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Risk Assessment and Analysis in a Chemical Industry

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Abstract

Chemical manufacturing sector in India is well established and has recorded a steady growth in the overall industrial scenario. The chemical and the allied industries are among the faster growing segments of Indian industry. The risks associated with the chemical industry are commensurate with their growth. Apart from their utility, chemicals have their own inherent properties and hazards like flammable, explosive, toxic or corrosive etc. Several major accidents had occurred in India and around the world killing many lives of people. Thus safety in a chemical industry is of prime concern and this project deals with safety in a chemical company (TCC LTD).There are several methods to improve the safety and minimize the risks like risk assessment, safety models, safety management systems. Several methods are implemented in the industries with safety standards like OSHA, HSE, etc. Even though many industries are implementing safety systems with these standards still injuries and accidents tend to happen due to many reasons. In this project these reasons are searched and necessary actions are taken by implementing a loss prevention programme so that the potential risks are detected and eliminated. The objective is to improve safety and working conditions by carrying out risk assessment in the chemical industry which is TRAVANCORE COCHIN CHEMICALS Ltd, ERNAKULAM.

Keywords: failure, loss management, occurrence, risk assessment, safety, severity

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INTRODUCTION

Organizations often adopt safety management system or behavior based system approaches to manage their safety functions in an attempt to achieve performance excellence. Safety is a critical issue in the chemical industry because chemical plants store and use large volumes of hazardous materials that can cause major incidents such as fires, explosions, and the release of toxic chemicals.

An effective safety management system is vital to improve the overall safety of the industry. In this project a chemical industry is selected and a loss management program is implementing to improve the safety in the firm.

In the past several accidents have taken place in the plant and generally in all the chemical industries there is always a risk of major hazard due to various reasons.[1,2]

A loss management program integrates the concepts of safety as well as identification, assessment and control of both hazards and risks for the express purpose of reducing harmful risks to people, environment, assets and production. In this project one of the elements in loss management has been taken and applied in the industry which is hazard identification and risk assessment and the risks are prioritized considering many factors.

LITERATURE REVIEW

Faisal Aqlan & Ebrahim Mustafa Ali, (2014) in their research, a framework combining lean manufacturing principles and fuzzy bow-tie analyses is used to assess process risks in chemical industry. Lean manufacturing tools and techniques are widely used for eliminating wastes in manufacturing environments. The five principles of lean (identify value, map the value stream, create flow, establish pull, and seek perfection) are utilized in the risk assessment process. Lean tools such as Fishbone Diagram, and Failure Mode and Effect Analysis (FMEA) are used for risk analysis and mitigation. Amell TK, Kumar, S & Rosser, BWJ (2001), the paper discusses ergonomic design principles and programs in terms of a practical, comprehensive corporation wide loss management view point. Comprehensive loss management may be new l to some individuals in the field of ergonomics, and hence its basic principles are introduced and discussed. The key element of any comprehensive ergonomic program and inherently the loss management program employing ergonomic strategies is the need for thorough and integrated information concerning Occupational Injury and Illness within the organization.[3–10] Andrew Hale, David Borys & Mark Adams (2015) The paper is based on previous work of the first two authors, developing a framework of occupational safety rule management at the workplace Based on a literature study, this paper analyses the similarities and differences between rules at the workplace level and the development, use and enforcement of regulations at the national level to influence and control organizational behavior.

The analysis uses the hierarchy of rules from goals, through process (risk management) rules to detailed action rules as framework for predicting the level of ownership and responsibility.

Siri Andersen & Bodil Aamnes Mostue (2012), they study the impact on the approaches by asking two questions: (1) what methods for risk analysis are used in the Norwegian oil and gas industry? (2) What are the risk analysis and risk management challenges in an IO context from the perspective of actors in the Norwegian oil and gas industry. Narayanagounder (2009) identified the limitation in traditional FMEA and proposed a new approach to overcome the limitations. The risk priority code was used to rank failure modes, when two or more failure modes have the same RPN. They proposed a new method to rank failure modes. An analysis of variance was used to compare the means of two risks priority number values when there is a disagreement in ranking scale of severity, occurrence and detection. H. Shiroyehzad (2010) applied FUZZY-FMEA preventive technique to decrease the failure rate in ERP implementation with the failure cause and effect by implementing fuzzy number. Burlikowskw (2011) describes about a new approach about production development and cost reduction using failure mode effect analysis. Popovic (2010) describes about the implementation of risk analysis parameter into the FMEA method and inconsistencies of the traditional method.

