Scenario Building and Simulation Analysis of Typical Accident at Berth of Loading and Unloading Ethanol

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Abstract. In this paper, the background was loading and unloading ethanol at berth No. 17 of a dock in Qinzhou. On the basis of analyzing the results of an ethanol leakage accident, ALOHA simulation software was used to simulate the threat zone of the accident, so as to obtain the area with leaked ethanol dispersion, the area affected by vapor cloud explosion, and the area affected by toxic hazard in the hazardous scenario. The research results provide effective information for the prevention, control, rescue, and handling of the accident of ethanol leakage at the dock, and bring brand-new solutions and thinking to the prevention and control of the leakage accident of hazardous chemicals.

Keywords: Ethanol leakage · ALOHA · accident simulation · prevention and control

1 Introduction

In the process of loading and unloading a liquid chemical at a dock, once a leakage accident occurs, in environmental conditions, the leaked material will be continuously vaporized and disperse into the surrounding area, producing an adverse effect on the health of operating personnel, and even causing acute intoxication of personnel if the concentration of the material is high. When the concentration of a boil-off gas reaches its explosion limit, and if the gas encounters an ignition source, the accident of explosion and flame will occur [1].

In recent years, many domestic and overseas scholars have utilized ALOHA to simulate the dispersion paths of hazardous chemicals in the air, and at the same time, gas concentrations have been calculated to determine the areas affected by accidents. It is significant to carry out analysis with ALOHA in emergencies, so as to guide the first aid treatments on the sites of accidents and take corresponding measures to reduce the casualties of the accidents [2]. Since 2000, domestic and overseas researchers have started to introduce the method of ALOHA software. For instance, Liang used ALOHA to estimate the dispersion shape of hazardous chemical substances in the atmospheric

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environment and the area affected by the substances, and in the form of images, described the concentrations of the dispersed substances, the areas affected by them, and other information [3]. Huang et al. used ALOHA to make a qualitative analysis of the area with toxic gas dispersion, and the hazardous areas with the accidents of vapor cloud explosion and boiled liquid dispersion in a chemical plant [4].

This paper took berth No. 17 at a dock of loading and unloading ethanol in Qinzhou as the research subject, and it was aimed at studying the effects of various accidents likely to occur once there is ethanol leakage, so as to obtain the areas affected by various leakage conditions. It is hoped that, by estimating the areas affected by leakage accidents, the relevant measures and opinions on risk control can be provided, and by predicting the areas affected by accidents, the capability of risk control can be enhanced.

2 Analysis of the Types of Ethanol Accidents

Ethanol is a colorless, transparent, fragrant, and volatile liquid, with such hazardous characteristics as flammability, explosibility, highly flowable dispersity, expansibility after heating, and easily gathering static charge [5]. Because ethanol has a low flashing point and strong chemical activity, it is categorized as a Class-1 hazardous chemical and shall be far from tinder, heat source, oxidant, and oxidizing acids.

If ethanol is leaked at normal pressure and temperature, it can be rapidly dispersed to the surrounding area to form a liquid pool, and if the pool encounters open fire, it can cause pool fire which mainly produces destructive heat radiation [6]. If heat radiation acts on containers and equipment, their internal pressure will rapidly increase, causing ruptures of the containers and equipment. If heat radiation acts on combustibles, they can be ignited; and if heat radiation acts on persons, they will suffer a burn or even death.

After ethanol is leaked, if its vapor is premixed with the surrounding air, if the ignition is delayed, and the space is confined, and if the vapor encounters open fire and a great amount of heat energy, flame and explosion will occur. After the vapor cloud explodes, its destructive effects mainly include the injury or damage of the surrounding persons, buildings, and such equipment as tank storage, caused by the explosive shock wave and the heat radiation of explosive fireball [7].

3 Simulation of Ethanol Leakage Based on ALOHA Software

The simulation software of ALOHA (Areal Locations of Hazardous Atmospheres) is a program jointly developed by the U.S. Environmental Protection Agencies (EPAs) Chemical Emergency Preparedness and Prevention Office (CEPPO) and the National Oceanic and Atmospheric Administration (NOAA) [8]. The software is used to calculate the results of accidents likely caused by various risk factors. ALOHA includes a database with approximately 1000 types of common chemicals. The information in this database includes types of chemicals, locations of emergencies (urban or suburb), weather conditions (temperatures, wind velocities, wind directions), and variables of emergencies (stored materials, dimensions of leakage hole, storage pressures), etc. [9].

