Volume 2, No. 12 December 2024
p-ISSN 3032-3037 | e-ISSN 3031-5786

ADVANCES IN SOCIAL HUMANITIES RESEARCH

IDENTIFICATION OF THE CAUSE OF THE FIRE OF FOUR TANK UNITS AT PT. TOX WITH FISHBONE AND DOMINO'S FACTORY METHOD

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Abstract

The oil and gas industry is prone to workplace accidents such as explosions and fires. PT TOX experienced a fire in an oil tank that had an impact on the environment and surrounding living things. This research uses a qualitative approach with fishbone analysis and domino's factory method to evaluate the cause of the fire. Data was collected through scientific journals and related news based on online databases. The results of the analysis using the fishbone diagram analysis method showed that the causes of the fire included leaks that spread gas vapors, inadequate operator response, absence of early detection (such as gas detectors and automatic alarms), damage to the tank structure, and volatile and flammable chemicals. To support further identification, researchers used the domino's factory analysis method which revealed factors such as poorly prepared management, tank corrosion, and unsafe actions such as moving products without safe procedures. The fire caused huge losses, including the destruction of four tanks by fire. Prevention of workplace accidents, especially fires, in the future can be done with regular training for operators, the use of fire protection equipment, periodic inspections, and revision of emergency response SOPs.

Keywords: Work Accident, Fire, Fishbone Diagram, Domino's Factory, Leakage

Introduction

Indonesia is a country that has abundant natural resources, one of which is petroleum. According to the Ministry of Energy and Mineral Resources, petroleum reserves as of January 1, 2018 are 7512.2 Million Stock Tank Barrels (MMSTB). The reserves consist of proven reserves of 3154.3 MMSTB and potential reserves of 4358 MMSTB. Of the total petroleum reserves, 2186.62 MMSTB (or 68.96%) are on land and the remaining 984.26 MMSTB (31.04%) are in the ocean (Fathnin, Alhilman, & Atmaji, 2018).

In an ever-evolving industrial world in oil and gas processes, the use of advanced technologies and tools, hazardous materials, and complex work procedures is extremely

dangerous if not managed properly. The implementation of the Occupational Safety and Health (OSH) system in the workplace can manage hazards and reduce risks. One part of SMK3 is to require business entities or industries to have an emergency response program (Emergency Response Preparedness). The goal is to reduce the risk of casualties and damage caused by accidents, fires, explosions, chemical poisoning, gas leaks, and natural disasters. Emergency response programs are created based on information about any emergencies that may occur in the company (Simionescu & Gavurova, 2023).

The storage tank is one of the vital objects in the production process that functions to store liquids such as crude oil, semi-finished and processed products, gases, chemicals, waste products, water and water/product mixtures in large quantities and with a large impact, so it is very important to carry out maintenance of the storage tank and risk management to prevent damage and control potential hazards contained in the storage tank area (Haqi, 2018).

A fire is an uncontrolled, unwanted, sudden occurrence of a fire that can cause casualties and property. Burning of an object outside the incineration site and in conditions and times that do not require the combustion process Fires can occur anywhere, whether in forests, cities, residential areas, public places, or in industries (R. Maharja, 2023).

Fire disasters are always unpredictable and predicted in advance. It is impossible for humans to guess when it happened, what caused it, how big it was in scope, and how big of an impact it had. Fire hazard is a hazard that is so fatal, potentially threatening, and the level of exposure to fire from the beginning of the fire to the spread of gases and smoke. This is bound to endanger buildings, ecology, or human life. Fires can occur intentionally or accidentally, and fires usually cause damage or damage to structures, as well as injuries or deaths of people. These fires are a serious threat to humans (R. Maharja, 2023).

Fire cases are a form of accident that requires special attention and requires prevention to reduce or even eliminate the possibility of fires. One of them can be risk management, because it is very important for the continuity of a business or activity in the event of a disaster such as a fire (Setiawan, Hardiyono, & Ramdan, 2024).

The International Labour Organization (ILO) states that fires in industry are one of the worst incidents in terms of occupational health and safety, causing nearly 70% of employee deaths. (Kuntoro, 2017) According to data from the United States Department of Fire Departments, there were 1,345,000 fires in the United States in 2015, with seven of them causing losses of US$14.3 billion. National Fire Safety Association, 2016 Based on actual information and disasters provided by the National Disaster Management Agency (BNPB), there were 2,551 industrial, residential and land fires until 2019 (BNPB, 2019). From 2014 to 2018, there were eleven non-land and forest fires, two of which caused deaths (Kuntoro, 2017).

