*International Conference on Mechanical, Industrial and Energy Engineering 2022*
*22-24 December, 2022, Khulna, BANGLADESH*

**ICMIEE22-179**

# Study of analyzing the flammable area from releasing LPG during filling the bottle in the LPG plant

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## ABSTRACT

The prevalence of LPG leakage is a threat to the safety of adjacent residents, the quality of the air, and occupational safety. It is necessary to analyze the toxicity of the releasing LPG for environmental safety and human health. The study is mainly concerned with the dangers posed by LPG emissions during bottling into cylinders. In this study, the areal location of hazardous atmosphere (ALOHA) models have been used to evaluate the risk of fire and explosion from various LPG compounds assuming variable amount of LPG released into the environment with constant wind velocity. The flammable area of the isobutene was less than the propane and butane. Consequences of hazards such as the release of hazardous substances into the environment are one of the most important tasks in increasing the degree of safety at the design stage or operation of industrial units. It's essential to assess fluid behavior after exposure to the environment, as well as the resulting emissions and potential injuries, as well as the safest radius for fire, explosion, and hazardous emissions. The results were utilized to derive appropriate evaluations of risk assessments, which can be made accessible to the industry in the hopes of reducing the possible effect of such accidents in the future.

Keywords: LPG, Safety, Explosion, Risk assessment, ALOHA.

## 1. Introduction

Liquefied Petroleum Gas (LPG) is a gaseous hydrocarbon compound formed mostly of propane ($C_3H_8$), butane ($C_4H_{10}$), and isobutane ($C_4H_{10}$), or a combination of these, that is produced as a by-product of crude oil or natural gas processing [1-3]. Every year, the demand for LPG expands throughout the world. The United States, the European Union, and countries in Northeast Asia such as China, Japan, and South Korea are the leading importers of LPG. On the other hand, the Middle East, West Africa, and Norway are the top exporters [4]. In 2014, China purchased 7.1 million tons of LPG (propane, butane, and mixed) from the US, up to 4.2 million tons in 2013. In 2014, the US exported roughly 14 million tons of LPG. In 2013, the Arabian Gulf shipped the greatest percentages of LPG [5]. Due to diminishing gas sources in Bangladesh, rationing natural gas for industrial use and promoting LPG as a family cooking fuel is becoming increasingly feasible. Bangladesh has the world's most permissive gas use policy. LPG is imported from several nations, including Singapore, Malaysia, Saudi Arabia, Abu Dhabi, and Kuwait, for more than 95% of the demand. They work with private enterprises to suit the market need. The government is encouraging the usage of LPG by offering favorable policies and incentives. However, the LPG business is predicted to treble by 2021, reaching 2.5 million tons, with many industry personnel on the way and little product diversification. When gas stocks become depleted, CNG cars will be changed to LPG fuel or auto gas [6]. In case of cylinder leakage, LPG instantly changes phase and is discharged in the form of gas. At room temperature and pressure, the LPG components are gas. But they liquefied at moderate pressures (0.7–1.4MPa) [7-8].

Demirbas et al. (2002) reported that an exothermic process happens when hydrogen mixes with the metal alloy (granular or particles). Thus, the gas is kept in these metal particles until heat is supplied to liberate the hydrogen and increase the pressure in the tanks. Heat is produced when a metal hydride absorbs hydrogen [8]. According to Pula et al. (2006), combustible material leakage or spillage can result in a fire that can be initiated by a variety of different igniting sources (sparks, open flames, and so on). Pool fires, jet fires, fireballs, and flash fires are the four types of fires that can occur in the offshore environment, depending on the types of discharge events. Flares, sea surface fires, and flowing liquid fires, among others, are always represented as one of the four recognized types. In addition, he said that an explosion is defined as a sudden and intense release of energy that causes a lethal blast, which is classified as physical, chemical, or nuclear, based on the type of energy released in the environment. A gas explosion is created by the fast formation and expansion of gases as a result of the rapid burning of a combustible material. A gas explosion is typically described by the degree of confinement and constriction in the region surrounded by the cloud of gas. Congestion in the form of obstacles raises the flow's turbulence level, resulting in more equally accelerated motion and overpressures [9].

