Available online at http://ijcpe.uobaghdad.edu.iq and www.iasj.net
Iraqi Journal of Chemical and Petroleum Engineering
Vol.23 No.3 (September 2022) 67 – 73
EISSN: 2618-0707, PISSN: 1997-4884

# Risk-Based Inspection Due to Corrosion Consequences for Oil and Gas Flowline: A Review

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## Abstract

The petroleum industry, which is one of the pillars of the national economy, has the potential to generate vast wealth and employment possibilities. The transportation of petroleum products is complicated and changeable because of the hazards caused by the corrosion consequences. Hazardous chemical leaks caused by natural disasters may harm the environment, resulting in significant economic losses. It significantly threatens the aim for sustainable development. When a result, determining the likelihood of leakage and the potential for environmental harm, it becomes a top priority for decision-makers as they develop maintenance plans. This study aims to provide an in-depth understanding of the risks associated with oil and gas pipelines. It also tries to identify essential risk factors in flowline projects, as well as their likelihood and severity, in order to reduce loss of life and increased expenditures as a result of safety issues. The monetary quantification was used to determine the leakage-induced environmental losses. Using a 5-by-5 probability-currency matrix, the level of environmental risk was evaluated the safety and risk-based inspection (RBI) is evaluated through the use of specific schedules to determine the likelihood of failure (LOF) and Consequence of Failure (COF). The risk level appears in the matrix, and appropriate maintenance steps should be taken to reduce risks, such as injecting corrosion inhibitors to protect the Pipelines, activating cathodic protection or coating. Overall, this research contributes to the prevention of petroleum product leakage due to the corrosion consequences in the transportation sector. Also, encourage non-environmental risk decision-makers to gain a better understanding of the risk level.

*Keywords: Oil leakage, Risk-Based Inspection (RBI), Likelihood of Failure (LOF), Consequence of Failure (COF)*

*Received on 11/05/2022, Accepted on 26/06/2022, published on 30/09/2022*

https://doi.org/10.31699/IJCPE.2022.3.9

## 1- Introduction

The petroleum resources are distributed unevenly, long-distance transportation is necessary. Vehicles, ships, and flowlines are the most common modes of transportation, with flowline transportation accounting for the vast bulk of these techniques. Natural catastrophes will cause damage to infrastructure due to external destructive power in the event of long-distance transit based on flowlines, Due to weak infrastructure, inadequate information sharing systems, and small-scale human development programs, developing countries are disproportionately affected by natural disasters.

However, the countries adopted a number of measures to minimize economic losses, including disaster management programs, social safety programs, and human development programs. Countries are that face severe challenges of flood, storm, epidemic, extreme temperature, etc., which affect its economic productivity [1], [2] resulting in hazardous chemical leakage.

As a result, there will be significant environmental damage and economic loss, which cannot be overlooked in day-to-day operations.

In 2010, an oil flowline in Michigan, the United States, burst, spewing 4.5 million liters of oil into the Kalamazoo River, in Arkansas, an oil flowline burst in 2013, forcing the evacuation of more than twenty homes [3],[4]. That said, it is imperative to ensure the safe operation of the conveying installation by a number of preventive measures, especially for metal flow lines over long distances.

Among these, risk assessment is a critical connection that can identify local regions prone to leakage, allowing for targeted and timely maintenance and repair. Risk assessment is the foundation for preventing and reducing environmental risks, which is an urgent demand for sustainable energy supply and societal development [5],[6]. The work of quantitative risk assessment includes determining the likelihood of the danger occurring and its implications.

The first goal of this project is to forecast the likelihood of natural disaster-related dangers [7]. based on the Pipeline and Hazardous Material Safety Administration (PHMSA). The proposed model can indicate the evaluation's objectivity. The correctness of the judgment, on the other hand, was entirely dependent on the database's applicability.

