International Journal for Research Trends in Social Science & Humanities
Volume 2 Issue 5
Sept-Oct 2024, PP 494-507

Safety Risk Assessment in Process Industry: A Review

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Abstract. The purpose of this research is to provide an overview of academic works on risk management in different industries with different objectives and then express their opinion to the researchers. The methods are literature-based and qualitative. The results of this study provide insight and complement further work with other researchers. Researchers have found little evidence of this. The recommendations of this study come from fields other than financial risk management, as many researchers do. The researchers hope that other researchers will use other variables in future studies, such as environmental destruction, the financial sector, and other variables from other financial sectors.

Index Terms- Hazard Identification, Risk Management, Risk Based Approach, ISO Standard, Process safety approach, Quality Risk Assessment, Process Safety Analysis

I. Introduction

Risk for each organization/ industry is consistently there, from year-to-year takes a chance in the organization have expanded and consistently foster as per existing activities in the organization.

With regard to organizations and risk management there is a statement from (Roberto, 2009) stating that organizational decay and collapse do not occur overnight. They evolve over time. They start with a small problem and the series of mistakes can often last months or years. Small problems become big problems as time goes by. The bug gets worse over time. One small mistake triggers the next. Once the series of events starts, you can stop them.

A process industry is an industry that focuses on increasing process efficiency and achieving flexibility. Lean principles such as small batch production and quick response to change are important in this industry.

The process industry encompasses many industries, including chemical, petrochemical, pharmaceutical, food and beverage (microbial), and biotechnology industries. This sector is important in manufacturing goods, energy production and providing various services.

The processing industry includes operation such as, the conversion of gases, vapours, liquids and solids, the production and conversion of raw materials, as well as the conversion of various types of forms of energy, the separation, mixing and storage of products.

The aim of the research is to present and propose a model for scientific knowledge and risk assessment in the process industry. The purpose of the research is to address the problems of fragmented hierarchy and poorly targeted measures in risk assessment in the industry.

Importance of Process Industries

- Process industries are important to the economy because they contribute to produce a wide variety of important products such as chemicals, pharmaceuticals, food and beverages and energy.
- It plays a key role in meeting the needs of various sectors and industries such as agriculture, healthcare, construction, and transportation.
- The process industry provides employment opportunities and promotes economic growth and development.
- It is important for innovation and technological development, which promotes research and development in areas such as material science, biotechnology, and process engineering. It is essential for innovation and technological advancements, driving research and development in areas such as materials science, biotechnology, and process engineering.

II. Literature Review

A literature review for risk assessment in the process industry reveals that there is a wide range of models and methods available, each with its own strengths and weaknesses. The most commonly used models include:

Hazard and Operability Study (HAZOP):

HAZOP is a qualitative risk assessment technique that is used to identify potential hazards and their consequences. It is a systematic and rigorous approach to risk assessment that can be used to identify hazards that may be difficult to identify using other methods.

Fault Tree Analysis (FTA):

FTA is a quantitative risk assessment technique that is used to identify the root causes of potential accidents. It is a top-down approach to risk assessment that starts with the identification of a potential accident and then works backwards to identify the root causes of that accident.

Event Tree Analysis (ETA):

ETA is a quantitative risk assessment technique that is used to identify the possible consequences of a single initiating event. It is a bottom-up approach to risk assessment that starts with the identification of a single initiating event and then works forwards to identify the possible consequences of that event.

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Bow Tie Analysis

Bow tie analysis is a visual risk assessment technique that is used to identify and assess the risks associated with process safety events. It is a comprehensive risk assessment technique that can be used to identify hazards, assess risks, and develop risk mitigation strategies.

Layer of Protection Analysis (LOPA)

LOPA is a quantitative risk assessment technique that is used to determine the required layers of protection for a process safety event. It is a systematic approach to risk assessment that can be used to ensure that adequate safeguards are in place to prevent process safety events from occurring.

Risk Assessment and Management Cycle (RAMC)

is a continuous risk assessment process used in the process industry to identify, assess, and manage risks. It is used for new and existing processes, products, and systems. The RAMC process is important because risks can change over time, so it is important to regularly review and update the risk assessment.

