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Risk Analaysis of Ethanol Blending Fuel in Refinery Industry using Event Tree Analysis and Topsis Method

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ABSTRACT

Chemicals have always posed risks including fire, explosion, and the release of harmful substances in process industries like the Petroleum Industry. The occurrence of such catastrophes has a significant impact on the resources for finances and daily living. In this research paper, the major safety-related causes and effects are identified through event tree analysis based on accidents and incidents while using ethanol as fuel. For this purpose, the accident and incident data collected so far while using ethanol in the fuel industry, detailed information about ethanol, and even tree analysis. The event tree analysis (ETA) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) analysis method is utilized to Identifying an initiating event of interest of accident. The event tree's structure also aids the analyst in identifying the locations where additional protocols or safety measures are required to mitigate accidents or lower their frequency.

***Keyword-** Ethanol, cause and effect, even tree analysis, accident and incident*

1. INTRODUCTION

The US DOE defines ethanol as an alternative fuel based on alcohol that is created through the fermentation and distillation of feedstock that has a large number of sugars and starch. Additionally, this sustainable fuel may be made from the lignocellulosic biomass of trees and some herbs, albeit the method for making sugar from cellulose is more difficult than that for making starch [1-6].

It can be used in various ratios with unleaded gasoline to operate Flex-fuel vehicles or gasolinepowered automobiles (FFV). It is only utilized in cars of that type in the specific scenario of Brazil. Similar to what happened with biodiesel, the depletion of fossil fuel supplies, the desire to lessen reliance on them, and the climate issue caused ethanol production to increase exponentially, especially after the year 2000.

The Renewable Fuel Association and the Earth Policy Institute provided the information, respectivel [7-14].

The most popular way to make ethanol is by fermenting sugars, however the pre-treatment varies depending on the feedstock utilized. When sugar cane or sugar beet is the starting material, sugars (sucrose) are removed by pressure or diffusion; hydrolysis is not necessary. Wet milling and dry milling are the two methods that can be utilized when corn is the primary raw material. The first creates starch, while the second creates a mash (milled corn and water). In both situations, simple sugar is produced by adding an enzyme (enzymatic hydrolysis) [15-19].

Due to the complex structure of lignocelluloses biomass, pre-treatment is necessary when using it. This pre-treatment entails crushing followed by acid or enzymatic hydrolysis. Yeast is then added to the fermentable mash to produce alcohol, carbon dioxide, and other small amounts of organic chemicals.

To extract the alcohol from the solids and water in the fermented mash, distillation is next performed. The alcohol is then dehydrated to remove any remaining water. Last but not least, pure ethanol is denatured (made hazardous by the addition of chemicals like gasoline or methanol). The distiller's dried grains with soluble, or DDGS, is another co-product of the dry milling process besides carbon dioxide [20-26].

Nowadays, the dry milling method is used to manufacture the majority of gasoline ethanol (67%) from corn. Due to its flammability, handling and storage of ethanol as well as grain dust (produced during the milling and drying of corn to produce DDGS) are the greatest dangers in this type of process. Both of these factors can lead to explosive atmospheres.

Because ethanol is flammable and can combine with air to generate explosive combinations, using ammonia to control pH and provide nitrogen for yeast can also have dangers. Grain engulfment and contracted labour are two additional potentially dangerous scenarios, as a lack of safety orientation at the plant could produce an accident.

Several mishaps that happened within the ethanol life cycle have been described in the literature.

Nevertheless, it is necessary to handle all accidents and incidents that occur at facilities efficiently and to gather information about them, their sequence of occurrence, mitigation strategies, potential causes, and outcomes.

The current paper's goal is to gather information on incidents, near-misses, and accidents that have happened at fuel ethanol plants and to maintain complete, accurate records of them. The date, time, company, location, status, facility area, and accident type are all examples of broad information that can be found about accidents and incidents.

The chronology of events, mitigation strategies, immediate causes, and effects on people, the facility, and the environment are all included in the data.

There isn't yet a centralised record with this kind of data. The database makes an effort to close the existing knowledge gap about fuel ethanol manufacturing. The efforts put out in earlier and related work served as the foundation for the current study. It duplicates the steps taken to create a database of mishaps and occurrences that happened in ethanol facilities between 1998 and October 2014 [27-30].

The database exclusively includes negative incidents that took place at fuel ethanol manufacturing facilities, including cellulosic plants with operational feedstock storage areas.