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Because of the large gap between the operational environment and the management level, not all flowlines were appropriate for the disclosed historical failure database. As a result, academics have devised the index score and fault tree approaches [8], [9]. The evaluation index system and basic event table for assessment were built after a thorough examination of the internal and external reasons of flowline failure. With limited historical fault data samples, the fuzzy comprehensive evaluation approach and expert judgment method utilized to assess risk were suitable for quantitative evaluation. and to provide a theoretically low failure rate over the flowline's lifetime There are methods for ensuring flowline reliability during service, such as corrosion control and routine-based maintenance [10],[11].

## 2- What Is Risk

Risk is diagnosed as the consequences of threat or chance of its incidence. In other words, risk is a processing which special strategies are used to take a look at the probability of a threat and additionally its impacts, the consequences are supplied primarily based totally on the intensity of studies and the quantitative or qualitative phases. The likelihood of an unexpected or unfavorable outcome can be referred to as risk. Risk is any action or activity that increases the possibility of suffering a loss of any kind.

A company may encounter and have to deal with a variety of dangers. Risks can generally be divided into three categories: financial risk, non-business risk, and business risk, the method carries figuring out probabilistic risks, predicting the area of incidence, estimating the probability of incidence and effect evaluation. Hazard refers to the properties which have the capability of inflicting a catastrophe at the same time as danger is threat possibility and its severity which can cause damage. When a pipeline has been assessed, in a reality the threat probability and its impacts in a precise section of the pipeline in step with the environmental conditions are depicted in a specific moment.

In this situation it should be said that environmental risk evaluation consists of figuring out the affected surroundings, time and spatial modeling of emissions and leakage, evaluation of essential ecologically components concerning environmental sensitivity, estimation of quantity of the threat in comparison with current requirements and figuring out danger mitigate actions. Accordingly, further to take a look at and evaluation various elements of hazard with complete acknowledgement to the environment of the area, environmental sensitivity, and additionally environmental values are used in the danger evaluation

Risk analysis involves answering the following three questions [12],[13]:

- What can go wrong
- How can it happen
- What are the consequences

The set R of the above three questions can be mathematically expressed as:

$$R = \{S_i, p_i, x_i\}, I = 1, 2, N \quad (1)$$

Where: $S_i$ is an event or an occurrence, $p_i$ is the probability of $S_i$ and $x_i$ is the consequence of $S_i$

## 3- Risk Based Inspection Process (Purpose & Methodology)

Flowline risk evaluations will be qualitative, as is common in the industry. Fig. **1** depicts a high-level summary of risk management philosophy [14], [15], [16], [17]

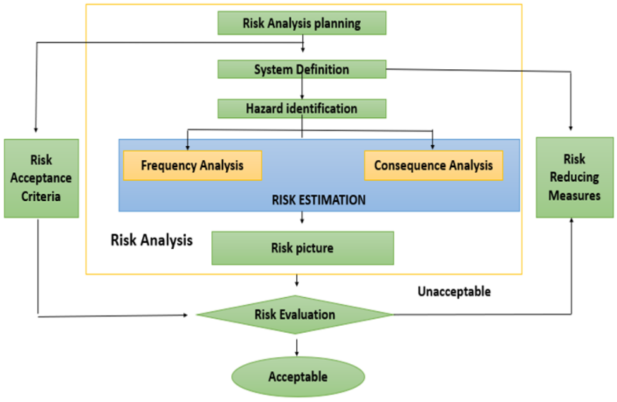


Fig. 1. Risk Assessment Process Flowchart [18], [19]

The purpose of an RBI analysis is to focus inspection efforts the sections of the flowline most at risk of failure with respect to an active damage mechanism. In RBI, risk is defined as the sum of the probability and consequences of failure in terms of math [20], [21].

$$Risk = LOF \times COF \quad (2)$$

Where:
LOF = Likelihood of failure
COF = Consequence of failure

3.1. Likelihood of Failure (LOF)

Likelihood of Failure or the Likelihood Factor is the sum of Equipment Factor (EF), Damage Factor (DF), Inspection Factor (IF), Condition Factor (COF), Process Factor (PF) and Mechanical Design factor (MDF).