In addition to these traditional risk assessment models, there is also a growing interest in using machine learning and artificial intelligence (AI) for risk assessment. Machine learning and AI can be used to identify hazards, assess risks, and develop risk mitigation strategies. However, machine learning and AI are still in their early stages of development for risk assessment and more research is needed to validate their effectiveness.

This literature review also reveals that risk assessment is an essential part of process safety management. Process safety management is a comprehensive approach to managing the risks associated with industrial processes. Risk assessment can help organizations in the process industry to:

- Identify and assess the risks associated with their processes, products, and systems.
- Develop and implement risk mitigation strategies to reduce or eliminate the risks.
- Monitor the effectiveness of their risk mitigation strategies.
- By using risk assessment, organizations in the process industry can improve the safety and quality of their products and services, and reduce the risk of accidents and incidents.

Here are some specific examples of how risk assessment is being used in the process industry:

- **Chemical Industry:** Chemical companies use risk assessment to identify and assess the risks associated with their chemical processes and products. This information is used to develop and implement risk mitigation strategies, such as engineering controls, administrative controls, and personal protective equipment.
- **Oil and Gas Industry:** Oil and gas companies use risk assessment to identify and assess the risks associated with their drilling, production, and transportation

operations. This information is used to develop and implement risk mitigation strategies, such as safety procedures, training programs, and emergency response plans.

- **Food and Beverage Industry:** Food and beverage companies use risk assessment to identify and assess the risks associated with their food production and distribution operations. This information is used to develop and implement risk mitigation strategies, such as sanitation procedures, quality control programs, and food safety training programs.

III. Risk Assessment Overview

Risk assessment is a systematic process of identifying, analysing and evaluating potential risks or Hazard/threats associated with a specific activity, process or situation.

According to the statement from (Calandro, 2015) Strategic risk management can help managers identify and track weak signals of unclear threats using internal (and related data) and external sources of information, including external intelligence. Simply the Risk assessment can be recognized as a systematic tool for determining & Describing Hazards Factor & their relationship to various Industries.

It Involves the identification, analysis & evaluation of potential hazards & risks associated with these processes. Risk assessment is used in various industries and sectors, including healthcare, manufacturing, construction, and environmental management, to ensure the safety of workers, the public, and the environment.

The goal of risk assessment is to minimize or eliminate risks, protect the health and safety of individuals, and prevent accidents, injuries, or damage to property or the environment.

Risk assessment plays a crucial role ensuring the safety & efficiency of industrial processes in various industries.
Significance of Risk Assessment in Process Industries: -

Risk assessment plays a crucial role ensuring the safety, Environmental protection, & operational efficiency of industrial processes in various industries. By systematically assessing and managing risks, industries make informed decisions to reduce potential hazards and ensure the safety of their processes.

Some of the main reasons why risk analysis is very important in the manufacturing industry are:

Accident Prevention

Risk analyses help identify potential hazards and risks, which enables the implementation of safety measures and accident prevention measures. In high-risk

industries such as the chemical industry or oil refining, accident prevention is most important to protect both human life and the environment.

Worker Safety

Manufacturing industries often involve complex machinery and hazardous substances. Risk assessment ensure the protection of employees against potential hazards by providing instructions on safe work practices and appropriate training.

Environmental Protection

Many industrial processes can have significant environmental impacts such as emissions, pollution, or chemical releases. Risk analyses help identify and reduce these risks, reduce environmental damage, and ensure compliance with environmental requirements.

Regulatory Compliance

Many regulatory agencies require organizations to conduct risk assessments as part of their compliance. Compliance with these regulations is essential to avoid legal proceedings and penalties.

Emergency Response Planning

Risk assessments inform the development of emergency response plans and ensure that organizations are prepared to effectively respond to and minimize the impact of accidents or disasters.

In summary, risk assessment is an invaluable tool in the process industry that promotes safety, environmental responsibility, legal compliance, and overall operational efficiency. It is a proactive approach that not only prevents accidents, but also improves the long- term sustainability of the industry and the communities involved.