The mathematical models used in ALOHA include such mature computation models as the Gauss model, DEGADIS heavy gas dispersion model, vapor cloud explosion, and BELEVE-Fireball [10]. By choosing an appropriate accident result model, and through calculation, the following results can be obtained: concentration of toxicant, heat radiation, and shock wave overpressure involved in the accidents of toxic gas dispersion, fire disaster, and explosion caused by chemical leakage.

3.1 Settings of Parameters

In this study, such parameters as the specific type of material, scenario, duration, and dispersion conditions of a leakage accident are selected mainly based on the actual working conditions of the research subject.

3.2 Selection of Accident Scenario

Selection of the Type of Material of a Typical Leakage.

The principles of selecting a typical type of material include those with a large volume of material transported, with a great danger of fire disaster, high volatility, strong toxicity, etc. Therefore, this time ethanol was selected as the typical type of material to carry out the calculation and estimation of the simulation.

Selection of Leakage Scenario.

According to the statistical data of relevant accidents, it is assumed that the scenario of leakage of container (LOC) in the process of loading and unloading for the operation of a ship is seen in Table 1.

Selection of Leakage Duration.

In the process of actual production, such measures as the detection and control of pressure and flow were adopted, and the personnel was appointed to inspection tours on the site of operation, so leakage duration usually didn't exceed 5 min. At the time of calculating leakage quantity, the maximum duration was considered as 5 min.

Selection of Typical Atmospheric Dispersion Conditions

The atmospheric conditions producing a major effect on gas dispersion include wind velocity, wind direction, atmospheric stability, the height of the mixing layer, and air temperature. According to the natural conditions of the area of the project, atmospheric conditions of dispersion were selected as shown in Table 2.

Table 1. Scenario of LOC in the process of loading and unloading for the operation of a ship

The scenario of loading and unloading for the operation of a ship	Location	Scenario of LOC
Loading and unloading with DN250 loading arm for the operation of ethanol ship at berth No. 17	Berth No. 17	Leakage was selected at the center hole, and the equivalent hole diameter of leakage was 25 mm.

Table 2. Selection of typical atmospheric conditions of dispersion

Air velocity	6.3 m/s
Wind direction	Prevailing wind direction (N)
Air temperature	20 °C
Relative humidity	82%
Atmospheric stability	D

3.3 Results and Discussion of Simulation

After the corresponding leakage model was selected, the leakage accident that occurred in the process of loading and unloading operation at the dock was simulated, and the calculation results are seen in Table 3.

It can be seen from Table 3 that, once a center-hole leakage accident occurs at berth No. 17, and the duration is 5 min, the corresponding leakage quantity of ethanol is 0.348 T. If the flammable and explosive liquid chemical in such a large quantity is leaked out, the accident with flame or explosion of vapor cloud will occur. If a center-hole leakage accident occurs at a ship in the event of loading and unloading ethanol, and the leakage duration is 5 min, the typical leakage case is simulated as below.

According to the simulation of ALOHA software, affected by the vapor cloud, the toxic area, the flammable area, and the predicted hazardous area with explosion overpressure are shown in Figs. 1, 2, and 3.

It is known from the simulation diagrams that: If a center-hole leakage accident occurs at a ship in the event of loading and unloading ethanol, and the leakage duration is 5 min, the vapor of leaked ethanol gathers in the downwind direction (i.e. in the south of the berth). Affected by ethanol vapor, the toxic area can reach a maximum distance of 90 m in the downwind direction; within the area from the leakage point to the point 60 m far away in the downwind direction, the general population including susceptible individuals may have irreversible or other severe and persistent injuries, so it is suggested that people in the area should escape from it immediately; within the area of 60 m to 90 m from the leakage point in the downwind direction, the general population including susceptible individuals may feel uncomfortable. The flammable area includes a maximum distance of 14 m in the downwind direction; the hazardous

Table 3. Leakage rate of typical material and relevant parameters

Leaked material	Ethanol
The hole diameter of leakage (mm)	25
Initial pressure (MPa)	0.2
Leakage rate (kg/s)	1.16
Leakage quantity (t)	0.348