In the process of the oil and gas industry it is very susceptible to explosions and fires. Some common causes of fires are caused by leaks, spills and the release of flammable materials such as oil and gas in pipes, tanks, and vessels (Syafitri, Nusantara,

Febriyanto, Zamardha, & Wahyudi, 2024). Precautions are necessary because fires are catastrophic. Fires in two industrial sectors can cause huge losses as they affect profits, operational processes, and workers' lives. Fires in the industrial sector can also cause environmental damage and disrupt production processes (Hooker, Hodges, Geary, & Wakefield, 2016). Based on the research, the results of the fire risk analysis show that the highest risk is in the Floating Storage Overloading (FSO) stage, the highest risk is in the stripper and wash tank stages, medium risk in mudipad, manifold and Sulfur Recovery Unit, while the lowest risk is in the Three Phase Horizontal Separator, boot gas and scrubber tank (Kowara, 2017).

Accident cases occur in various oil industries in the world in various forms such as fires, oil spills, gas leaks and others. In the period from 1972 to 2011, there were 53 cases of accidents in the oil industry, 6 incidents in the form of gas leaks, 17 cases of fires, 4 cases of explosions, 20 cases of explosions accompanied by fires. These incidents show that accidents in the form of oil leaks and fires are frequent occurrences in the oil industry (Idris, Rusli, Nasif, Ramli, & Lim, 2022).

There was a fire of four oil tanks at the PT. TOX in March 2021. Hundreds of residents around the scene had to be rushed to a safer place due to this fire. The fire also resulted in 29 people being slightly injured and 6 people seriously injured. In addition, the fire caused PT. TOX lost 400,000 barrels of production and the refinery was only able to operate after four to five days (Kompas).

To identify and analyze research problems, various tools are usually used to make data processing easier for readers to understand, diagrams are one such tool. The diagram is often known as a fishbone diagram (FISHBONE). This diagram is one of the seven basic quality tools that are often used by researchers in processing and analyzing event data. This diagram can identify cause and effect in many problems. This diagram is useful for analyzing and finding factors that have a significant influence on determining the quality characteristics of work output. In identifying a problem or event that occurs, this diagram has five factors that can be used by an engineer, namely machinery or technology, methods, materials, humans, and the environment (Fitriana, Suroto, & Kurniawan, 2017).

Theories related to the causes of accidents vary greatly and have been widely discussed in many literatures. One of the pioneers of this theory was Herbert William Heinrich, in his book Industrial Accident Prevention which was first published in 1933. The theory developed by Heinrich is famous for the Domino theory, where there is a sequence of events that trigger an accident. This sequence chain is known as a domino. In the domino theory, Heinrich proposed that there are 5 dominoes (events) that cause an accident to occur, including the social environment and ancestry, the fault of the operator and/or worker, unsafe conditions or unsafe actions, accidents and the last is the injury that occurs to the worker Each stage in the domino mentioned above is related to each other. If the first domino "falls", it results in the fall of another domino and triggers an accident. This theory is very simple and has weaknesses, Sabet et al. (2013) argue that this theory

focuses on individual errors and does not consider the contribution of management and organizational errors (Latif et al., 2023).

In addition to criticism, some academics cite the advantages in the use of domino theory from Bird and Loftus. Khanzode et al. (2012) mentioned that the domino theory is able to dynamically describe the causes of accidents because of the ease of use of the theory. Hosseinian and Torghabeh (2012) and Sabet et al. (2013) stated that this theory is easy to understand and teach, and errors in accidents can be easily identified due to the simplicity of using the domino theory. This theory has been used for decades and is still relevant to current conditions. Therefore, the domino theory can be used as a method to find the cause of accidents, especially mining accidents. Based on the above considerations, the domino theory is used as the basis for analysis to find the cause in the case study of the accident in this paper (Latif et al., 2023).

The main purpose of this study is to identify the factors that caused the fire of four tanks in PT. TOX uses the FISHBONE Method and DOMINO'S FACTORY. In addition, this article aims to explore various aspects related to tank fires at PT. TOX based on the investigation report. By paying attention to the findings and recommendations produced by (Kowara, 2017), we can identify general patterns as well as specific causes behind the four-tank fire at PT. TOX. Through a deeper understanding of the factors that cause process accidents, it is hoped that the oil and gas and petrochemical industries can take more effective and proactive preventive measures to prevent similar incidents in the future

Research Methods

Research Approach

This study uses a qualitative approach with the aim of analyzing in depth the causes of fires that occurred in the facilities of PT. TOX in 2021. The qualitative approach was chosen because it is able to provide a comprehensive understanding of complex phenomena by considering various interrelated causal factors.