Risk Assessment Types

There are several different types of risk assessments, each tailored to specific needs & contexts. Some of the common types of risk assessments include: -

Qualitative Risk Assessment

Qualitative risk assessment is a method which involves assessing & prioritizing risks based on subjective judgement & qualitative descriptions, without assigning numerical values to the likelihood or impact of risks. It involves assessing risks in terms of their likelihood & impact, often using qualitative scales such as high, medium, & low.

This approach is less precise than Quantitative risk assessment.

Quantitative Risk Assessment

This method involves assessing & Measuring risks using numerical values, calculations, statistical analysis, mathematical models to estimate the likelihood & impacts of risks. This approach provides a more precise and quantitative

understanding of risk, which is particularly useful in complex and information-rich situations.

Semi Quantitative Risk Assessment

This method is a hybrid approach which combines qualitative & quantitative elements, using a scoring system or ranking to assess risks based on predefined criteria.

In semi-quantitative risk assessment, risks are accessed using a combination of numerical values and qualitative descriptors.

This is particularly useful when a full quantitative analysis is not possible due to limited data or resources, but the risk understanding is more accurate than purely qualitative approaches.

Microbiological Risk Assessment

Microbial risk assessment is a systematic & Scientific approach to evaluate the potential risks associated with the presence & activities of micro-organisms, such as bacteria, viruses, & fungi.

This type of risk assessment is specific to the food industry & focuses on evaluating the impact of food borne bacteria on public health.

Health and Safety Risk Assessment

Focuses on identifying and mitigating risks related to workplace health and safety. This includes assessing physical hazards, chemical exposure, and ergonomic risks in industrial and occupational settings.

Environmental Risk Assessment

Evaluates potential environmental risks and impacts associated with activities, projects, or operations. This can include assessing pollution, habitat destruction, and contamination.

Legal Risk Assessment

Examines legal risks associated with contracts, litigation, and legal decisions. It helps businesses and organizations manage their legal exposure.

Compliance Risk Assessment

Focuses on assessing the risks related to non- compliance with laws, regulations, and industry standards. It is essential for industries subject to strict regulatory oversight.

These are just some of the many types of risk assessments that exist. The decision of the proper sort of risk assessment relies upon the objectives, context of the assessment, & setting of the evaluation whether it's for safety, Monetary Direction, compliance, or different purposes.

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Fig 1: Risk Assessment Steps

Fig 2 Risk Assessment Matrix

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IV. Risk Assessment Methodology

Risk assessment involves the evaluation of risks taking into consideration the potential direct and indirect consequences of an incident, known vulnerabilities to various potential threats or hazards, and general or specific threat/hazard information. There are numerous methodologies and technologies for conducting risk assessment.

1. Threat Based Risk Assessment

One approach is to assemble the results of a Threat Assessment, numeric value of Risk for each asset and threat pair.

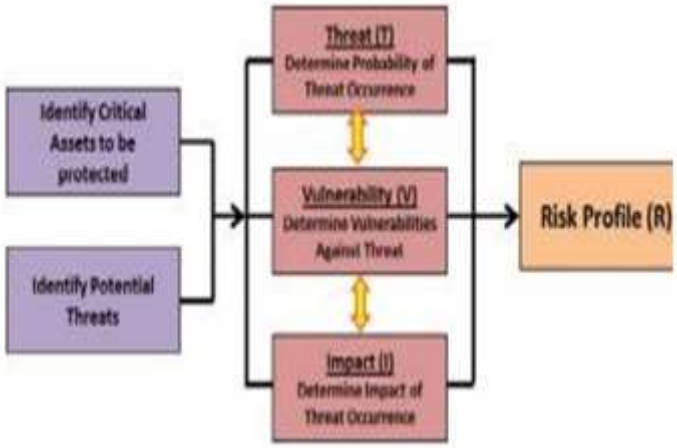

Fig 3 Illustration of risk assessment process

The Risk Assessment methodology introduced herewith employs both quantitative and qualitative techniques to provide findings resulted from a systematic computation of ratings, which are supported by logical arguments backed by factual data. It is based on the methodology used by the Federal Emergency Management Agency (US) [4- 5] and on a similar risk assessment model to mitigate potential terrorist attacks against buildings. The methodology compiles the results of the threat assessment, vulnerability assessment and impact assessment to arrive at a numeric value for the risk to each asset against specific threat in accordance with the risk formula:

Risk = T x V x I
Where T = Threat Rating,
V = Vulnerability Rating and
I = Impact Rating The entire process of Risk assessment can be summarized as

- identify the assets and people that need to be protected.
- perform a threat assessment to identify and define the threats that could cause harm to the facility and its inhabitants. Identify assets and threats.

