

DISPERSION MODELING OF ACCIDENTAL RELEASES OF PROPANE GAS

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Abstract: This paper investigates the impact of accidental release of propane gas in surrounding areas consequences of propane gas leak studying the negative effects on both the environment and individuals. Subject of the research is impact of accidental release of propane gas in in business zone "Ramići-Banja Luka", Banja Luka. The ALOHA software has been used in this paper to modelling of propane release. The modelling was performed for an accidental release of 4,000 kg propane from unsheltered single storied for one hour. For a typical average atmospheric condition in location, this accidental propane release would cause a red zone of 101 metres (AEGL-3=33,000 ppm), orange zone of 159 metres (AEGL-2=17,000 ppm) and yellow zone of 324 metres (AEGL-1=5,500 ppm) to downwind from the source.

Key words: air pollution, ALOHA, propane, modelling.

INTRODUCTION

Improper handling and accidental release of hazardous chemicals pose serious public health hazards. The intensity of such accidents depends on the nature of release, toxicity of the material, population density and meteorological factors [1]. Propane is a gas at normal pressures and temperatures but is often stored under pressure as a liquid. When a tank rupture or broken valve causes a sudden pressure loss in a tank of liquefied gas, the liquid boils violently and the tank contents foam up, filling the tank with a mixture of gas and fine liquid droplets (called aerosol). Flash boiling is the term for that sudden vaporization of a liquid caused by a loss of pressure [2].

The data on human exposure to propane are very limited. Most data, especially the animal data, indicate that cardiac sensitization as an important effect. However, as with other alkanes, CNS depressing effects are also to be expected. The available data are not sufficient to determine which of the two effects occur at lower concentrations [3]. OSHA Permissible Exposure Limit (PEL): for General Industry is 1000 ppm. National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL): 1000 ppm. NIOSH Immediately Dangerous to Life or Health Concentration (IDLH): 2100 ppm (lower explosive limit) [4].

Commission Regulation (EU) 2017/874, concerning the use of butane (E943A), isobutane (E 943B) and propane (E 944) in color preparation [5], in the context of their use as extraction solvents, define acceptable residue level per substance of 1 mg/kg in final food.

This study is focused on assessing the risks and vulnerability of population around a propane storage.

MATERIALS AND METHODS

LOCATION AND PROPANE STATION

Subject of the research is impact of accidental release of propane gas in in business zone "Ramići-Banja Luka", Banja Luka (Pictures 1). Banja Luka is a city in Republic of Srpska (Bosnia and Herzego-

vina). Banja Luka is located in Vrbas valley and is surrounded by hills 200-600 meters above sea level high. Banja Luka is the second biggest city in B&H with the population of 200,000. Situated in a basin 164 m above sea level, where the Dinaric Alps from the south descend into the Pannonian Basin in the north.

Banja Luka has temperate continental climate with the prevailing influences from the Pannonian plain. It belongs to the Central European Time zone (GMT +1) and. The average annual temperature reaches 10.7°C, the average January 0.8°C, whereas the average temperature in July reaches 21.3°C.

PHYSICAL-CHEMICAL CHARACTERISTICS AND IMPACT OF PROPANE

Propane is a three carbon alkane with the chemical formula C_3H_8 . Propane is a colorless gas with a faint petroleum-like odor gaseous hydrocarbon (compound of carbon and hydrogen), the third member of the paraffin series following methane and ethane. It is shipped as a liquefied gas under its vapor pressure. Contact with the unconfined liquid can cause frostbite by evaporative cooling. Easily ignited. The vapors are heavier than air and a flame can flash back to the source of leak very easily. The leak may be either a liquid or vapor leak. The vapors can asphyxiate by the displacement of air. Under prolonged exposure to fire or heat the containers may rupture violently and rocket. A unique feature of propane is that it is not produced for its own sake, but is a by-product of two other processes, natural gas processing and petroleum refining. It is separated in large quantities from natural gas, light crude oil, and oil-refinery gases and is commercially available as liquefied propane or as a major constituent of liquefied petroleum gas (LPG). Although a gas at ordinary atmospheric pressure, propane has a boiling point of $-42.1^\circ C$ ($-43.8^\circ F$) and thus is readily liquefied under elevated pressures. It therefore is transported and handled as a liquid in cylinders and tanks. In this form, alone or mixed with liquid butane, it has great importance as a fuel for domestic and industrial uses and for internal-combustion engines [6, 7]. Propane is a byproduct of various refinery processes. It is often used to produce liquefied petroleum gas. Liquefied petroleum gas is generally a mixture of predominantly butane and propane in varying proportions, but sometimes propane is the main component liquefied petroleum gas used as (bus) fuel [3].