$$LOF = EF+ DF +IF + COF + PF+ MDF \quad (3)$$

a. Equipment Factor - The criteria to define are determined by the size of the considered system.
b. Damage factor is a measurement of the risk linked with known damage mechanisms that are active or potentially active in the process in assessment.
c. The Inspection Factor is a measure of the inspection program's success in identifying the unit's active or expected damage processes.

d. The Condition Factor is used to assess how well plant maintenance
e. The Process Factor is a measure of the likelihood that aberrant operations or disturbed conditions may trigger events that will result in a loss of containment.
f. The Mechanical Design Factor assesses various features of the equipment used in the operation.

3.2. Consequence of Failure (COF)

The failure consequence or consequence factor is the sum of the chemical factor (CF), Quantity Factor (QF), State Factor (SF), Auto Ignition Factor (AF), Pressure Factor (PRF) and Credit factor (CF).

$$COF = CF + QF + SF + AF + PRF + CF \quad (4)$$

Chemical Factor is a measure of a chemical's inherent potential to ignite. It is based on material that makes up the majority or is typical of the tank contents. The NFPA Flammable Hazard rating for flash and reactivity is used to calculate the chemical factor [22].

a. Quantity Factor represents the maximum number of materials that could be discharged from a unit in a single scenario
b. The State Factor is determined by the fluid's typical boiling point, which indicates how quickly the fluid will evaporate and scatter when released into the environment.
c. The Auto-ignition Factor is a penalty that is applied to fluid that is treated at a temperature higher than the auto-ignition temperature.
d. The Pressure Factor denotes the fluid's proclivity for being released quickly, resulting in a higher likelihood of immediate type effects.
e. Credit Factor is the sum of multiple sub-factors of technical systems in place that might mitigate event damage.

In order to carry out the Risk Assessment, the Likelihood Category and Damage Consequence Category are determined from the Likelihood Factor and the Consequence Factor respectively by using risk assessment matrix.

## 4- Risk matrix

The risk matrix approach can be used to assess the likelihood and severity of losses in flow lines to establish future maintenance plans [23]. Based on the results of the risk calculation and the risk matrix, decision makers can evaluate the risk level and develop targeted programs to decrease environmental risks [24].

4.1. Probability Impact Matrix

The probability and impact of an event's occurrence are assigned to the total on a random basis, which may be a specific classification, making risk computation quite simple as shown in Table **1**. [25-32].

Table 1. Streamlined model of the probability and impact classification

| Calcsilicate probabilities | Score | Impact Classification | Score |
|---|---|---|---|
| Low | 1 | Major | 3 |
| Medium | 2 | Medium | 2 |
| High | 3 | Easily | 1 |

The risk manager or project team members will proceed to multiply the two variables after granting the total (scores) for likelihood and impact of risk categories they have identified. The operation's outcome will eliminate any risk.

This approach was used to create an impression of the risk of the audience not showing up for the scheduled classes in the project "Seminar: Trends in the restructuring and modernization of agriculture in the area of the Local Action Group (LAG) Mountain Valley 2013".

The first step was to define the probability of risk occurrence by using Table **2** [33].

Table 2. Likelihood score risk

| Level of Likelihood | Score |
|---|---|
| Very low | 0-20 |
| Low | 21-40 |
| Medium | 41-60 |
| High | 61-80 |
| Very high | 81-100 |

The second step was to set the impact on a scale of 1 to 5 by using Table **3** [33].

Table 3. Impact Analysis

| Magnitude of impact | Impact definition | Score | Rating |
|---|---|---|---|
| High impact/ High probability | Very high<br>They are the most serious threats to which business owners should be vigilant. | 5 | A |
| High impact / Medium probability medium impact /High probability | High<br>These dangers have a high chance of happening or having a significant impact. | 4 | B |
| Medium impact / Medium probability | Medium<br>The chances of the risks having an impact are medium. | 3 | C |
| Medium impact / Low probability Low impact / Medium probability | Low<br>These risks can occur in a variety of circumstances and have a low to medium impact. | 2 | D |
| Low impact / Low probability | Insignificant<br>There are risks that have a low likelihood of occurring and having a low impact. As a result, it is possible to overlook it. | 1 | E |

The third step was to compute the risk exposure values as shown in Table **4**.