- Conduct a vulnerability assessment to identify weaknesses that might be exploited by a terrorist or aggressor.
- Compute the risk using the results of the asset value, threat, and vulnerability assessments.

2. Hazard Exposure Analysis

Exposure analysis identifies the existing and future critical infrastructure systems and assets located in areas that susceptible to hazards.

Exposure analysis can quantify the number, type, and value of critical community infrastructure located within identified hazards areas, and show which systems and assets are exposed to multiple hazards.

3. What-if Analysis

What-if hazard analysis is a structured brainstorming method for developing threat and hazard scenarios and assessing their likelihood and consequences. This can be used to develop a strategy for managing risk from identified scenarios.

4. Failure Mode and Effects Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is a risk analysis method used in various industries, including manufacturing, to identify and manage potential failures in products, processes, services and systems. This helps to understand possible failure modes, their causes and the effects they can have on the entire system. FMEA is considered a robust risk assessment method and is widely used in the process industry.

- FMEA helps to identify and control potential defects in products, processes, services and systems.
- It is a systematic approach that includes the analysis of failure modes, their causes and possible effects on the entire system.
- The purpose of FMEA is to proactively identify and prioritize potential risks, enabling organizations to take corrective actions and minimize the impact of failures.
- FMEA is usually performed by a multidisciplinary team that includes experts from different fields to ensure a comprehensive analysis.
- *The process consists of three main stages: identification of failure states, assessment of their severity, occurrence and detectability, and prioritization of measures aimed at reducing risks.

V. Risk Assessment Model

By following these tips, organizations can develop and implement effective risk mitigation and management programs.

A risk assessment model is a tool used to identify, assess, and manage risks. It is a systematic approach to understanding the risks associated with a particular activity, process, or product.

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In addition to these traditional risk assessment models, there is also a growing interest in using machine learning and artificial intelligence (AI) for risk assessment. Machine learning and AI can be used to identify hazards, assess risks, and develop risk mitigation strategies. However, machine learning and AI are still in their early stages of development for risk assessment and more research is needed to validate their effectiveness.

Risk assessment models are used in a variety of industries, including the process industry, the oil and gas industry, the chemical industry, and the food and beverage industry. Risk assessment models can be used to assess the risks associated with a wide range of activities, including process design, product development, and operations.

By using a risk assessment model, organizations can identify, assess, and manage risks more effectively. This can help to improve safety, quality, and efficiency.

Case Studies on Risk Assessment Model

Case Study 1

A chemical company was developing a new process for producing a chemical product. The company used a HAZOP to identify potential hazards and their consequences associated with the new process. The HAZOP team identified a number of potential hazards, including the risk of a chemical release.

The company then used an FTA to assess the likelihood of the chemical release hazard. The FTA team identified a number of root causes of the potential chemical release, including equipment failure, human error, and process design errors. The company then used an ETA to assess the consequences of a chemical release. The ETA team identified a number of potential consequences, including injuries, fatalities, and environmental damage.

The company then prioritized the risks based on their likelihood and severity. The company concluded that the risk of a chemical release was a high-priority risk.

The company then developed risk mitigation strategies to reduce or eliminate the risk of a chemical release. The company implemented a number of risk mitigation strategies, including installing safety equipment, providing training to employees, and reviewing the process design.

The company then implemented and monitored the risk mitigation strategies. The company regularly inspects the safety equipment, provides refresher training to employees, and reviews the process design to ensure that it is still safe.

Case Study 2

An oil and gas company was operating a drilling platform in the Gulf of Mexico. The company used a risk assessment to identify and assess the risks associated with the drilling platform.

The risk assessment team identified a number of potential hazards, including the risk of a fire or explosion, the risk of an oil spill, and the risk of a worker injury or fatality.

The team assessed the likelihood and severity of each hazard and prioritized the risks based on their likelihood and severity. The team concluded that the risk of a fire or explosion was a high-priority risk.