SOFTWARE ANALYSIS

Numerical models may be considered from two angles: first, as operational models applied by decision makers in which results should be clear and instantly available, and second, as models in which simulation time is less important, and more importance is given to the accuracy of results and the most thorough consideration of the complexity of phenomena. There are various parameters and criteria for assessing the impacts of toxicity of chemical materials. Losses and damages caused by the release and spread of toxic chemicals depend on the concentration of toxic chemical and its contact time. In order to conduct incident modelling, ALOHA software (Aerial Location Hazardous Atmosphere) Version 5.4.7 was used. ALOHA allows the user a choice of several accident scenarios, then uses an appropriate source algorithm to inject material into the air over a limited time. The source emission time may vary between limits of one minute to one hour. A flat, homogeneous earth is assumed. For purposes of solar radiation and day/night decisions, time is fixed at the moment the leak begins [8]. ALOHA is the hazard-modelling program for the CAMEO software suite, which is used widely to plan for and respond to chemical emergencies. ALOHA allows to enter details about a real or potential chemical release, and then it will generate threat zone estimates for various types of hazards. ALOHA can model toxic gas clouds, flammable gas clouds, BLEVEs (Boiling Liquid Expanding Vapour Explosions), jet fires, pool fires, and vapour cloud explosions. The threat zone estimates are shown on a grid in ALOHA and they can also be plotted on maps in MARPLOT, Esri's ArcMap, Google Earth, and Google Maps. The red threat zone represents the worst hazard level, and the orange and yellow threat zones represent areas of decreasing hazard [9].

Simulation of the accident positioned according to the entered coordinates (44°84'19.80"N 17°17'85.34"E) (Picture 1). Accident simulation positioned according to the entered coordinates, it can be rotated in the direction of the wind that blows at a certain point.

RESULTS AND DISCUSSION

Propane station is about 200 m away from the first residential building, north (Pictures 1).



Picture 1. Position and distance of station from the first residential object [Google Earth]

To model hazards with ALOHA, we have entered the required scenario information. Required Inputs:

- Enter basic scenario information (such as date, time, and location).
- Choose a chemical from ALOHA's chemical library.
- Enter atmospheric information (such as wind speed and direction, air temperature, and cloud cover) by hand or automatically using a portable station for atmospheric measurements (SAM).

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- Choose a source: direct, puddle, gas pipeline, or tank.
- Enter source information (such as release amount, tank dimensions, and whether the chemical is burning).
- Specify the Levels of Concern (LOCs) you want ALOHA to use when estimating the threat zones or use the default LOCs ALOHA offers.
- Choose the type of hazard (such as toxicity or thermal radiation) you want ALOHA to use when estimating the threat zones.

The entered data in software for propane is shown in the Picture 2.

Text Summary ALOHAS 5.4.7

SITE DATA:
 Location: SANJA LORA, RS, BiH
 Building Air Exchanges Per Hour: 0.52 (sheltered single stories)
 Time: April 12, 2018 1047 hours BT (using computer's clock)

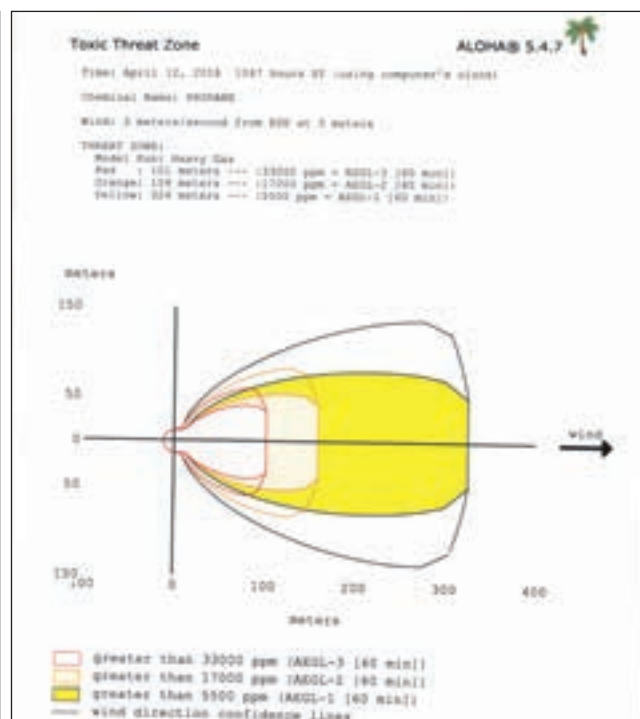
CHEMICAL DATA:
 Chemical Name: PROPANE
 CAS Number: 74-98-6 Molecular Weight: 44.10 g/mol
 AEGL-1 (40 min): 5500 ppm AEGL-2 (40 min): 17000 ppm AEGL-3 (40 min): 33000 ppm
 TDLM: 2100 ppm LEL: 21000 ppm UEL: 95000 ppm
 Ambient Boiling Point: -42.3° C
 Vapor Pressure at Ambient Temperature: greater than 1 atm
 Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
 Wind: 3 meters/second from 000 at 3 meters
 Ground Roughness: URBAN or forest CLOUD COVER: 5 tenths
 Air Temperature: 12° C Stability Class: D
 No Inversion Height Relative Humidity: 50%