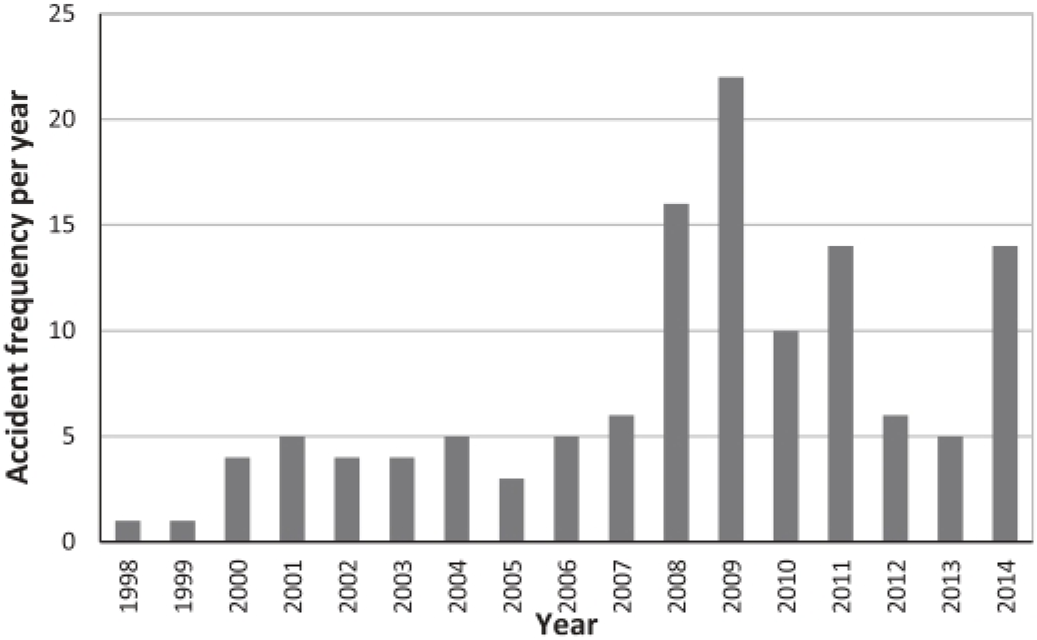
Accidents and incidents that occur in facilities that make ethanol for other purposes at homes, on the road, during transportation, and in facilities that are still under construction were not taken into account. Once more, the major goal was to compile the scattered data in order to finish the existing bio fuel database. To obtain the research objective, section 2 has classified as Literature Review, section 3 methodology, section 4 as result and section 5 as conclusion.

2. Literature Review

Several reputable bodies have thought about the implications of exposure to excessive amounts of ethanol intake on human health [31-33]

Alcohol in this context is also thought to be a teratogen and to have other reproductive effects, such as foetal alcohol syndrome (FAS), which is a well-known health effect caused by high maternal alcohol consumption (greater than 90g per day) during pregnancy and results in long-lasting physiological changes to the foetus. Chronic, moderate to heavy oral consumption of ethanol (as alcoholic beverages) was primarily linked to the development of diseases of the liver [34-36].

Furthermore, excessive oral alcohol use has been linked to a higher risk of cancer at several locations, including the female breast, the liver, and the endocrine system.



. Figure 1 Annual numbers of accidents at ethanol plants [55]

The majority of accidents involved fires; in fact, 95 out of 125 registered events (or 63% of cases) involved a fire in the facility. As an explosion may start a fire or a release may cause one, an accident may fall under more than one category. Figure 1 depicts the annual number of accidents at ethanol plants [37].

An accident is defined by the Occupational Safety and Health Administration as an unforeseen circumstance that results in either property damage or person injury (OSHA, 2013). An incident is an unanticipated, unwelcome event that interferes with the accomplishment of a task [38].

A risky situation, event, or unsafe action that might have resulted in an accident but for the preventing factor is known as a "near miss" (Jones et al., 1999). The fact that near misses frequently occur before accidents and offer a chance to lower risk factors, improving plant safety, makes keeping track of them crucial [39-42].

There were 83 plants in total that reported accidents, which were split up as follows: There are 5 facilities in Europe, including 2 in France, 1 in the Netherlands, 1 in Scotland, and 1 in Spain, in addition to the 73 facilities in the United States. The number of facilities also includes 73 in Australia, 3 in Brazil, 2 in Canada, 1 in India, and 1 in Japan. It is possible to confirm that there are more accidents than there are plants because some plants have had accidents more than once.

