

# Assessment of Accidental Release of Ethanol and Its Dangerous Consequences Using ALOHA



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## 1 Introduction

Due to rapid industrialization, chemical demand has been increased tremendously, which poses a major threat to safety in industries. Process industries are always susceptible to major fire, explosion and accidental dispersion of hazardous chemicals. Most of the industrial chemicals are toxic, corrosive, flammable and poisonous in nature, unexpected or accidental release have adverse effect on human as well as for environment, and sometimes, it can lead to major catastrophe like Bhopal gas tragedy (Khan and Abbasi 1999). In distillery industries, ethanol is the extraction of sugarcane molasses, barley, wheat, etc. from fermenting it which further used in petroleum products, pharmaceutical companies, etc. (Horn et al. 2000). Ethanol can be directly blended with gasoline, reacted with isobutylene to form the oxygenated fuel additive ethyl tert-butyl ether (ETBE), or burned directly as a clean fuel. Blends of either ethanol or ETBE with gasoline force engines set for gasoline to run lean and can substantially reduce carbon monoxide emissions; so nowadays, the use of ethanol in gasoline is quite common (Wyman and Hinman 1990). There are many studies which shows the flammable characteristics of the ethanol and if not handled properly could lead to catastrophe, the heat generated due to ethanol is  $26.78 \text{ kJ g}^{-1}$ , and the closed-cup flash point is  $16 \text{ }^\circ\text{C}$  (Hurley et al. 2015; Lyondell Chemical Company 2003). Some studies show that more than 20% of ethanol in any mixture is enough to form fire load (Fischer et al. 1987).

In this study, the Areal Locations of Hazardous Atmospheres (ALOHA) model has been chosen to simulate the scales of impact (threat zones) in the event of toxic chemical release (Hillairet et al. 2009). ALOHA is the program which is widely used in modeling the potential hazard of chemical releases in industries. Dispersion model is applicable for the fluid flow system which are classified as heavy gases (heavier

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than the air) and volatile chemical vapor cloud (Inanloo and Tansel 2015). ALOHA 5.0 provides user a choice of several accident scenarios, then uses a suitable source algorithm to release material into the air over a period of time (Shao and Duan 2012).

The simulation results based on Emergency Response Planning Guidelines (ERPG) and corresponding immediately dangerous to life or health (IDLH) values. The results and assessment of the simulation used for improvisation of safety during the handling of such types of chemicals and further used to analyze the potential harm and damage hence improve the risk assessment of the industry (Curran 2012).

Emergency response planning is a method which gives complete guideline for safe evacuation in case of fire and explosion (Tseng et al. 2008). Failure of which could lead to huge losses. Hence, the main objective of this study is to simulate the consequence modeling of toxic gas dispersion and evaluate the radius or area of the dispersion. This study quantifies the threat zones and areas which can be affected due to accidental release (Arunraj and Maiti 2009).

In this simulation, Aloha software helps to determine the dispersion of gases into the atmosphere whether it is leaking from pipes, spilling from tanks and a pool fire from puddle. It also predicts the concentration of gases at a different location and depicts the result in the form of graphs. So, it is easy to calculate the dispersion of vicious gases in the surrounding after an escaping of any chemical releases. Moreover, ALOHA can evaluate the instant area which is immediately dangerous to life and health or level of concern LOC. In this assumption, we can trace the footprint of gas with it. The Areal Locations of Hazardous Atmospheres (ALOHA) model has been chosen to show the results in the form of the graphs giving the approximation idea about the hazardous atmospheric location and its severity level which helps industries to carefully perform a risk assessment and improve the emergency response planning (Tseng et al. 2008).

In this study, ALOHA is used to simulate the toxic release of ethanol from storage tank and predict the impact zones considering the recent accident happened in sugar industry during loading of ethanol, ALOHA estimate the threat zone area where the results help to identify the contributors of the accidents and help other industries to improve the safety while handling ethanol.

## 2 Research Methodology

### 2.1 Description of Location and Atmospheric Condition

The city of Uttar Pradesh, Meerut, has been selected for the study. In order to identify detail analysis, here are some atmospheric condition of Meerut; it lies between 28° 58 longitude and 77° 42 latitude. In this study, we took two seasons, i.e., summer having a temperature of 40 °C and winter having a temperature of 20 °C. Its wind speed varies between 3 and 6 m/s.