In this paper, we want to present a problem that simulates the threat zone by assuming the amount of LPG release during bottling. It also deals with the analysis of the toxicity of propane ($C_3H_8$), butane ($C_4H_{10}$), and isobutene ($C_4H_{10}$) and comparing each

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other for finding which one is more threat to the environment.

## 2. Methodology

The study is mainly concerned with the dangers posed by LPG emissions during bottling into cylinders. In this study, the areal location of hazardous atmosphere (ALOHA) models have been used to evaluate the risk of fire and explosion from various LPG compounds assuming variable amount of LPG released into the environment.

Another notable concern is the environmental emissions of toxic gas emissions. One of the primary purposes of modeling chemical dispersion in the environment is to determine the amount of density expressed over time and distance. ALOHA is the most powerful and widely used program to mimic the environmental response of substance release. ALOHA stands for "Areal Locations of Hazardous Atmospheres" and is particular computer software that assists us in better responding to unintentional chemical releases by predicting and forecasting the leaking process. This software can forecast all of the consequences of chemical discharge, including flames and toxic substances in the environment. This application was developed by the Environmental Protection Agency (EPA) to simulate accidents caused by the discharge of toxic and explosive substances. To reduce user mistakes, the application has a big database (data for over 1000 chemical compounds) and a simple working environment. Regardless of the gravity of the risk of chemical exposure, a crisis response plan must have been created [7]. ALOHA software is simple to use and requires few inputs. As a result, its assumptions occasionally diverge from real circumstances. However, the impact range is just about in the same range +/- 10%, which is acceptable [10].

### 2.1 Governing Equation

The discharge rate (kg/s) is calculated using the source model, and the airborne concentration (ppm or mg/m$^3$) is estimated using the dispersion model. Finally, the fire and explosion models are employed to calculate thermal heat flow. Fluid mechanics formulas may be used to compute the liquid discharge rate from a storage tank [10].

$$G_L = C_d A \rho_l \left(\frac{2(p-p_a)}{\rho_l} + 2gH\right)^{1/2} \qquad (1)$$

Where, $G_L$ denotes the liquid mass emission rate (kg/s); $C_d$ is the discharge coefficient (dimensionless); and A denotes the discharge holoe area (m$^2$). $\rho_l$ =liquid density (kg/m$^3$); p=liquid storage pressure (N/m$^2$ absolute); $p_a$ =downstream (ambient) pressure (N/m$^2$ absolute); g=gravity acceleration (9.81 m/s$^2$); H=liquid height above hole (m)

Using following Equation, calculate the airborne concentration of a chemical owing to dispersion from a continuous release source using the Gaussian Dispersion Model [10].

$$C(x,y,z) = \frac{G}{2\sigma_y \sigma_z u} exp\left[-\frac{1}{2}\left(\frac{y}{\sigma y}\right)^2\right]\left[exp - \frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2 + \right.$$

$exp- \ 1 \ 2 \ z+H\sigma z2$ Where x,y,z are the distances from the source, and m is the magnitude of the distance. (x denotes downwind, y denotes crosswind, and z is vertical) G = vapour emission rate (kg/s); H = height of source above ground level + plume rise (m); $\sigma_{y,}\sigma_z$ = dispersion coefficients (m), function of distance downwind; u = wind velocity (m/s).

## 3. Modeling and Analysis

For analyzing different hazardous area of the LPG bottling plant by using ALOHA software where chemical data of propane ($C_3H_8$), butane ($C_4H_{10}$), and isobutene ($C_4H_{10}$) are shown in the Table 1. Least and upper acute level of different LPG in ALOHA are shown in Table 2. In this analysis the wind velocity, environmental temperature and releasing time were remained constant. The wind velocity, environmental temperature and releasing time were 4.3ms$^{-1}$, 31$^0$C and 60min respectively. This study mainly focused on the amount of the releasing LPG how much effect the environment from its fire and flammable explosion from its vapor cloud. Several study show that these releasing LPG contained with different radioactive substance.