SOURCE STRENGTH:
 Direct Source: 4000 kilograms Source Height: 0
 Release Duration: 1 minute
 Release Rate: 64.7 kilograms/sec
 Total Amount Released: 4,000 kilograms
 Note: This chemical may flash boil and/or result in two phase flow.

THREAT ZONE:
 Threat Modeled: Overpressure (blast force) from vapor cloud explosion
 Type of Ignition: ignited by spark or flame
 Level of Congestion: uncongested
 Model Suit: Heavy Gas
 Red: LOC was never exceeded --- 18.0 psi = destruction of buildings
 Orange: LOC was never exceeded --- 13.5 psi = serious injury likely
 Yellow: LOC was never exceeded --- 11.0 psi = shatters glass

Picture 2. Entered data in software for propane



Picture 2. Toxic threat zone

The rate at which a chemical becomes airborne is critical to the size and duration of a toxic or flammable cloud. ALOHA employs a variety of models to estimate the rate at which a chemical is released from confinement and enters the atmosphere; these are referred to as source strength models [10]. In this study is used direct source. An instantaneous or continuous release of chemical vapours into the air from a single point. This is the only option that allows for an elevated release.

A direct source option allows the user to directly specify the amount of chemical vapours introduced into the air from a point in space. The user can specify an instantaneous release, or a steady-state release of finite duration. This option can be used with gases that are denser than air and are affected by gravity, or gases that behave as neutrally buoyant. ALOHA allows for a release above ground level for gases that behave as neutrally buoyant [10]. The source emission time may vary between limits of one minute to one hour [11]. The study was used for 1 minute.

ALOHA uses a graphical interface for data entry and display of results. The area where there is a possibility of exposure to toxic vapours, a flammable atmosphere, overpressure from a vapour cloud explosion, or thermal radiation from a fire are represented graphically as threat zones. Threat zones represent the area within which the ground-level exposure exceeds the user-specified level of concern at some time after the beginning of a release. All points within the threat zone experience a transient exposure exceeding the level of concern at some time following the release; it is a record of the predicted peak exposure over time. In some scenarios, the user can also view the time dependence of the exposure at specified points [10].

Picture 3 shows the threat zone in case of accidental release of propane.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population could experience life-threatening health effects or death. AEGL-2 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population could experience irreversible or other serious, long-lasting adverse health effects. AEGL-1 is the airborne concentration (expressed as ppm or mg/m³) of a substance above which it is predicted that the general population could experience notable discomfort and irritation. However, the effects are not disabling and are transient and reversible upon cessation of exposure [12].

The affected areas which are harmful to human exposures at different levels are detected. The affected areas are divided into three level of concerns namely red zone, orange zone, yellow zone. Red zone is the affected area in which there is severe concentration of toxic gas and exposure to which may cause life threatening health effects or even death. Exposure to Orange Zone may cause long lasting adverse health effects and in Yellow zone average individual may feel notable discomfort, irritation but reversible upon cessation of exposure.

The modelling was performed for an accidental release of 4,000 kg propane. For a typical average atmospheric condition in location, this accidental propane release would cause a red zone of 101



metres (AEGL-3=33,000 ppm), orange zone of 159 metres (AEGL-2=17,000 ppm) and yellow zone of 324 metres (AEGL-1=5,500 ppm) to downwind from the source (Picture 2).

It is expected that the red zone will expand at least 101 m along the wind (Picture 3).