## 2.2 ALOHA Dispersion Model

The Areal Location of Hazardous Areas is a freeware software tool developed by the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA), Chemical Emergency Preparedness and Prevention Office (CEPPO) and US Environmental Protection Agency (USEPA). The Gaussian model of dispersion has been used to model the dispersion of methane gas as it is neutrally buoyant and will spread with the downwind direction (Jones et al. 2013). ALOHA tool is adopted to simulate the accidental release of ethanol from storage tank and the simulation results are shown in Table 1.

This simulation is approaching the toxic material ethanol which is colorless and has a boiling point of 78.5 °C (Coward and Boruta 1995). This makes the chemical hazardous to human being and environment. Ethanol is widely used in industries for making perfume and paint. Any mishandling and leniency may lead to catastrophic. Hence, this simulation helps workers and industries to closely analyze the risk involved in handling of ethanol and prepare emergency response according to it and in a more systematic way. It has been observed that most of the accidents occurred during high rush time, so emergency response was not followed in a systematic manner; this study gives a brief idea about threat zones involves which may help industries to formulate their risk assessment and emergency planning to save people and property.

**Table 1** Ethanol release scenario for simulation

Hypothetical scenario of simulation fixed parameters	Scenario 1 (Summer)	Scenario 2 (Winter)
Temperature	Summer: 40 °C	Winter: 20 °C
Relative humidity	50%	20%
Elevation of wind speed measurement	737.07 ft	737.07 ft
Total amount burned	4226 lb	4365 lb
Model of release	Direct release	Direct release
Model	Heavy gas dispersion	Heavy gas dispersion
Cloud cover	5 tenths	5 tenths
Terrain roughness	Urban or forest	Urban or forest
Manipulated parameters	–	–
Atmospheric stability level	B	C
Wind speed	5 m/s	3.6 m/s
Total duration burn	28 min	28 min

### 3 Limitation

ALOHA's simulation is not able to detect exact release of chemical; it assumes the chemical is mixed with air immediately but is not happen in actual; that is why it shows bell-shaped curve of any concentration. ALOHA's simulation is not able to determine the end products, i.e., smoke, particulate matter, radioactive particles. In this simulation, it is not able to determine the flying debris of container while having an explosion.

The concentration estimates by ALOHA can be inaccurate at very low wind speeds especially less than 3 miles per hour as the pollutant cloud is unable to mix with the surroundings quickly and ALOHA is unable to predict the concentrations especially near the source. ALOHA assumes the wind speed and direction to be constant throughout simulation. But in reality, wind speed and direction change with respect to time.

### 4 Result and Discussion

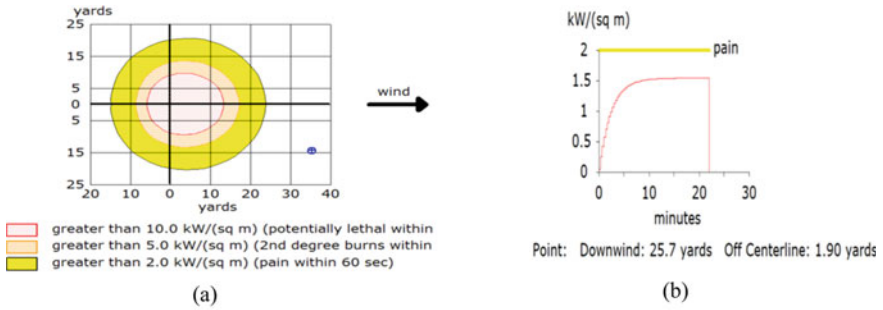
ALOHA model was used to simulate the release of ethanol chemical from a tank in the distillery plant. This simulation has been tabulated in Tables 1, 2 and Figs. 1, 2. The transport of ethanol is a complex process and in case of any loss of control, can prompt an accident; therefore, the simulation results from this study can prove to be very helpful in determining the affected distance over which injury can occur. Additionally, the results seem to be helpful in construction of an effective response plan during such situation.