3. Methodology and Data collection

3.1 Events sequence of before the ethanol accidents/Incidents

- The facility's dryer system appeared to start catching fire while third shift workers were present due to leftover materials (likely corn dust). Both dryers' combustion units activated their fire suppression systems, the ductwork heated up, the fire department was called, and as a result, flames shot out of the roof duct piping seams.
- A ring dryer, a piece of machinery used to dry distiller's grain, caught fire.
- The raw material stockpile of corn stover bales caught fire.
- While the plant was running, some of the processed material caught fire when it got stuck in the ductwork and started a small fire.
- A worker was working in a 23,946 m3 bin that contained 4927.5 m3 of corn; he entered to remove corn from an outlet, but the corn began to flow, trapping him. When the worker's coworker tried to contact him, he realised the first operator was missing because he had stopped responding to his radio.
- When some grain became trapped as it passed through a dryer blower during routine operation, it likely heated up and caused a fire.
- When lightning struck the plant during a fierce thunderstorm, it started a fire that burned about 5,000 cubic metres of ethanol. Flames were visible for miles as the tank cover flew 15 metres away.
- A grain elevator at the plant caught fire.

- Outside the building, incinerators caught fire.
- In the plant's storage shed, there was a fire
- At the plant, a fire broke out.
- Under a silo, heat from a broken bearing ignited the corn mash.
- The facility was operating normally when one of the grain bin dryers experienced a mechanical issue that led to a fire [43-49].

3.2 RISK ANALYSIS

In order to perform risk analysis, conduct business feasibility studies, and organise and manage industrial prototype hazard analysis research in an Indian context, the main goal of risk assessment research is to present a thorough yet straightforward methodology [50-57].

3.2.1 Event Tree Analysis

Event tree analysis (ETA) examines responses in the context of a single initiating event and establishes a framework for evaluating the outcomes' probabilities and conducting a system-wide analysis. It is a top-down, logical modelling approach that looks ahead and accounts for both success and failure. After an event has occurred, this method of analysis is used to examine the outcomes of working or broken systems [58-62].

Fault tree analysis can be used to determine the failure probabilities for intermediate events, and success probabilities can be determined from

1 = chance of success (ps) + chance of failure (pf).

For instance, if we know that pf=.1 from fault tree analysis, we can solve for ps using basic algebra, yielding ps = (1) - (pf) and ps=.9, respectively, for the equation 1 = (ps) + (pf).

Guidelines For Conducting An Event Tree Analysis

- Create the system: Indicate what must be done or where the lines should be drawn.
- Identify the circumstances of the accident: Conduct a system assessment to find potential risks or accident scenarios in the system design.

- Find the triggering circumstances: With the aid of a hazard analysis, compile a list of initiating events.
- Pick out the transitional moments: Choose the best defences for the circumstances at hand.
- Draw a diagram of an event tree.
- Identify the chances that an event will fail: If it is not possible to obtain the failure probability, compute it using fault tree analysis.
- Opt for the most dangerous result: Calculate the overall probability of the event paths to determine the risk.
- Analyze the likelihood of the result: Examine the risks of each option and decide if they are acceptable.
- Suggestions for corrective action If an approach's outcome risk is too high, make design changes that lower the risk.
- Observe the ETA: For the entire procedure, create event tree diagrams and update them as required to reflect new information.

