Consequence modeling of Ethyl Acetate storage tank

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Abstract. Consequence modeling of ethyl acetate 40 KL aboveground storage tank was carried out under different scenarios. The toxic concentration of ethyl acetate beyond IDLH (i.e. 2000 ppm) covered up to 23 meters from the release source when there was a leak that occurred 2 inches from the bottom of the tank. The flammable vapor cloud enveloped up to 13 meters from the release source when the concentration of ethyl acetate was beyond 60% of LEL (i.e.13080 ppm). The mass of the fire ball was considered as 100% in order to get the worst case scenario during BLEVE. Based on the mass of the methyl acetate the diameter and duration of the fire ball was 190 meters and 12 seconds respectively during BELVE.

1. Introduction
The risks associated with the pharmaceutical manufacturing industries are proportionate to their fast growth and development in India. These industries have high probability for incidents due to the use of highly flammable and toxic materials in the process [1]. Some of the chemicals which are highly flammable include ethyl acetate, ethanol, methanol, toluene etc.

In general, the flammable liquids will be stored in aboveground or underground storage tanks at a dedicated location according to the Indian Petroleum Rules, 2020. These chemicals will be transferred to day tanks and to process area from the local day tanks. The release of these flammable liquids during the process can cause fire and thermal radiation. The damage to people and property can be controlled with effective emergency preparedness. The consequence modeling is required in order to estimate the potential for damage or injury from a specific incident [1,2,3].

Several softwares are available for the consequence modeling of hazardous chemicals. In this study, ALOHA (Areal locations of Hazardous Atmosphere) software was used for modeling the consequence [4]. This software was developed by the Environmental Protection Agency (EPA), USA.

There are several consequence modeling studies are available for different chemicals [1,2,3] such as LPG, Ammonia, Toluene etc. under different conditions. However, there were no studies reported on Ethyl acetate. Ethyl acetate is a solvent and is suitable for food applications, and is a commonly
used chemical in the pharmaceutical manufacturing process. According to the Indian Manufacture, Storage and Import of Hazardous Chemicals Rules 1989 (Amended in 2000) Ethyl acetate is a hazardous chemical and categorized under “very highly flammable liquids”. So, it is essential to understand the consequence analysis of Ethyl acetate. In this research paper, consequence modeling of the ethyl acetate was carried out for the 40 KL aboveground storage tank.

2. Materials and Methods
Ethyl acetate solvent was considered for the consequence modeling. Ethyl acetate is highly flammable and low toxic. When exposed to Ethyl acetate at 400 PPM, it will cause irritation to eyes and nose. IDLH (immediately dangerous to life or health) value of Ethyl acetate is 2000 ppm. However, it is difficult to obtain high exposure concentrations at normal temperature. The following consequence models were obtained: 1) Toxic area of vapor cloud, 2) Flammable area of vapor cloud, 3) Thermal radiation from pool fire and 4) Thermal radiation from BLEVE (Boiling Liquid Expanding Vapor Explosion).

The consequence modeling in terms of affected distance from source was determined using the ALOHA 5.4.7 software [5]. The various factors required for the consequence modeling by the aid of ALOHA includes geographical conditions, atmospheric data, and chemical data and source details.

In this work, we have considered the tank’s total volume to be 42 KL containing liquid Ethyl acetate of 40 KL with L/D ratio of 2 [6]. The leak size was considered to be 2 inch from bottom of the tank due to rupture of the pipe line [7].

The incident location considered is in Visakhapatnam Pharma SEZ (Special Economic Zone) area. The atmospheric data of Visakhapatnam was considered from the reliable sources [8], average temperature of air was 35°C, average wind speed was around 4.3 m/s, and relative humidity was 70%. D-stability class was considered during the dispersion modeling in order to consider the neutral conditions based on the recommendation from ALOHA.

3. Results and Discussion
Consequence models were obtained for Ethyl acetate in different scenarios such as toxic area of vapor cloud, flammable area of vapor cloud, thermal radiation from pool fire and thermal radiation from BLEVE. Table 1 summarizes the consequence modeling in terms of affected distance from the source for ethyl acetate as per the assumptions stated in the section 2 of this paper.

| S.No. | Effect/ Scenario                        | Effected distance from source (in m) |
|-------|----------------------------------------|-------------------------------------|
| 1     | Toxic area of vapor cloud              | 400 ppm, 2000 ppm                   |
| 2     |                                        | 96, 23                               |
| 3     | Flammable area of vapor cloud          | 60% LEL, 10% LEL                    |
| 4     |                                        | 13, 31                              |
| 5     | Thermal radiation level during pool fire| 10 kW/m², 5 kW/m²                   |
| 6     |                                        | 13, 16                              |
| 7     |                                        | 2 kW/m², 2 kW/m²                    |
| 8     | Thermal radiation - BLEVE             | 2 kW/m², 2 kW/m²                    |
| 9     |                                        | 280, 403                            |
| 10    |                                        | 634                                 |

3.1. Toxic area of vapor cloud
Figure 1 shows the threat zones of toxic area of vapor cloud for Ethyl acetate which obtained from ALOHA software. It is obvious that the distance is indirectly proportional to concentration, higher the
concentration lower the distance covered. The orange zone covers 23 to 96 meters from the release source when the concentration of Ethyl acetate is beyond 400 ppm and less than IDLH (i.e. 2000 ppm). When people are exposed in orange zone, they can feel irritation to eyes and nose. The red zone covers up to 23 meters from the release source when the concentration of Ethyl acetate was beyond IDLH (i.e. 2000 ppm). The red zone was not drawn by ALOHA software because effects of near-field patchiness make dispersion predictions less reliable for short distances. However, the value can obtained from ALOHA program separately. When people are exposed in red zone, it can lead to life-threatening health effects or death.

