction and Operation of Gas Pipeline Projects in Pakistan”, Pakistan Journal of Engineering and Applied Sciences, vol .2, 2008.

[19] B. Yadhushree, B. Shiva, and S. Keerthi, “Qualitative Risk Assessment and HAZOP Study of a Glass Manufacturing Industry”, International Journal of Advance Research, Ideas and Innovations in Technology, vol.. 3, pp. 776-787, 2017.

[20] D. Ristic, “A Tool for Risk Assessment”, Safety Engineering, pp. 121-122, 2013.

[21] F. Haddada, “Assessment of Corrosion Risks in the Oil and Gas Pipelines in Libya’s Onshore/offshore Field”. MSc. Thesis, Engineering Management Department, University of Tripoli, 2018.

[22] A. Azzayat, "A Study to Develop a Model for the Corrosion Risk Assessment in Crude Oil Storage Tanks", MSc. Thesis, Engineering Management Department, University of Tripoli : Tripoli, Libya, 2009.

[23] A. Ellabib, “Corrosion Risk Management of the Steam Boilers in Azzawiya Oil Refinery Company”, MSc. Thesis, Engineering Management Department, University of Tripoli, Tripoli, Libya, 2009.

[24] S. Brereton and T. Altenbach, "Risk Ranking Methodology for Chemical Release Events”, Probabilistic Safety Assessment and Management. International Conference on Probabilistic Safety Assessment and Management, New York City, NY, 1998.

[25] J. Roland, T. Susannah, and H. Phil, “Proposal for the Development of an International Recommended Practice in Pipeline Defect Assessment and Repair Selection”, International Conference on the Evaluation and Rehabilitation of Pipelines Prague, 2008..

[26] J. Alonso and M. Lamata, “Consistency in the Analytic Hierarchy Process: A New Approach.”, International Journal of Uncertainty, pp. 445−459, 2006.

[27] T. Saaty, “Decision Making with the Analytic Hierarchy Process”, International Journal of Services Sciences, pp. 83-97, 2008.

[28] L. Stirn and P. Groselj, “Estimating Priorities in Group AHP Using Interval Comparison Matrices”, Multiple Criteria Decision Making, vol. 8, pp. 144-159, 2013.

[29] M. Xie and Z. Tian, “Risk-Based Pipeline Re-Assessment Optimization Considering Corrosion Defects”, Sustainable Cities and Society, vol. 38, pp. 746–757, 2018.