RISK ASSESSMENT EVALUATION OF HEXANE STORAGE TANK IN A SUNFLOWER OIL PLANT BY USING AREAL LOCATION OF HAZARDOUS ATMOSPHERE (ALOHA)

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ABSTRACT

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The purpose of risk assessment about hexane gas as a hazardous chemical is to prevent losses resulting from accidents arranging from injury to death and disasters impacting products, factories, employees, and the environment. Since hexane gas especially in storage tanks is easily flammable, evaporates, and is toxic, this chemical is vulnerable to an accident. The aim of this work is to examine the outcomes of hexane gas in a storage tank in the case of fire or expansion in the extraction unit of a sunflower oil factory. Moreover, as edible oils gain a significant role in human nutrition due to the main energy source with numerous usage purposes and oil growing demand by the excessive growth of the world population, efficiency in the production of sunflower oil from its seed is increased by new modern methods such as chemical extraction by hexane. To make this investigation on the storage tank of hexane during chemical extraction of sunflower oil, the Areal Location of Hazardous Atmosphere (ALOHA) software is applied by simulating three different scenarios as leakage of hazardous chemicals as hexane from its storage tank to the environment without fire (first scenario), during this dispersion with pool fire formation (second scenario), the release of hexane gas with boiling liquid expanding vapor explosion (BELEVEs) (third scenario). These different scenarios will be identified and examined in this thesis to prevent potential accidents. This work will further help to detect threats and safety zones under adverse atmospheric conditions depending on physicochemical feature of hexane gas.

Keywords: Hexane, Hazardous Chemical Storage Tank, ALOHA, Explosion, Gas Cloud Dispersion

ÖZ

AYÇİÇEK YAĞI TESİSİNDEKİ HEKSAN DEPOLAMA TANKININ TEHLİKELİ ATMOSFERİN ALANSAL LOKASYONU KULLANARAK RİSK DEĞERLENDİRMESİ

Sevim, Ayşenur
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Kasım 2022, 201 sayfa

Tehlikeli bir kimyasal olarak bilinen hekzan gazının risk değerlendirilmesinin yapılmasındaki amaç ölüm ve yaralanmalar ile biten kazaların ve ürün, fabrika, çalışan, çevre üzerinde yıkıcı etkiye sahip felaktlerin önüne geçmektir. Hekzan gazı kolaylıkla tutuşabilen, alev alabilen, uçucu ve toksik özelliklere sahip tehlikeli kimyasal madde olduğu için, depolanması sırasında da kazaların oluşması kaçınılmazdır. Bu çalışmada, ayçiçek yağı üretiminde ayçiçeği tohumundan yağ eldesi için ekstraksiyon ünitesinde kullanılan hekzan gazının, depolanması sırasında yangın ve patlama ihtimallerine karşı olası sonuçları incelenmektedir. Ayrıca, yemeklik yağların pek çok farklı alanda temel enerji kaynağı olmaları ve dünya nüfusundaki artış ile birlikte yemeklik yağa olan talebin de artmasından dolayı insan beslenmesinde önemli bir rol oynamaktadırlar. Bu yüzden, ihtiyacı karşılamak adına bazı teknolojik yöntemler (hekzan kullanımı ile gerçekleştirilen kimyasal ekstraksiyon gibi) kullanılarak ayçiçek tohumundan ayçiçek yağ üretimi arttırımı gerçekleştirilir. Kimyasal ekstraksiyon yönteminde çözücü olarak kullanılan ve zararlı kimyasal olarak önümüze çıkan hekzanın depolanması esnasında meydana gelebilecek olası olumsuz sonuçları incelemek adına Areal Location of Hazardous Atmosphere adı verilen bilgisayar programı üç farklı senaryoyu canlandırmak üzere kullanılmıştır. Bu farklı senaryolar (tanktan sızan hekzan gazının herhangi bir yangın olmaksızın sadece çevreye yayılan gaz bulutu oluşturması (birinci senaryo), sızıntı sırasında havuz tipi yangın oluşması (ikinci senaryo), hekzan sızıntısının kaynayan sıvı genleşen buhar patlaması yangınına sebebiyet vermesi (üçüncü senaryo) en olumsuz atmosfer koşullarında tehdit ve güvenlik bölgelerinin tespit edilebilmesi için hekzan gazının fiziksel ve kimyasal özelliklerine bağlı olarak kaza oluşumuna göre bu araştırmada tanımlanmakta ve incelenmektedir.