## 4. Result and Discussion

Most of the LPG bottling plant use mixture of 30% of propane and 70% of butane in Bangladesh. In that case we analyzed the threat zone of propane ($C_3H_8$), butane ($C_4H_{10}$), and isobutene ($C_4H_{10}$) . Assuming different amount of LPG gas with constant wind velocity is shown in Table 3. On the other hand, Toxic area and flammable area of vapor cloud with different amount of LPG release (such as propane ($C_3H_8$), butane ($C_4H_{10}$), and isobutene ($C_4H_{10}$)) as shown in Table 4 and Table 5 respectively. For toxic area analysis the value of AEGL-1, AEGL-2 and AEGL-3 is 5500, 17000, 33000ppm. For releasing 0.25kg/s propane, the red zone is 11m, orange zone in 11m and yellow zone is 27m. . For releasing 0.25kg/s butane, the red zone is 10m, orange zone is 11m and yellow zone is 21m. The threat zone for toxic area of Isobutene is same as butane. For releasing 0.5kg/s propane, the red zone is 11m, orange zone in 18m and yellow zone is 35m. . For releasing 0.5kg/s butane, the red zone is 10m, orange zone is 13m and yellow zone is 29m. The threat zone for toxic area of Isobutene is same as butane. For releasing 0.1kg/s propane, the red zone is 15m, orange zone is 23m and yellow zone is 49m. . For releasing 0.5kg/s butane, the red zone is 11m, orange zone is 20m and yellow zone is 40m. The threat zone for toxic area of Isobutene is same as butane. From Table 4 and Table 5 it can be shown that the threat zone is increasing with increasing the amount of releasing LPG. That's why the worker of the bottling plant can't be safe in that region with this amount of LPG release.

**Table 1:** Chemical data of different LPG in ALOHA

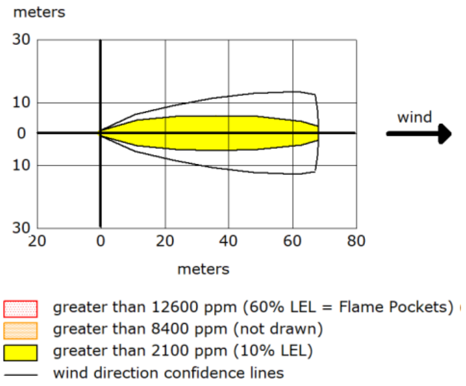
| LPG | AEGL-1 (60 min) (ppm) | AEGL-2 (60 min) (ppm) | AEGL-3 (60 min) (ppm) | Ambient Boiling Point($^0$C) |
|---|---|---|---|---|
| Propane ($C_3H_8$) | 5500 | 17000 | 33000 | -42.2 |
| Butane ($C_4H_{10}$) | 5500 | 17000 | 53000 | -0.6 |
| Isobutane ($C_4H_{10}$) | 5500 | 17000 | 53000 | -11.7 |

**Table 2:** Least and upper acute level of different LPG in ALOHA

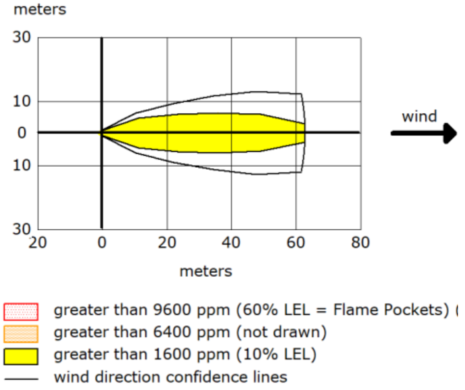
| LPG | LEL (ppm) | UEL (ppm) |
|---|---|---|
| Propane ($C_3H_8$) | 21000 | 95000 |
| Butane ($C_4H_{10}$) | 16000 | 84000 |
| Isobutane ($C_4H_{10}$) | 18000 | 84000 |