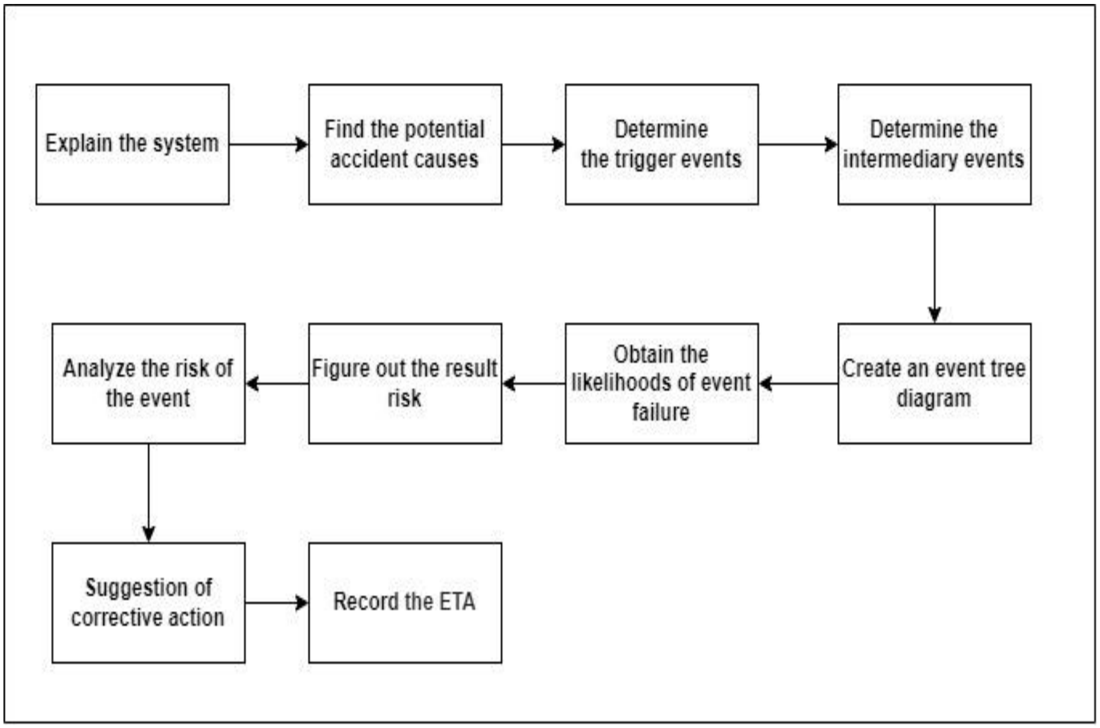


Fig.2 Steps involved in Event Tree Analysis

The diagram of the event tree shows each possible path from the initial event. A horizontal line that starts on the diagram's left side and branches vertically to represent the initial event. Whether the initiating event was successful or unsuccessful is indicated by the vertical branch. When the path is represented by a tag, such as 1s where s denotes a success and 1 is the event number, or 1f where 1 is the event number and f denotes a failure, a horizontal line is drawn at the top and bottom of the vertical branch to indicate the success or failure of the first event. Until the desired outcome is achieved, this process is repeated endlessly. Figure 2 despite the steps involved in event tree analysis.

3.2.2 TOPSIS Method

This approach suggests that the best alternative should be the one that is the most distant from the positive ideal solution and the most near to the negative ideal solution. As a result, it offers the solution that is both the most like the ideal outcome and the least like the undesirable one. The primary methodology for choosing the best option from those provided is shown in the following diagram:

Step 1. Set the objectives for the research and attribute evaluations.

Step 2. Learn the overall significance of various characteristics in relation to the goal.

The relative normalised weights of the attributes are calculated using the geometric mean method because it is quick and straightforward to determine the maximum Eigen value and to lessen consistency in solution.

$$GMj = [\prod b_{ij}]^{1/M} \quad \dots (1)$$

$$W_j = GM / \sum GM_j \quad \dots (2)$$

Calculate A3 and A4 so that A3 = A1 x A2 and A4 = A3 /A2, respectively. A2 = [w1, w2,..., wj] T and A1 = Matrix of decisions.

Find the highest possible Eigen value, max (average of matrix A4). By dividing (max - M) by (M - 1), the consistency index (CI), where M is the size of the matrix, can be calculated.

When the CI value is lower, the consistency deviation is smaller. Numerous attributes are used to calculate the value of the random index (RI). The consistency ratio (CR) = CI/RI must then be calculated; a value of CR 0.1 is considered acceptable.

Step 3. Analyze the decision matrix that has been normalised.

$$r_{ij} = x_{ij} / \sqrt{(\sum x_{ij}^2)} \quad \ldots (3)$$

$i = 1, \ldots, m; j = 1, \ldots, n$

Step 4. The weighted, normalised decision matrix should be calculated.

$$V_{ij} = W_{ij} \times r_{ij} \quad \ldots (4)$$

Step 5. Find the best answers—both positive and negative—and implement them. Positive attributes are valued at their highest in the ideal solution, while negative attributes are valued at their lowest. Similar to this, the minimum and maximum values for the positive and negative attributes, respectively, are both negative.

Step 6. Determine the separation factor. The formula for positive separation measures is

$$S_i^{+} = [\sum(V_j^{+} - V_{ij})^2]^{1/2} \quad \ldots (5)$$

The calculation of negative separation measures is

$$Si^{-} = [\sum(V_j^{-} - V_{ij})^2]^{1/2} \quad \ldots (6)$$

Step7. Calculate how close the current solution is to the ideal one.

$$P_i = S_i - (S_i^{-} + S_i^{+}) \quad \ldots (7)$$

Step 8. List the alternatives in decreasing Pi order.

An ETA is an inductive procedure that depicts all potential outcomes from an unintended (initiating) occurrence while accounting for additional factors and events, as well as whether or not the safety barriers have been installed effectively [63-67].

4. RESULT AND DISCUSSION

Based on the evaluation of criteria Table, column 3 and row 2 values 5 mean that comparison of criteria 1 and criteria 3 then the 5 value represent very high priority. Similar to evaluate the alternatives based on the each criterion. Then, the final result is shown in the below table. Figure 3 express the hierarchy of TOPSIS research objective.