This study utilizes two analysis methods, namely Fishbone (Ishikawa) and Domino's Theory, to evaluate the cause of the incident. The Fishbone method is used to identify and group the causative factors into five main categories, namely humans, machines, materials, methods, and the environment. This method helps in visualizing the linkages between factors, so that the root cause can be found systematically.

Meanwhile, Domino's Theory is used to analyze the cause-and-effect relationship in the series of events that lead to the fire. This theory focuses on five main elements, namely the social environment, human error, unsafe conditions, incident events, and their impact. This approach provides an overview of how risk factors develop into an incident

Data collection

The data collection technique in this study involves the collection of scientific journals and news related to the fire incident at PT. TOX. Scientific journals are accessed through online databases to obtain relevant theories and methods, including studies on the analysis of the causes of industrial incidents. News is taken from reliable mass media

sources, both print and digital, which provide information about the chronology of events, the condition of facilities, and the views of experts or authorities. The data collected from these two sources are verified and selected to ensure their validity and relevance to the research.

Analysis

The data analysis technique in this study uses two main methods, namely Fishbone and Domino's Theory, to evaluate the causes of fires in PT. TOX. Fishbone analysis begins by grouping the causative factors into five main categories, namely humans, machines, materials, methods, and the environment. Ishikawa diagrams are used to map the relationships between factors so that the root cause of fires can be identified in a structured manner. In addition, analysis with Domino's Theory was carried out to understand the series of cause-and-effect relationships that caused fires. The five main elements of this theory are social environment, human error, unsafe conditions, incident events, and the impact of damage or injury are then studied to describe how these factors affect each other. The combination of these two methods provides a more integrated and in-depth perspective in identifying the root cause of the problem and compiling recommendations for improvement.

Results and Discussion

On Monday, March 29, 2021, at 00.57 WIB, there was a large fire accompanied by an explosion in the area of PT TOX's 42T-301EFGH tank. This incident resulted in four tank units burning out, two residents died, and four others suffered burns. PT TOX's refinery with a production capacity of 125 MBSD, is one of the main facilities that supplies fuel oil (BBM) needs for the West Java and Greater Jakarta regions. The fuel produced is sent through a distribution pipeline from Balongan to the Plumpang fuel terminal, Jakarta. The refinery has four main complexes, namely the Hydro Skimming Complex, the Distillation & Hydrotreating Complex, the Residue Catalytic Complex, and the Propylene Olefine Complex.

The chronology of the incident shows that on Sunday, March 28, 2021, at 14.30 WIB, the operator carried out a blending process using HOMC 92 in tank 42T-301G to produce Pertalite (RON 90). However, laboratory results showed that the RON level had not met the expected standards, so blending activities continued. At 23.07 WIB, the operator detected a drastic drop in the liquid level in the tank through ATG monitoring in the control room. Furthermore, the field operator reported a leak in the 42T-301G tank, which was accompanied by steam mist and oil jets around the tank. The process of reducing the height of the tank is carried out by moving the contents of the product to the 42T-301F tank by gravity. However, at 00.57 WIB, a large explosion occurred, causing a fire that engulfed four tanks at once.