### 4.1 Flammable area of vapor cloud

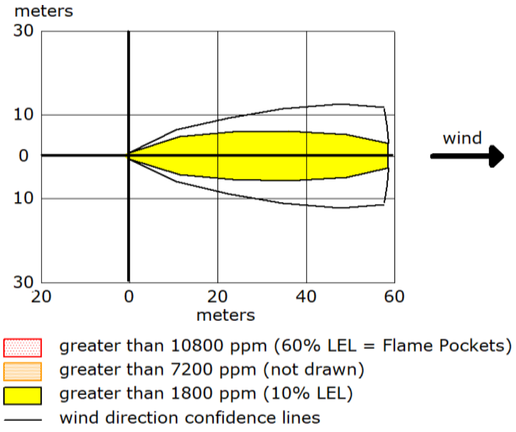
The Flammable area of the Vapor cloud for propane ($C_3H_8$), butane ($C_4H_{10}$), and isobutene ($C_4H_{10}$) are shown in the Fig.1. The flammability of the vapor cloud increases as the amount of LPG released increases. LPG vapor at concentrations ranging from 2% LEL to 10% LEL generates an explosive composite [7].



(a) Propane



(b) Butane



(c) Isobutane

**Fig. 1:** Flammable area of vapor cloud (a) Propane (b) Butane (c) Isobutene

We see ALOHA's threat zone estimate for this scenario. According to ALOHA, the yellow threat zone extends 60 meters downwind from each LPG property. Within this zone, ground-level LPG concentrations might exceed the AGEL-1 level. At concentrations above the AGEL-2 level, people could experience serious health effects or find their ability to escape to be impaired.

The LEL concentration of propane, butane and isobutene are 21000, 16000, 18000ppm. For analyzing flammable vapor cloud ALOHA used 60%LEL for red zone, 40%LEL for orange zone and 10%LEL for yellow zone analysis. The flammable area of vapor cloud for releasing 0.25kg/s propane, the red, orange and yellow zone are 16, 21 and 49m respectively. The flammable area of vapor cloud for releasing 0.25kg/s butane, the red, orange and yellow zone are 15, 20 and 46m respectively.

**Table 3:** Assuming variable amount of releasing LPG with constant wind velocity.

| LPG | Amount of release gas(Kg/s) | Release time (min) | Wind Velocity ($ms^{-1}$) |
|---|---|---|---|
| Propane | 0.25 | 60 | 4.3 |
| | 0.50 | | |
| | 1.00 | | |
| Butane | 0.25 | 60 | 4.3 |
| | 0.50 | | |
| | 1.00 | | |
| Isobutane | 0.25 | 60 | 4.3 |
| | 0.50 | | |
| | 1.00 | | |

**Table 4:** Toxic area of vapor cloud with different amount of LPG release

| LPG | Toxic area(m) | | |
|---|---|---|---|
| | Red AEGL-3 | Orange AEGL-2 | Yellow AEGL-1 |
| Propane | 11 | 11 | 27 |
| | 11 | 18 | 35 |
| | 15 | 23 | 49 |

| | | | |
|---|---|---|---|
| Butane | 10 | 11 | 21 |
| | 10 | 13 | 29 |
| | 11 | 20 | 40 |
| Isobutane | 10 | 11 | 21 |
| | 10 | 13 | 29 |
| | 11 | 20 | 40 |

The flammable area of vapor cloud for releasing 0.25kg/s isobutene, the red, orange and yellow zone are 13, 18 and 43m respectively. If increasing the amount of releasing LP gas the flammable are of the releasing gas also increase as shown in Fig. 2. The blast wave created by the gas leak in the analyzed source is no bigger than 8psi at any distance in the event of a vapor cloud explosion induced by an LPG gas leak [7].