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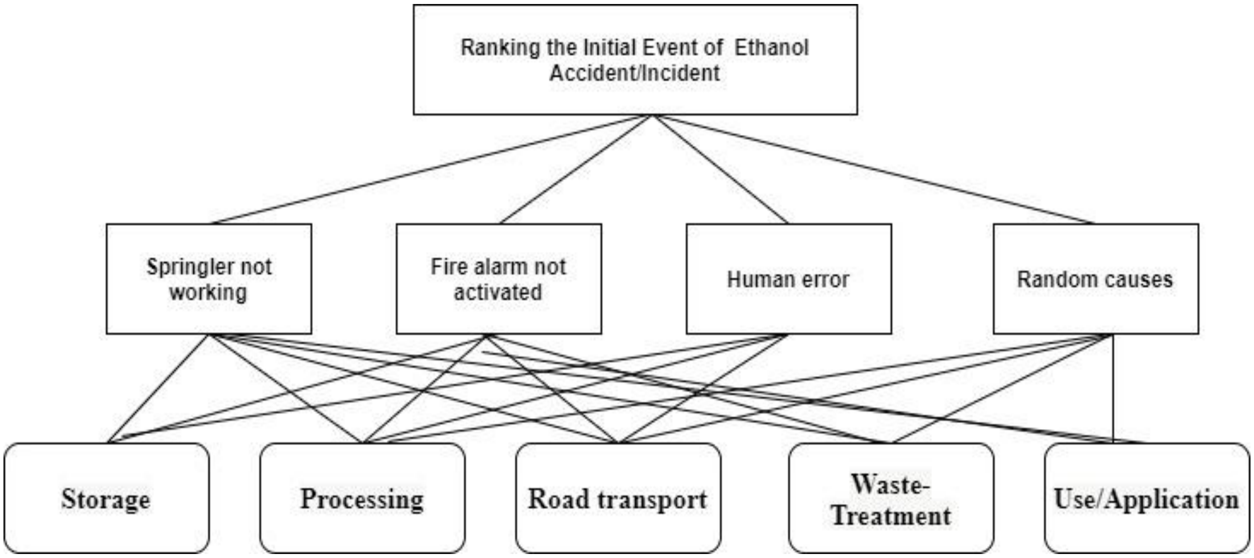

Fig .3 TOPSIS objective

Form the Figure 3, Aim of the research such ranking the initial event of ethanol accidents and incidents. Then, criteria and alternatives are described and the Table 1 express the pair wise matrix of objective based on the criteria.

Table. 1 Criteria evaluation

Criteria evaluation matrix	C1	C2	C3	C4
C1	**1**	**5**	**4**	**2**
C2	**1/5**	**1**	**2**	**1**
C3	**¼**	**½**	**1**	**2**
C4	**½**	**1**	**1/2**	**1**

Form the pair-wise matrix to evaluate the criteria by the TOPSIS scale 1 to 5 , Where

- C1- Criteria one- Sprinkler not working
- C2- Fire alarm not activate
- C3- Human Error
- C4- Random causes

Table 2 despite the risk priority number based on the TOPSIS scale and the initial event of ethanol production the following importance has been note carefully.

Table.2 TOPSIS Risk Priority Number

Alternatives	Risk priority by TOPSIS scale	Priority of risk
Application	1	Very Low priority
Waste treatment	2	Low priority
Processing	3	Moderate priority
Road Transport	4	High priority
Storage	5	Very High priority

Based on the TOPSIS analysis, high priority of Storage must need to concentrate the safety and the continuation of road transport, processing, waste treatment and the application.

5. CONCLUSION

The current work demonstrates that additional maintenance work is necessary to prevent equipment mechanical failures, which are the primary cause of accidents. On the other hand, when using maize as a feedstock, special attention should be paid to the procedure and tools involved in obtaining co-products. Accidents have been observed to occur more frequently in this region. Last but not least, extra care should be taken to store ethanol and ammonia safely by removing any sources of ignition and including the necessary ventilation.

Even though current standards can be put into practise to increase safety, addressing the risks associated with fuel ethanol production calls for significant expertise. This expertise can be attained by reviewing previous accidents and incidents. It is essential to establish and keep up a database of accidents and incidents at ethanol production facilities as a result of this.

The TOPSIS and Even Tree Analysis were pointed out the high priority ethanol production. Future direction of the research is to find out the safety precaution for this research outcomes as a good novelty.

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