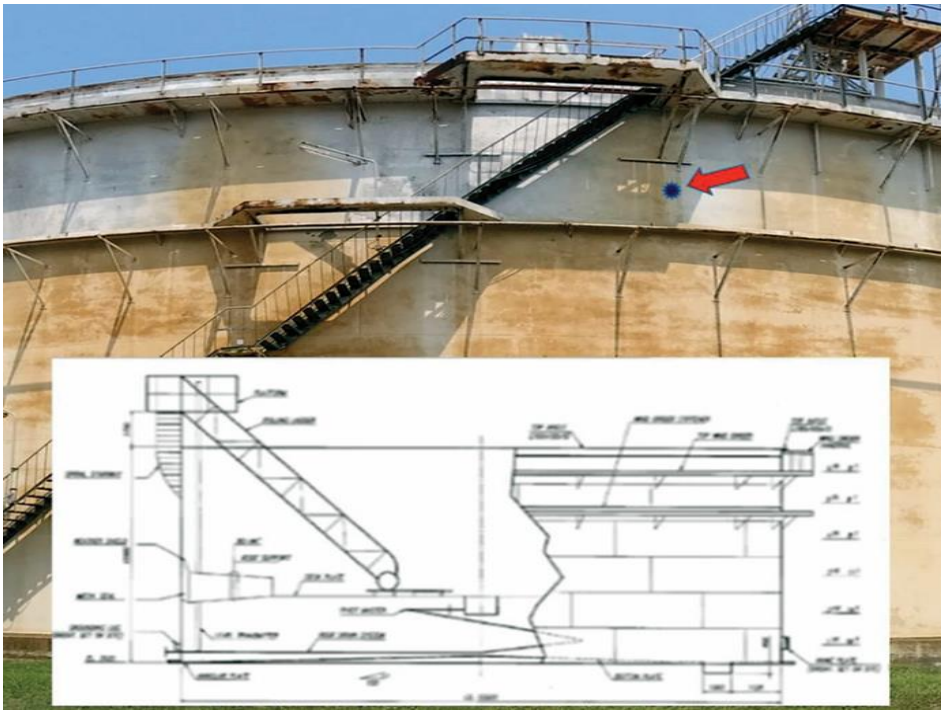

Figure 1. Simulation of Tank Leak Area Position

The results of the investigation show a number of factors that contributed to this incident. The decrease in tank level detected at 23.07 WIB indicated a leak, which then caused the spread of gas vapor around the tank area. Another fact is that the tank area has not been equipped with early warning systems, such as alarms, gas detectors, and lightning protection. In addition, it was found that the transformer cover in the Sub Station 24 area was detached and bounced as far as 50 meters, which is suspected to be one of the sources of heat that triggered the fire. Further investigation showed that the leak in the tank wall was most likely caused by local corrosion or mechanical stress on the tank weld joint. After finding this finding, the author conducted an approach to analyzing the cause of the fire using the fishbone method and obtained the following results:

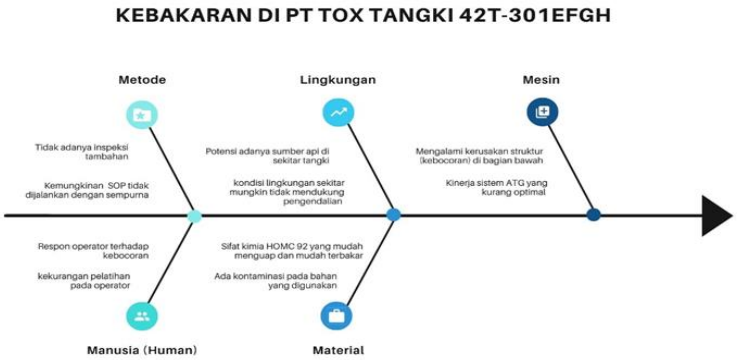

Figure 2. Cause analysis using the fishbone method

The fire in the tank of the 42T-301EFGH PT TOX can be analyzed through a fishbone diagram by identifying several causative factors. From a human perspective, the operator's response to the leak seems to be less than optimal due to the lack of experience and training in handling emergency situations. This lack of training has an effect on the delay in risk mitigation when leaks are detected. In terms of methodology, the absence of additional periodic inspections and the possibility of SOPs not being implemented perfectly are factors that aggravate the situation. Regular inspections that should be carried out can help detect potential damage early.

Environmental factors also make a significant contribution. The tank area is not equipped with early detection systems such as gas detectors and automatic alarms, so the potential for fires cannot be prevented quickly. In addition, the possibility of fire sources around the tank and environmental conditions that are not supportive of control also increase the risk. In terms of materials, the volatile and flammable chemical properties of HOMC 92 fuel increase the risk of incidents, especially if there is contamination of the material. In the engine aspect, leaks in the tank structure due to damage or weakness of materials and the performance of the ATG (Automatic Tank Gauge) system that is not optimal in detecting leaks are additional causes.

In addition to using the fishbone method, the author also approached using the domino's factory method and obtained the following results:

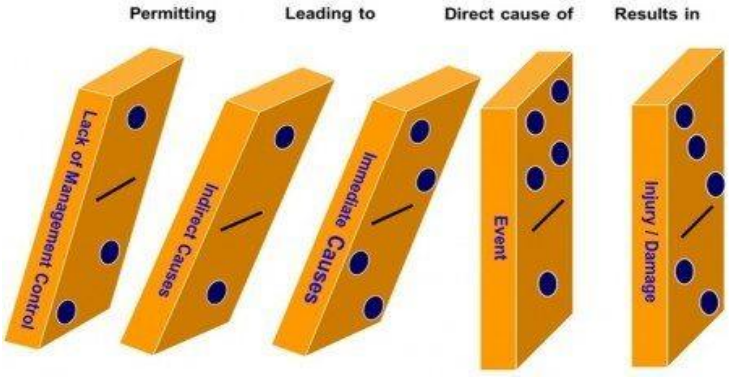

Figure 3. Cause analysis using the domino method

1. Management (Lack of Control)

The Management factor was the initial trigger in this incident. A number of deficiencies were identified, such as:

a. There is no early warning system (alarm and gas detector) in the tank area.
b. Lack of protection against lightning, even though the area is prone to flammable substances.
c. Lack of training for personnel in dealing with emergency conditions.
d. The surveillance system is inadequate to identify potential leak risks that previously existed.