#### 4.1 Scenario 1

Figure 1b shows the graphs which ALOHA simulation gives after putting all the atmospheric conditions and geographical data. Figure 1a shows thermal radiation threat zone are in which categories the area according to their severity, the parameter taken to define the threat zone is the heat energy flowing per unit area per unit time, i.e., heat flux density. From the scenario 1, it has been observed that threat zones are classified in three categories based on heat flux density. The maximum threat

**Table 2** Threat zone of chemical substance ethanol

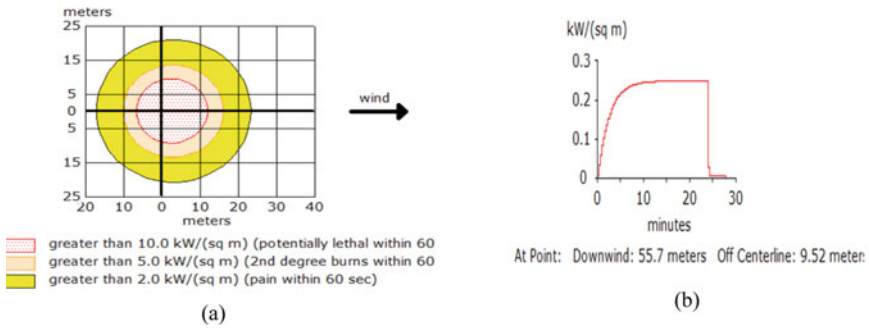
S. No.	Toxic in effect	Scenario 1 (threat zone in summer)	Scenario 2 (threat zone in winter)
	Ethanol	ERPG 1 (1800 ppm): 21 m ERPG 2 (3300 ppm): 16 m IDLH (3300 ppm): 12 m	ERPG 1 (1800 ppm): 12 m ERPG 2 (3300 ppm): 16 m IDLH (3300 ppm): 23 m



(c)

**Fig. 1** Flammable, toxic area and thermal radiation due to dispersion of ethanol, wind speed 5 m/s

or risk factor involves in the location where flux is  $10 \text{ kW/m}^2$  and it covers areas which are close to the storage tank and distance up to 12 m. The pink area shown in graph Fig. 1a lies under moderate threat zone where heat flux density is greater than  $5 \text{ kW/m}^2$  but less than  $10 \text{ kW/m}^2$ , covers distance up to 16 m and has a potential to cause second degree burns. The region marked in yellow shows the area where flux is greater than  $2 \text{ kW/m}^2$  but less than  $5 \text{ kW/m}^2$ , covers distance up to 21 m and can cause pain within 60 s of exposure time. In this scenario, ERPG-1 constitutes of 1800 ppm concentration, ERPG-2 and IDLH value is 3300 ppm.



(c)

Fig. 2 Flammable, toxic area and thermal radiation due to dispersion of ethanol, wind speed 3.6 m/s

## 4.2 Scenario 2

Figure 2b shows the graphs which ALOHA simulation gives after putting all the atmospheric conditions and geographical data. Figure 2a shows thermal radiation threat zone are in which categories the area according to their severity, the parameter taken to define the threat zone is the heat energy flowing per unit area per unit time, i.e., heat flux density. From the scenario 1, it has been observed that threat zones are classified in three categories based on heat flux density. The maximum threat or risk factor involves in the location where flux is 10 kW/m<sup>2</sup> and it covers areas which are close to the storage tank and distance up to 10.93 yards. The pink area shown in

graph Fig. 2a lies under moderate threat zone where heat flux density is greater than  $5 \text{ kW/m}^2$  but less than  $10 \text{ kW/m}^2$ , covers distance up to 15 yards and has a potential to cause second degree burns. The region marked in yellow shows the area where flux is greater than  $2 \text{ kW/m}^2$  but less than  $5 \text{ kW/m}^2$ , covers distance up to 24 yards and can cause pain within 60 s of exposure time. In this scenario ERPG-1 constitutes of 1800 ppm concentration, ERPG-2 and IDLH concentration is 3300 ppm.

## 5 Conclusion

From the simulation, it can be observed that the primary causes of accidents are atmospheric stability level, wind speed and season of the year. As aloha simulation performed for two scenarios, i.e., summer and winter season, the results show that due to different atmospheric condition and other factors such as wind speed, temperature, etc. plays an important role in the dispersion of any toxic release. The results of simulations have shown that there is significant in IDLH, ERPG-1, ERPG-2 zones as atmospheric conditions change. The results obtained in summer season the ILDH zone cover 12 m, whereas in winter season, it covers 23 m, which gives a clear picture that the dispersion distance is more in summer as compare to winter. The difference in dispersion region is due to high wind velocity which increases the dilution of gas in the atmosphere rapidly. This gives clear evidence that impact due to threat zone depends on atmospheric and geographical conditions of the area. Further, this study enables the industries which are handling ethanol to plan their risk assessment and management to cope up with any kind of discrepancies in the future. If industries perform ALOHA in the initial stage to predict the future mishappening, it would not only give a reference for safety officer of the rescue operation but also help to notify the areas which are near to that industry which enables them to take necessary precaution to ensure their safety.

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