Table 4. Calculation of the exposure risk

| Nr. cart. | Risk | Occurrence likelihood* | | Impact* | | Degree of risk exposure ** | |
|---|---|---|---|---|---|---|---|
| | | Probability | Score | Probability | Score | Rating | Score |
| 1. | Without learners | Very low | 20 | Very high | 5 | E | 12,5 |
| 2. | A small number | Low | 40 | High | 4 | D | 22 |
| 3. | Reasonable number | Medium | 60 | Medium | 3 | C | 31,5 |
| 4. | Full house | High | 80 | Low | 2 | B | 41 |
| 5. | More than places | Very high | 100 | Very low | 1 | A | 50,5 |

In the final stage, a risk matrix was created, as illustrated in Fig. **2**.

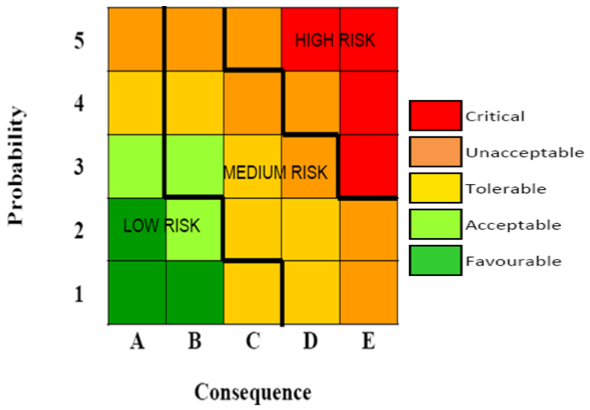


Fig. 2. Risk categories of flowlines

## 5- Categorization of Risk

A 5x5 matrix of likelihood and consequence, as shown in Fig. 2., is used to create risk categories. There are five categories of probability (1 is the lowest probability and 5 is the highest probability of failure) and five consequence categories (A being the lowest and E being the worst consequence of failure). Colors are used to indicate risk categories in the matrix; for example, red indicates critical, orange indicates unacceptable, yellow indicates tolerable, light green indicates acceptable, and green indicates favorable. For the sake of inspection priority, three degrees of risk ranking are developed. System, group, or equipment items are rated as "high," "medium," or "low" risk based on the results of this risk classification (risk screening): the following three levels of risk have been identified:

- Low risk – The level of risk is acceptable. In general, action must be performed to ensure that risk remains contained within this zone; often, this entails operator rounds, cleaning, and basic visual checks to ensure that equipment condition has not changed.
- Medium risk - The risk is acceptable. To guarantee that hazards do not escalate into the red high-risk region, action (such as NDT and other condition monitoring activities) should be conducted to measure the level of deterioration.
- High risk - The risk is too high. To keep risk within an acceptable range, action must be made to reduce probability, consequence, or both [34],[35],[36].
-

## 6- Remaining Life Assessment

The chance of failure from general internal or external wall thinning was determined when available for static pressure equipment and flowlines based on information provided in the relevant, historical inspection reports utilizing wall thickness measurement data. The internal corrosion likelihood was calculated using a long-term corrosion rate derived from wall thickness measurement data, while the external corrosion likelihood was calculated using an in-built corrosion rate derived from the level of environmental exposure and the condition of the external coating. The remaining life Eq. (5) was calculated using the worst-case corrosion rate Eq. (6) as follows [37]:

$$CR = \frac{(NWT - MWT)}{(Date\ of\ inspection - Date\ of\ comissioning)} \tag{5}$$

$$RL = \frac{MAT}{CR} \tag{6}$$

## 7- Conclusions

Pipeline failure rates in the production gathering system may be expected to increase exponentially without implementation of a risk assessment.