This shows a significant lack of control from the management in supervising and implementing safety and maintenance systems in the tank area.

2. Basic Causes

Some of the root causes of these accidents include:

a. Lack of Engineering: Absence of gas leak detectors in the tank area.
b. Lack of competence: Officers are poorly trained in dealing with fuel leaks, which is a dangerous situation.
c. Lack of communication (Inadequate Communication/Information): Communication in handling emergencies, both internal and external, does not go well.
d. Lack of Leadership/Supervision: Inadequate supervision in abnormal situations.

This root cause provides the foundation for the continued occurrence of leaks until the explosion.

3. Immediate Causes

The direct cause was the leakage of the 42T-301G tank which resulted in gas vapor spreading around the tank. There are several possible causes of this leak:

a. Corrosion on tank walls, especially in the Heat Affected Zone (HAZ) area, which can be caused by localized corrosion, fatigue corrosion, or other corrosion factors.
b. Tears in the tank walls due to mechanical loads that may be exacerbated by the up-and-down movement of the tank, or large pressures.
c. In addition, there was exposure to gases that reached flammability limits around the SS-24 transformer, which triggered explosions and fires.

4. Unsafe Acts

In this case, unsafe actions can be associated with:

a. The transfer of fuel products to other tanks is carried out by gravity, which, although carried out as an emergency measure, is not able to stop the leak.
b. The absence of adequate protection systems, such as gas detectors or lightning protection, makes leaks undetected early.
c. Personnel who do not have sufficient competence in handling the fuel leak situation, which ultimately worsens the situation.

5. Damage/Accident

The main accident was a large explosion and fire involving four tanks (42T-301E/F/G/H), which occurred at 00:57 WIB. This was triggered by the gas vapor spreading and reaching the SS-24 transformer area, which became the source of the explosion after the gas reached the flammable range.

6. Losses/Injury

The consequences of this accident are enormous:

a. Four tank units suffered total loss.
b. Two people died and four people suffered burns.
c. The impact on fuel production at PT TOX's refinery, which is the main source of fuel supply for West Java and Greater Jakarta, has the potential to disrupt fuel distribution in the region.

Figure 4. Areas Affected by Fire

To prevent similar events in the future, some recommendations can be applied based on the analysis of fishbone theory and Domino Heinrich. From the human side, regular training is needed for operators on emergency response procedures and the operation of fire protection equipment, accompanied by simulation of emergency situations. This supervision and training must be increased to ensure personnel are ready to deal with fuel leaks. In terms of methods, periodic inspections of the tank system and review of SOPs are urgently needed to ensure disciplined implementation. The tank area should be equipped with early detection systems such as gas detectors and lightning protection to minimize the risk of fire.

In addition, a review of lightning protection systems and protection of electrical equipment, especially in high-risk tank areas, is urgently necessary. The fuel used needs to go through testing to avoid contamination. Maintenance of the ATG system and tank structure must be carried out regularly to increase the sensitivity of leak detection as well as strengthen the tank material against the risk of damage.

Improved communication and supervision during tank operations is also important to ensure informed decision-making in critical situations. With these measures, we can address the underlying causes and prevent further damage in refinery operations, as well as improve overall operational safety

Conclusion

After identifying the cause of the tank fire at PT. TOX using fishbone diagrams and also domino's factory, it can be concluded that there are several factors that cause fires to occur, this consists of human factors (operators) who do not have the competence to face fires, then there are environmental factors, machines, methods, and also materials. After further review using the Dominos's Factory analysis method, it was found that other causes of work accidents were weaknesses in risk management, lack of early detection systems, suboptimal material conditions, and lack of personal competence in handling emergencies. This incident highlights the importance of strengthening safety systems, such as the installation of early detection systems, improvement of operational procedures, periodic inspections, and improvement of competence These measures are expected to prevent similar incidents in the future, improve operational safety, and minimize the risk of losses in the oil and gas industry sector.

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