The team developed risk mitigation strategies to reduce or eliminate the risk of a fire or explosion. The company implemented a number of risk mitigation

strategies, including installing safety equipment, providing training to employees, and developing emergency response procedures.

The company also implemented a risk-based inspection and maintenance program to ensure that the safety equipment was properly maintained and that the emergency response procedures were still effective.

Case Study 3

- A food and beverage company was manufacturing a new type of food product.
- The company used a quality risk assessment (QRA) to identify and assess the risks to the quality of the new product.
- The QRA team identified a number of potential hazards, including the risk of contamination, the risk of product failure, and the risk of allergens.
- The team assessed the likelihood and severity of each hazard and prioritized the risks based on their likelihood and severity. The team concluded that the risk of contamination was a high-priority risk.
- The team developed risk mitigation strategies to reduce or eliminate the risk of contamination. The company implemented a number of risk mitigation strategies, such as improving sanitation procedures, training employees on food safety, and testing the product for contaminants.
- The company also implemented a quality control program to ensure that the product met all of the quality standards.

VI. Risk Mitigation and Management

Risk mitigation and management are essential processes for identifying, assessing, and controlling risks. There are a variety of strategies that can be used to mitigate and manage risks, and the best approach will vary depending on the specific risks involved.

Some common risk mitigation and management strategies include:

- **Avoidance:** This involves avoiding the risk altogether. For example, if a company is considering launching a new product, it may decide to avoid the risk of product failure by not launching the product at all.
- **Reduction:** This involves reducing the likelihood or severity of the risk. For example, a company can reduce the risk of a data breach by implementing strong cybersecurity measures.
- **Transfer:** This involves transferring the risk to another party. For example, a company can purchase insurance to transfer the risk of financial loss due to a natural disaster.
- **Acceptance:** This involves accepting the risk and taking no action to mitigate it. This is typically done for risks that are very unlikely to occur or that would be very expensive to mitigate.

In addition to these general strategies, there are also a number of specific risk mitigation and management strategies that can be used in the process industry. For

example, process safety management (PSM) is a comprehensive approach to managing the risks associated with industrial processes. PSM includes a number of risk mitigation and management strategies, such as:

- **Hazard Identification:** This involves identifying all of the potential hazards associated with a process.
- **Risk Assessment:** This involves assessing the likelihood and severity of each hazard.
- **Risk Mitigation:** This involves developing and implementing strategies to reduce the likelihood or severity of each hazard.
- **Emergency Preparedness and Response:** This involves developing and implementing plans to respond to accidents and emergencies.

By using a combination of general and specific risk mitigation and management strategies, organizations in the process industry can improve the safety and quality aemergence of other digital technologies, AI has the capability to harness these data and leverage on the abilities of other technologies to improve construction.

VII. Conclusion

This Research paper on Safety Risk Assessment in Process Industry provides a comprehensive overview of the key concepts and practices related to hazard identification, risk management, and process safety analysis. The document is structured in a way that allows readers to gain a thorough understanding of the topic, starting with an introduction that highlights the importance of risk management in organizations and industries. The document then delves into the various components of a risk-based approach to safety, including hazard identification, risk assessment, and risk control measures.

One of the key takeaways from this research paper is the importance of implementing a quality control program to ensure that products meet all quality standards. This is particularly important in the process industry, where even small mistakes can have significant consequences. The document provides examples of successful process safety analysis in different industries, highlighting the importance of identifying potential hazards and implementing appropriate risk control measures. The ISO standard is also discussed in detail, with the document emphasizing the role that this standard plays in improving fire safety in the workplace. The ISO standard provides a framework for organizations to identify and manage risks related to fire safety, and the document provides practical guidance on how to implement this standard in practice.

Overall, this research paper serves as a valuable resource for researchers, practitioners, and policymakers interested in improving fire safety in the workplace. The literature-based and qualitative methods used in this study provide valuable insights into the current state of research in this field and highlight the need for further investigation into other variables, such as environmental destruction and financial sectors. The document concludes by emphasizing the importance of ongoing research

and collaboration in this field to ensure that organizations and industries are able to effectively manage risks related to fire safety.

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