According to the probability of failure (POF) and the consequence value (COF) the risk of limiting the number of pipeline failures in the short-term. The establishment of a functional risk-based integrity management system (RBIM) is envisaged. Provide the most effective means of managing future integrity to support safe and reliable production.

A key element of such a system will be the development of an appropriate strategy for controlling the threat of internal and external corrosion. Though not insignificant, developing a strategy for the control of external corrosion is likely to be relatively straight-forward task in comparison to internal corrosion and will entail a combination of soil corrosivity analyses, pipeline inspection, remediation (coating/CP) and/or repair.

Control of internal corrosion is considered to be the most significant challenge in maintaining safe and reliable operation of the gathering system and is likely to become increasingly challenging as water cuts continue to rise. The solution is likely to entail a combination of chemical corrosion inhibitor injection, use corrosion-resistant materials and reconfiguration of large parts of the gathering system (e.g., routing production fluids through field manifold and trunklines). However, it is expected that an optimized solution may only be established on the basis of a comprehensive feasibility study, which will require input various disciplines within company (including integrity, projects, process and sub-surface optimization) such that the requirements and constraints of each are satisfied.

**Nomenclature**

| Symbol | Description | Unit |
|---|---|---|
| RL | Remaining life | Years |
| MAT | Minimum allowable thickness | mm |
| CR | Corrosion Rate | mm/yr |
| NWT | Nominal wall thickness | mm |
| MWT | Measured wall thickness | mm |

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# الفحص القائم على المخاطر بسبب عواقب التآكل لخطوط تدفق النفط والغاز: مراجعة

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*[2] قسم هندسة البترول ، جامعة بغداد ، العراق*

**الخلاصة**

إن صناعة البترول ، التي تعد إحدى ركائز الاقتصاد الوطني ، لديها القدرة على توليد ثروة هائلة وإمكانيات عمل. يعتبر نقل المنتجات البترولية أمرًا معقدًا وقابل للتغيير بسبب المخاطر الناجمة عن عواقب التآكل. قد تؤدي التسريبات الكيميائية الخطرة التي تسببها الكوارث الطبيعية إلى الإضرار بالبيئة ، مما يؤدي إلى خسائر اقتصادية كبيرة. إنه يهدد بشكل كبير هدف التنمية المستدامة. عند نتيجة ذلك ، يصبح تحديد احتمالية التسرب واحتمالية حدوث ضرر بيئي أولوية قصوى لصانعي القرار أثناء قيامهم بتطوير خطط الصيانة. تحاول هذه الدراسة توفير فهم شامل للمخاطر المرتبطة بخطوط تدفق النفط والغاز. كما يحاول تحديد عوامل الخطر الأساسية في المشاريع الانسيابية ، بالإضافة إلى احتمالية حدوثها وخطورتها ، من أجل تقليل الخسائر في الأرواح وزيادة النفقات نتيجة لقضايا السلامة. تم استخدام التقدير الكمي النقدي لتحديد الخسائر البيئية الناجمة عن التسرب. باستخدام مصفوفة احتمالية 5 × 5 ، تم تقييم مستوى المخاطر البيئية.والفحص القائم على المخاطر من خلال استخدام جداول معينه لتتحديد احتمالية الفشل والعاقبه يظهر مستوى المخاطر في المصفوفة ، ويجب القيام بخطوات صيانة مناسبة لتقليل المخاطركحقن مثبطات التاكل او تفعيل الحمايه الكاثوديه او تغليف الانبوب . بشكل عام ، يساهم هذا البحث في منع تسرب المنتجات البترولية نتيجة التآكل في قطاع النقل. أيضًا ، شجع متخذي القرارات غير البيئية على اكتساب فهم أفضل لمستوى المخاطر.

الكلمات الدالة: تسرب النفط ،الفحص على اساس المخاطر ، احتمال الفشل، نتيجة الفشل