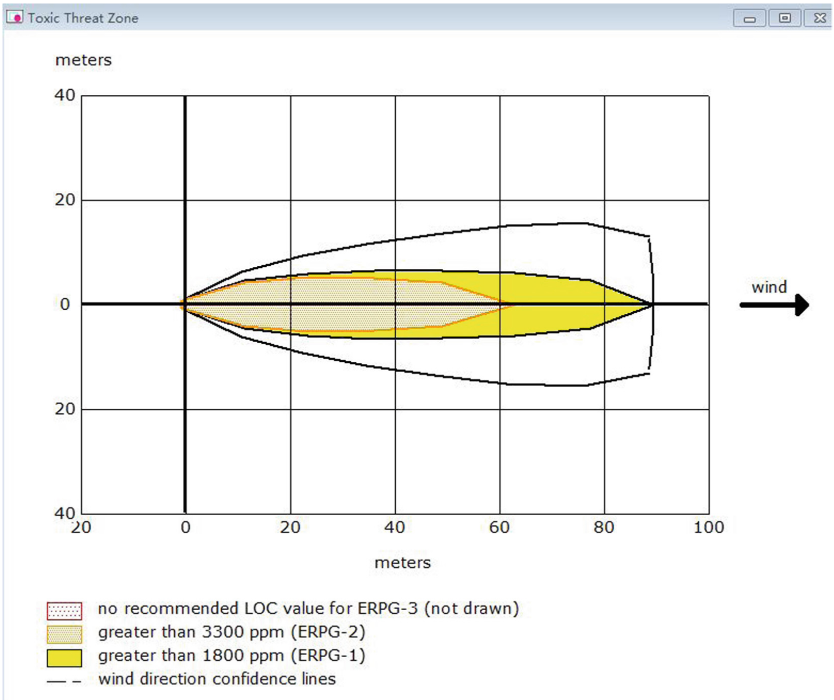

Fig. 1. Simulation diagram of toxic hazardous area

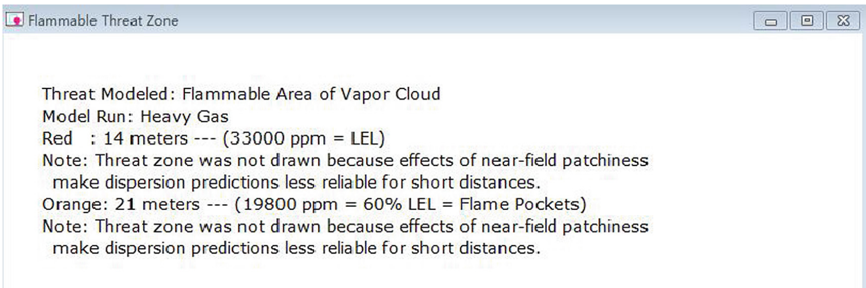

Fig. 2. Simulation diagram of the flammable area

area with explosion overpressure covers a maximum distance of 16 m in the downwind direction.

4 Conclusions

According to the results of this study, if center-hole leakage occurs at berth No. 17 and the duration is 5 min, the leakage will cause an intoxication accident or accident of fire disaster with vapor flame and the accident of vapor explosion. Affected by ethanol