**Table 5:** Flammable area of vapor cloud with different amount of LPG release

| LPG | Flammable area(m) | | |
|---|---|---|---|
| | Red AEGL-3 | Orange AEGL-2 | Yellow AEGL-1 |
| Propane | 16 | 21 | 49 |
| | 21 | 28 | 68 |
| | 29 | 38 | 94 |
| Butane | 15 | 20 | 46 |
| | 21 | 26 | 63 |
| | 28 | 35 | 88 |
| Isobutane | 13 | 18 | 43 |
| | 19 | 23 | 59 |
| | 26 | 33 | 81 |

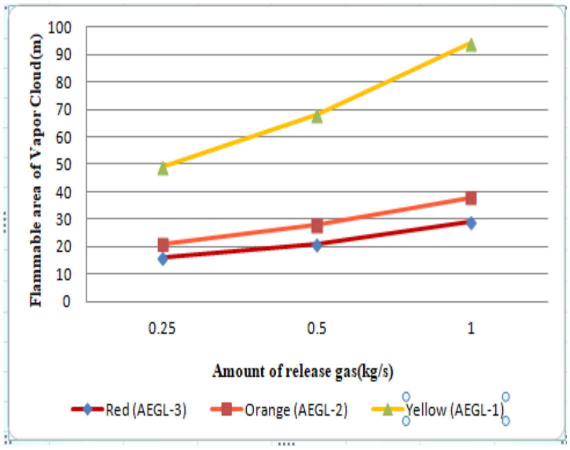


**Fig. 2:** Flammable area of Vapor cloud with variable amount of release gas.

The flammable explosion of isobutene is less than the explosion of propane and butane as shown in Fig. 3. In low-wind circumstances, the gas is expelled (immediately or constantly), forms a cloud, and disperses with an initial velocity. A fire and explosion risk assessment is necessary to apply the appropriate mitigation methods and emergency response protocols to protect employees [9].

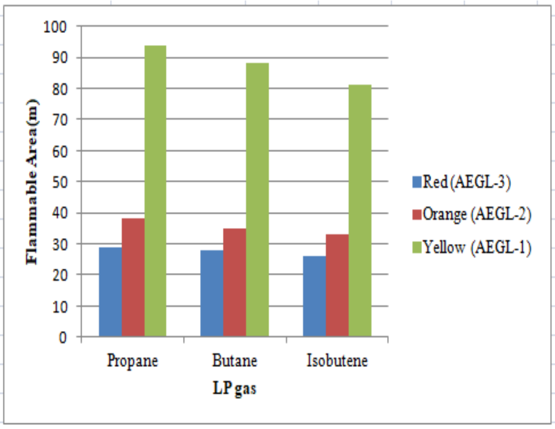


**Fig. 3:** Flammable area of Vapor cloud with different LP gas.

## 5. Conclusion

In this study we have been analysed threat zone of LPG bottling plant with different amount of LPG release using ALOHA software. Here we have been observed that the threat zone is increasing with increasing the amount of release. On the other hand the propane is more hazardous than butane and isobutene. Instead of point/area modelling, a grid-based technique can be used to improve modelling and analysis of radiation and overpressure impact of releasing LP gas at various locations in the process area for future research. This means that a reader should be able to understand the essential nature of the conclusion without reading the entire paper. The conclusion typically ends with an outlook that describes possible extensions of the presented approaches and planned future work.

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## NOMENCLATURE

G : Vapour emission rate, kg/s
$H$ : height of source above ground level + plume rise, m
$\sigma_{y,}\sigma_z$ : dispersion coefficients
$u$ : wind velocity, m/s$^1$
$C_d$ : discharge coefficient
$\rho_l$ : liquid density, kg/m$^3$
p : liquid storage pressure, N/m$^2$
$p_a$ : downstream (ambient) pressure, N/m$^2$