Anand Pillai, Jin Wang (2002) they use traditional FMEA and prioritize risk using RPN method. But this traditional FMEA has many drawbacks and in this paper these are addressed by fuzzy rule based and grey relation theory approach.

COMPANY PROFILE

The Travancore Cochin Chemicals Limited, Udyogamandal is a State Public Sector Undertaking owned by

Government of Kerala. Reflecting the quality policy of commitment and excellence. TCC has a good track record of profitable operation and healthy industrial relations. A heavy chemical industry engaged in the manufacture and marketing of Caustic Soda, Chlorine and allied chemicals, TCC is accredited with ISO 9001: 2008 certification

The company was originally formed as Travancore & Mettur Chemical Co. in 1949 (a partnership between FACT and Mettur Chemical & Industrial Corporation Ltd.) during the time of Seshasayee Brothers. It was the first Rayon grade caustic soda plant in the country. Later the company was registered under Companies Act, 1913 with Government of Travancore- Cochin as major shareholder under the name "The Travancore-Cochin Chemicals Ltd". Now the Government of Kerala holds 79% shares in the Company. The Company manufactures basic industrial chemicals Caustic Soda and Chlorine products. These chemicals have wide application in the mineral processing, manufacture of paper and pulp, textiles, soaps and detergents, pesticides, aluminium, polyvinyl chloride, petrochemicals, drugs & pharmaceuticals, oil refining, water purification, etc. The licensed capacity of TCC is 85,800 TPA of Caustic Soda. Company has obtained 'ISO certification 9001–2008' in the year 2006

The major products of the company are the following:
Caustic Soda
Chlorine
Hydrochloric Acid
Sodium Hypochlorite

LOSS MANAGEMENT ELEMENTS

- Management leadership, commitment and accountability.
- The assessment, analysis and management of risks.
- Operations and maintenance
- The competency and training of employees.
- The competency and integration of contractors.
- Change management.
- Reporting, investigating and analyzing previous incidents, and taking follow-up action.
- Community awareness and emergency preparedness.
- Continuous improvement.

These loss management elements together constitute an effective safety management system in the company. Many of the elements are covered because OSHA standard is the one the industry is following at present. The second element risk assessment is carried out in the plant to identify the potential risks and prioritize the risks based on RPN number. Usually in a chemical company HAZOP or LOPA analysis is applied as it is based on process deviation and protective barriers for a scenario respectively, but because they are very complex procedure functional FMEA is applied in the plant to find the causes and effects of risks and recommend for additional safeguards if needed.

Failure Modes Effect Analysis

Failure mode effect analysis was originally developed by NASA to improve and verify the reliability of space program hardware. FMEA is one of the most important and widely used tools for reliability analysis.

Failure Mode

Failure modes are sometimes described as the categories of failure. A potential failure mode describes the way in which a product or process could fail to perform its desired function (design intent or performance requirements) as described by the needs, wants, and expectations of the internal and external customers/users. Examples of failure modes are: fatigue, collapse, cracked, performance deterioration, deformed, stripped, worn (prematurely), corroded, binding, seized, buckled, sag, loose, misalign, leaking, falls off, vibrating, burnt, etc.

Failure Cause

This is a list conceivable potential cause(s) of failure assignable to each failure mode. The causes listed should be concise and as complete as possible. Typical causes of failure are: incorrect material used, poor weld, corrosion, assembly error, error in dimension, over stressing, too hot, too cold, bad maintenance, damage, error in heat treat, material impure, forming of cracks, out of balance, tooling marks, etc.

Failure Effect

The outcomes of the risks or failure that leads to many losses and the severity will vary for each effects.

Different Types of FMEA Analyses

- Functional FMEA
- Design FMEA
- Process FMEA

Design FMEA reduces the effect of failures in sub and main assemblies and it improves the design quality and reduces cost. Process FMEA identifies the deviation in the process flow, materials, methods, people and environment. Functional FMEA analyze a system as a whole and improves the reliability by identifying the failures and enhances the safety of the system under study. Functional FMEA is used in this study and the system is the plants at the industry.[11]

OCCURRENCE (O)

Occurrence ratings for FMEA are based upon the likelihood that a cause may occur based upon past failures and the probability of frequency the failure occurs (Table 1).

Table 1. *Occurrence Rating.*

SCORE	LIKELIHOOD OF OCCURRENCE (O)	
9,10	Very frequently	Can happen more than two times in an year.
7,8	Frequently	Likely to happen once in 2 years
5,6	Occasional	Likely to occur in 3 years.
3,4	Rarely	Incident has occurred in similar facility and may occur here within 5 years
1,2	Unlikely	Given current practices and procedures, not likely to occur in the facility.