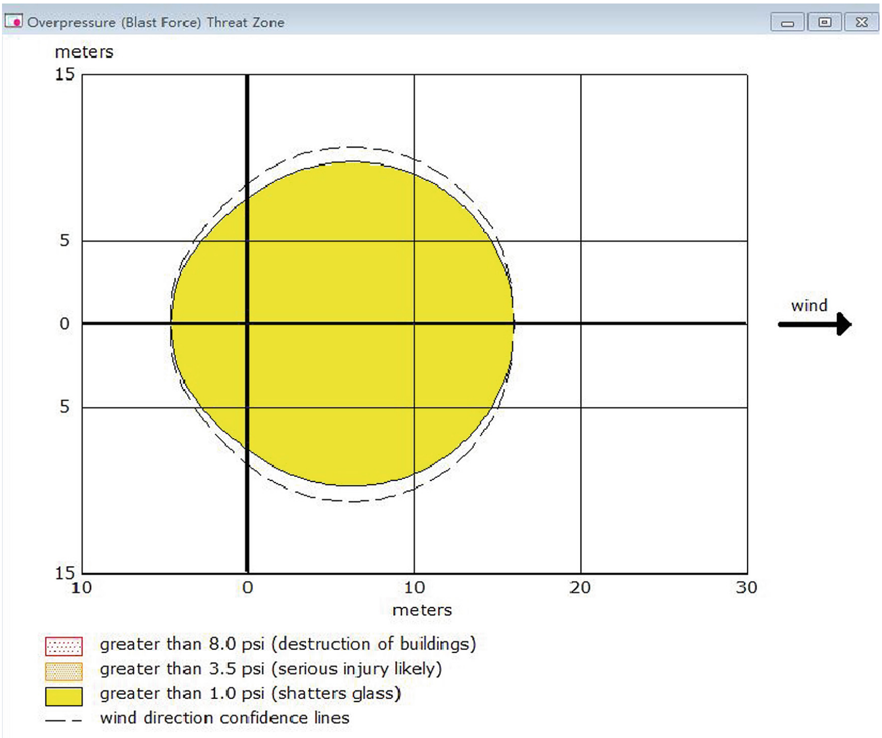

Fig. 3. Simulation diagram of the predicted hazardous area with explosion overpressure

vapor, the toxic area reaches a maximum distance of 90 m in the downwind direction; the flammable area includes a maximum distance of 14 m in the downwind direction; the hazardous area with explosion overpressure covers a maximum distance of 16 m in downwind direction.

This study only took the loading and unloading of ethanol at berth No. 17 of a dock as a research subject, and in practice, the area affected by leakage accident in the process of loading and unloading ethanol at a dock may be different in quantity because various types of parameters are different from each other. However, what can be assured is that the area affected by the accident of leakage and dispersion in loading and unloading ethanol at a dock can be as large as several kilometers in terms of dispersion distance. Therefore, when carrying out emergency handling tasks, relevant personnel can estimate hazardous spaces and areas, and according to the areas affected by various factors, take pertinent measures of precaution, control, rescue, etc., so as to improve the efficiency of emergency handling.

References

1. Hou Ronghua, Liu Kening. Determination of Environmental Impact Factors of Port Construction Project and Evaluation of Its Hazards [J]. Water Transport Engineering, 2007 (03): 1–7

2. Jiao Jiao, Zhang Jing, Ji Yaqin, etc. Application of ALOHA in Sudden Large Steam Pollution Accident [J]. Journal of Safety and Environment, 2015,15 (03): 151–155
3. Liang Hu. ALOHA software predicts the distribution of hazardous chemicals leakage area [J]. Security, 2007 (02): 30–32
4. Huang Haoyi, Xie Jianlin. Application and analysis of ALOHA software in vinyl chloride leakage accident [J]. Energy and Environmental Protection, 2021, 35 (02): 86–93
5. Miao Jinming, Liu Qianqian, Zhang Xianjin. Quantitative Simulation Analysis of Accident Consequences in Ethanol Tank Farm [J]. Journal of Beijing Vocational College of Labor and Social Security, 2012, 6 (01): 36–39
6. Xiong Liansen. Quantitative risk assessment of inland waterway transportation of LNG tanks [D]. Chongqing University, 2021. DOI: https://doi.org/10.27670/d.cnki.gcqdu.2021.001067
7. Zhang Yue. Study on the rupture failure process of liquid storage tank in fire environment [D]. Dalian University of Technology, 2020. DOI: https://doi.org/10.26991/d.cnki.gdllu.2020.001850
8. Wei Li. Application of ALOHA software and HAZOP analysis method in safety evaluation of typical chemical enterprises [J]. Contemporary Chemical Research, 2021 (09): 93–95
9. Liu Zhihao. Analysis on multi risk factors coupling effect of accidents in petrochemical tank farm [D]. Guangdong University of Technology, 2022. DOI: https://doi.org/10.27029/d.cnki.ggdgu.2022.001979
10. Pan Haijuan, Liu Guangqiang, Zhou Junbo. Comparative study on simulation software of hazardous chemicals leakage accident diffusion in port area [J]. China Water Transport (the second half of the month), 2018, 18 (01): 84–85