![Diagram of threat zones](image1)

**Figure 1.** Threat zones of toxic area of vapor cloud for ethyl acetate from ALOHA

3.2. **Flammable area of vapor cloud**

Figure 2 shows the threat zones of toxic area of flammable area of cloud for Ethyl acetate which was obtained from ALOHA software. It is obvious that the distance is indirectly proportional to concentration, higher the concentration lower the distance covered. The yellow zone covers 13 to 31 meters from the release source when the concentration of Ethyl acetate is beyond 10% of LEL (i.e. 2180 ppm) and 60% of LEL (i.e. 13080 ppm). All works to be suspended in this zone during the emergency to minimize heat/spark/flame sources. However, emergency activities can be carried out with necessary precautions.

The red zone covers up to 13 meters from the release source when the concentration of Ethyl acetate beyond 60% of LEL (i.e. 13080 ppm). All works to be suspended in this zone during the emergency to minimize heat/spark/flame sources. As far possible emergency activities (i.e. firefighting) is to be carried out from beyond the red zone. Flammable area of cloud zones was also not drawn by ALOHA software because effects of near-field patchiness make dispersion predictions less reliable for short distances.
3.3. Thermal radiation from pool fire

Figure 3 shows the threat zones of thermal radiation during pool fire for Ethyl acetate which was obtained from ALOHA software. It is obvious that the distance is indirectly proportional to concentration, higher the concentration lower the distance covered. The yellow zone covers 16 to 21 meters from the release source when the heat radiation from pool fire of Ethyl acetate is beyond 2 kW/m\(^2\) and less than the 5 kW/m\(^2\). When people are exposed to thermal radiation from pool fire in yellow zone, they can feel pain within 60 seconds.

The orange zone covers from 13 to 16 meters from the release source when the heat radiation from pool fire of Ethyl acetate is beyond 5 kW/m\(^2\) and less than the 10 kW/m\(^2\). It can cause second degree burns within 60 seconds when people are exposed to thermal radiation from pool fire in orange zone. The red zone covers up to 13 meters from the release source when the heat radiation from pool fire of Ethyl acetate is beyond 10 kW/m\(^2\). When people are exposed to thermal radiation from pool fire in red zone, it can lead to lethal within 60 seconds.
3.4. Thermal radiation from BLEVE

BLEVE is a kind of explosion which caused due to the rupture of pressurized liquid in a tank. The pressure in tanks reaches abnormal condition when Methyl acetate temperature reaches beyond the boiling point. This situation can arise due to thermal radiation from pool fire from same tank or material from adjacent tank and BLEVE from other tanks located nearby. The mass of the fire ball was considered as 100% in order to get the worst case scenario. Based on the mass of the Methyl acetate the diameter and duration of the fire ball was 190 meters and 12 seconds respectively, these values were computed from ALOHA software modeling.

Figure 4 shows the threat zones of thermal radiation during BLEVE for Ethyl acetate which obtained from ALOHA software. It is obvious that the distance is indirectly proportional to concentration, higher the concentration lower the distance covered. The yellow zone covers 403 to 634 meters from the release source when the heat radiation from BLEVE of Ethyl acetate is beyond 2 kW/m² and less than the 5 kW/m². When people are exposed to thermal radiation from BLEVE in yellow zone, they can feel pain within 60 seconds.

![Thermal radiation zones](image)

**Figure 4.** Threat zones of thermal radiation during BLEVE for ethyl acetate from ALOHA

The orange zone covers 280 to 403 meters from the release source when the heat radiation from BLEVE of Ethyl acetate was beyond 5 kW/m² and less than the 10 kW/m². It can cause second degree burns within 60 seconds when people are exposed to thermal radiation from BLEVE in orange zone. The red zone covers up to 280 meters from the release source when the heat radiation from BLEVE of Ethyl acetate was beyond 10 kW/m². When people are exposed to thermal radiation from BLEVE in red zone, it can lead to lethal within 60 seconds.

The data obtained from ALOHA software is useful for planning the emergency preparedness of Ethyl acetate storage tank. It is always recommended to prevent the chemical release or fire incidents from the storage facility. The following recommendation will be useful for prevention of chemical
release and fire incidents during the storage of Ethyl acetate which are not limited:

- All the electrical fitting must be flame proof according to the hazardous area classification
- Ensure the electrical continuity by bonding and earthing to the storage tank
- Ensure the electrical continuity by bonding all the pipe line flange joins
- Ensure the electrical continuity by bonding and earthing while unloading or loading operations from the taker
- The minimum safe distance between storage vessels must be maintained
- Regular inspection to be carried out for the storage tank, pipelines, electrical wires and fitting etc.
- Suitable bund wall to be provided for the storage tank
- Notice board on “no smoking/mobile/necked flame” to be displayed
- Possibilities for nitrogen interstation to be explored for the storage tank
- Flame arrestor to be provided the vent line
- Train the workforces related to hazard and precautions while handling Ethyl acetate

4. Conclusions
Consequence modeling of Ethyl acetate in different scenarios was computed using ALOHA software. The orange zone for toxic cloud area covers 23 to 96 meters from the release source which cases the irritation to eyes and nose. The red zone for toxic cloud area covers up to 23 meters, it can lead to life-threatening health effects or death. The red zone during thermal radiation from BELVE covers up to 280 meters from storage tank, it will be lethal for humans within 60 seconds for personnel located in this zone. The red zone during the flammable area of vapour cloud covers up to 13 meters from the storage tank, as far possible emergency activities (i.e. firefighting) is to be carried out from beyond this red zone. The data obtained from this research work will be useful for planning the emergency preparedness of Ethyl acetate storage tank.

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