The occurrence is determined by analyzing the past failures, the frequency of failures and discussing with the safety experts. Table 1 gives the scoring criteria as per the industry ranges from 1 to 10.The occurrence is determined by studying and analyzing in the plant for three months and discussing with safety department.

SEVERITY (S)

The end consequence or effect of a particular failure. It usually varies and it is ranked from 1 to 10. The severity of any failure varies from minor injuries to fatalities and property damages.

The identified failures effects are given scores based on its effect. For example chlorine leakage can be fatal in the industry (Table 2).

DETECTION (D)

Detection is an assessment of the probability that the existing controls will detect the cause of a particular failure and prevent it from happening (Table 3).

Detection is the ability of the existing devices to predict a potential failure and it can prevent a major hazard from happening.

RISK PRIORITY NUMBER (RPN)

This is one of the method to prioritize the risks using FMEA. The higher the RPN number the risk will be on the unacceptable side. Risk priority number (RPN) strategy is utilized to evaluate risk for which the accompanying components must be taken into account. RPN. It gives an idea on which risk has to be looked into more seriously and helps to rate the seriousness for every impact of failure. To rate the probability of the event for each cause of a failure. To rate the probability of detection for every failure or it is the probability of determining the failure before it damages the equipment.[12]

RPN=SEVERITY×OCCURRENCE×DETECTION

Table 2. *Severity Rating.*

SCORE	SEVERITY OF RISK (S)	
9,10	Fatal	Results in major destruction to factory
7,8	Permanent disabling injury/can create acute health problems	Major destruction to process area.
5,6	One or more serious injury	Result in major destruction to equipment
3,4	Single injury , not severe, down time	Minor problem for equipment.
1,2	Minor or no injury; no lost time	No problem to equipment.

Table 3. *Detection Ranking.*

SCORE	DETECTION (D)
10	Almost impossible
9	Very remote
8	Remote
7	Very low
6	low
5	moderate
4	Moderately high
3	High
2	Very High
1	Almost certain