Picture 3. Examples of scenario of toxic area of vapour cloud (release and spread of gas)

ALOHA software used 60 minutes Acute Exposure Guideline Levels (AEGLs), as Toxic Levels of Concern (LOCs). LOCs are used to assess the toxicity threat of a chemical release. LOCs are used to assess the toxicity threat of a chemical release. A toxic LOC indicates threshold concentration of exposure to a chemical that could hurt people if they breathe it in for a defined length of time. Generally, the lower the toxic LOC value for a substance, the more toxic the substance is by inhalation. The most common public exposure guidelines are Acute Exposure Guideline Levels (AEGLs), Emergency Response Planning Guidelines (ERPGs) and Temporary Emergency Exposure Limits (TEELs). available to date and all three tiers (AEGL-1, AEGL-2, and AEGL-3) are developed for five exposure periods: 10 minutes, 30 minutes, 60 minutes, 4 hours and 8 hours [12] (Table 1).

Table 1. AEGLs values for Propane in ppm [3]

Exposure Time	Toxic level		
	AEGL-3 ³ (lethal)	AEGL-2 ² (disabling)	AEGL-1 ¹ (nondisabling)
10 minutes			10,000 ppm ^a
30 minutes			6,900 ppm ^a
60 minutes			5,500 ppm ^a
4 hours	33,000 ppm	17,000 ppm	5,500 ppm
8 hours			5,500 ppm

¹The **AEGL-1** value is greater than 10% of the lower explosive limit for propane in air of 23,000 ppm. Therefore, safety considerations against the hazard of explosion must be taken into account.

²The **AEGL-2** values for all time periods is 17,000 ppm, which is greater than 50% of the lower explosive limit for propane in air of 23,000 ppm. Therefore, extreme safety considerations against the hazard of explosion must be taken into account.

³The **AEGL-3** values for all time periods is 33,000 ppm, which is greater than the lower explosive limit for propane in air of 23,000 ppm. Therefore, extreme safety considerations against the hazard of explosion must be taken into account.

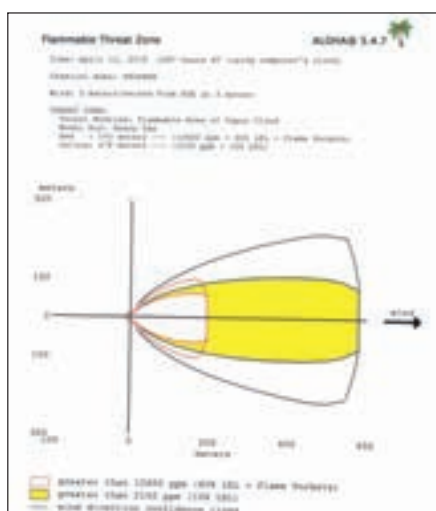
MODELING THE EFFECT OF STEAM CLOUD BURNING

Based on the vulnerable zone calculation and based on the model of a heavy gas, iso-concentration lines flammable zones:

Red zone: 193 metres (12600 ppm = 60% LEL) zone in which the concentration of propane reaches 60%LEL.

Yellow zone: 578 metres (2100 ppm = 10% LEL) zone in which the concentration of propane reaches 10 %LEL.

Lower explosive limit (LEL): The lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). The term is considered by



Picture 4. Iso-concentration lines flammable zones scenario of burning vapor cloud of propane

many safety professionals to be the same as the lower flammable limit (LFL). As a rule, if it is flammable gas or steam concentrations greater than 10% evacuation of the area is carried out.

The zone in which the concentration of propane reaches 60% LEL includes a part of the business zone, while the zone in which the concentration of propane reaches 10% LEL includes the population in this zone and part of the business zone (Pictures 4).

The toxicity of propane is low, so very high concentrations can be assumed in propane abuse. The predominant effects observed in such cases are effects on the upper and lower airways of the respiratory tract and on the brain [3].

CONCLUSION

Propane is a chemical with low toxicity, but can be dangerous for human health. Dispersion modelling was performed for an accidental release using ALOHA software. For a typical average atmospheric condition of Banja Luka, this accidental propane release would cause a red zone of 193 metres (12,600 ppm = 60% LEL) and yellow zone stretching to greater than 578 meters (2,100 ppm = 10% LEL) to downwind from the source.

ALOHA is designed for use during accidental chemical spills to help spill response professionals assess the risk to human populations associated with toxic air hazards, thermal radiation from fires, and blast effects. This paper focuses on the study of ALOHA software and expects to provide some help for the rapid and accurate predetermination of involved areas and the effective organization and direction of evacuation in different areas by the decision maker who is responsible of the emergency rescue during accidents caused by hazardous chemicals.

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