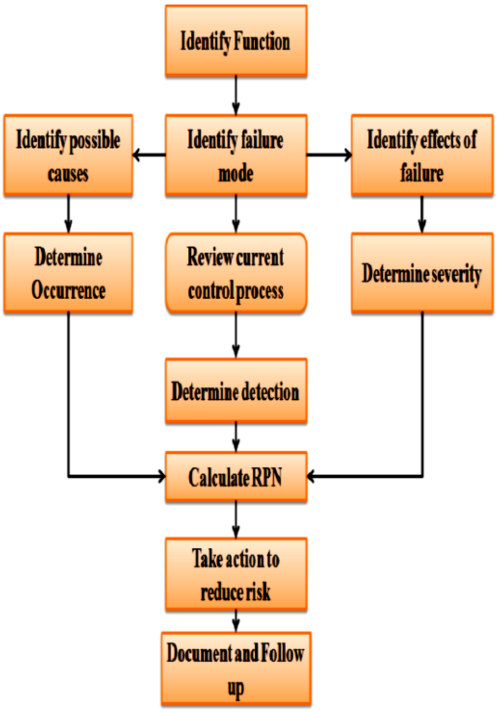

Fig. 1. *FMEA Process.*

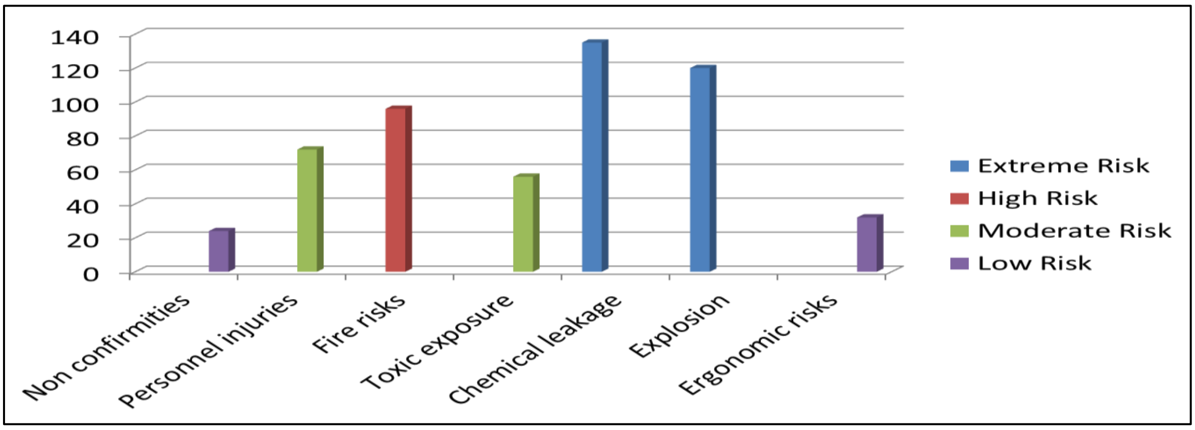

Fig. 2. *RPN Chart.*

From the table using FMEA the risks are prioritized based on the ranking and leakage of chemicals and risk of explosion have the highest RPN and both have values above 100 and according to the companies safety criteria these risks are unacceptable and needs additional protective barriers thus reccomendations are given along with existing safe guards to improve the detectability and reduce the severity and occurrence of top 5 risks or failure modes. Figure 1 shows the FMEA process and Figure 2 shows the risks in terms of RPN value (Tables 4, 5).

Table 4. *FMEA Table.*

RISK	CAUSES	EFFECTS	S	O	D	RPN	RANK
Product non-conformities	Adding wrong chemicals to certain batches. Improper cleaning of pipes and tanks	Dissatisfaction of customers Loss of reputation Time and money waste.	4	2	3	24	7
Injuries to personnel	Employees not following safety procedures. Lack of awareness and supervision.	Loss of man hours Compensaations Medical costs	4	6	3	72	4
Fire risks	Visitors/workers using cigarettes in production area. Electrical and electrostatic spark.	Fire. Explosion. Severe personal injuries and property damage.	8	4	3	96	3
Toxic material exposure	Dealing with acids like HCl, sulphuric acids and other reactive chemicals. Workers not wearing proper safety equipments.	Operators get infected. Compensation and medical costs	7	4	2	56	5
Leakage of chemicals	Improper functioning of the valves. Deteriorated tanks used for filling and storing chlorine gas. When filter or pipeline gets clogged. Leakage when transferring chlorine from one cylinder to another.	Inhaling chlorine gas can be fatal. Loss of money due to spill. Chances of explosion when leaked gas react with air. Chronic respiratory disorders if the concentration exceeds limit.	9	3	5	135	1
Risk of explosion	flammable materials stored outside. Condenser and boiler explosion during chemical process.	Severe injuries to workers. Equipment damage. Financial loss. Environmental damage in worst scenario.	10	3	4	120	2
Ergonomic risks	Improper working postures like extreme bending and lifting. Poor ventilation systems.	Decreased productivity. Health issues	4	4	2	32	6

RESULTS

Table 5. *Results and Recommendation Table.*

RISK/FAILURE	RANK	EXISTING CONTROL MEASURES	RECOMMENDATIONS	S	O	D	RPN
Leakage of chemicals		Manual Alarm signals PPE'S like SCBA, escape respirators	Automatic alarm systems Detector tubes will give chlorine concentration readings. Installation of sensors in pump that help to stop in case of high/low pressure. Ventilation fans should be provided with suction near floor level. Emergency kit at the site.	9	3	3	81
Risk of explosion		Periodic inspection by safety supervisor and safety audit by experts.	Provide automatic shut off valves at the pipings carrying chemicals. Carry out explosion risk assessments by specialists	10	2	3	60
Fire risks		Fire fighting equipments.	Installation of fire fighting alarms and systems. Training session to visitors and contract workers.	8	3	3	72
Injuries to personnel		Training and awareness. Safety signs and posters.	Install cameras to monitor unsafe acts. Penalties who doesn't follow safe procedures and incentives to workers who follow them.	4	4	3	48
Toxic material exposure		PPE like gloves ,clothing, boots etc..	Adjusted work schedules. Training workers/contract workers on importance of PPE.	6	3	2	36

The Table 4 shows the analysis and Table 5 shows the results the recommendation and if this is implemented the RPN values of the unacceptable risks will come down under 100, which can be accepted. [13–17]

CONCLUSIONS

Using FMEA analysis the risks in the main plant including chlorine filling station has been identified and prioritized. Leakage of chemicals and risk of explosion have been found above acceptance level and protection barriers have been recommended. The additional control measures to minimize the risks, has also been suggested. Risk Priority Graph has been plotted showing various risks with RPN. Although all the elements of loss management cannot be implemented the risk assessment is completed in the main plant in the industry where there are risks to workers and it is analyzed in this project.

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