Anahtar Kelimeler: Hekzan, Tehlikeli Kimyasal Depolama Tankı, ALOHA, Patlama, Gaz Bulutu Yayılımı

To My Lovely Family

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INTRODUCTION

1.1 Background Information

In history, the background of Environmental Protection Agency started with a book which is Rachel Carson's Silent Spring. It was published in 1962 to notice pollution in the United States by emphasizing effects of excessive pesticide usage on forests and birds. Then, the Cuyahoga River in Ohio was flamed due to its pollution in 1969, resulting in reaction against pollution. After that, Environmental Protection Agency (EPA) was founded in 1970 to prevent environment, quality of air and water and people health, and its first success was ban of DDT mentioned on Silent Spring book (EPA, 2021).

The chemical accident at Union Carbide's pesticide plant in Bhopal, India was the worst damage on December 2, 1984. The reason for that disaster was the leakage of methyl isocyanate gas from its storage tank. This disaster which is releasing of 40 tons amount of this toxic gas resulted in a catastrophe based on the deaths of approximately 3.800 people and diseases making 150.000 numbers of people disabled. After this storage tank accident, the manufacture of this toxic gas as methyl isocyanate was maintained by this same company in West Virginia, USA. Also, after around one year of the accident occurred in Bhopal, Indi, the same toxic gas was released from the factory to the environment where is Kanawha Valley in West Virginia. This was a repetition of the Bhopal accident (Broughton, 2005).

After these two similar accidents connected with leakage of hazardous chemicals from its storage tank occurred under the same brand in its different plants, the decision was made to restrain these dramatic accidents by setting up an organization named the Emergency Planning and Community Right to Know Act (EPCRA) in 1986. The purpose of this community is to prepare a guideline about toxic hazardous chemicals to supply information about their usage and storage conditions to companies by leading them with preparation of an emergency plan during fire and explosion and gas dispersion to the environment.

After formation of Toxic Releases Inventory (TRI) with data collection, an orange book named as Hazardous Materials Emergency Planning Guide was published in 1987. Accidental Release Information Program (ARIP) was formed on a tool with accidental database to prohibit similar accident, which suppling informative parameters for formation of Risk Management Program (RMP). Then, green book as Technical Guidance for Hazards Analysis (NRT-1) was published and focused on fatal hazards based on dispersion of hazardous materials. In that point, Computer Aided Management of Emergency Operations (CAMEO) was released in 1988 as software application by EPA's Office of Emergency Management (OEM) and the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA), and the Seattle Fire Department to detect chemical crises. Then, required precautions were formed by enforcement of Process Safety Management (PSM) by Occupational Health and Safety Administration (OSHA) in 1992, and Risk Management Plant RMP by EPA in 1996. After making some improvements, while PSM focuses on people working in plants to guard workers from negative impacts on accidents, the main aim of RMP is conservation of the surrounding and public. Finally, when required data based on hazardous chemicals were collected day by day according to development of new software, book publishing and organizations, Areal Location of Hazardous Atmosphere (ALOHA) was developed as CAMEO software suite (EPA, 2021).

In terms of hazardous chemicals, they result in accidents while their transportation, storage, and usage in the process because they have risky chemical properties about flammability, easy vaporization, toxic effects, corrosion, and reaction with other chemicals. Also, they bring about not only fire or explosion but also catastrophic impacts on the environment, workers, and properties regarding the domino effect (Wang et al., 2020). Because of that reasons, Occupational Health and Safety practices for risk assessment have a multidisciplinary aspect such as regulations, organizations, surrounding, social impacts and work organization by using engineering, software, ergonomic and design applications etc. together (ILO, 2009). ALOHA is the one of these multidiscipline in the software group. In the big picture, CAMEO includes three pieces which are viz. CAMEO for data base, ALOHA and MARPLOT for mapping. ALOHA is preferred to detect threat zones of gas cloud after dispersion of hazardous chemicals from environment by considering chemical properties, atmospheric parameters, special conditions, location of target area mapping by MARPLOT and essential information modeled in CAMEO (Prasol Chemicals Private Limited, 2021).

1.2 Statement of Problem

Generally, though risk assessments of factories are made by usage of traditional methods, usage of software applications for risk evaluations has been increased day by day. In terms of literatures, although most of them focuses on similar industries such as chemical, petrochemical and oil industries, specified sectors such as food production factories are very rare. Also, while same hazardous chemicals such as tolune, ammonia, methanol and ethanol etc. were studied commonly, there was a few research for other chemicals as hexane. On the other hand, although there were little research in food sector and hazardous chemical used in this sector, there were not detailed about the hexane gas as dangerous chemical or ALOHA software was not prefered as method.

Also, there was few numbers of studies focusing on biogas station, petolium gas storage and chemical factory by using ALOHA software in Turkey. As a brief, since studies related with both ALOHA software application for risk assessment have been studied rarely, this paper will be first by including both food industry and ALOHA software methodology.

1.3 Objectives and Scope of the Study

The main objective of this study is to detect flammable, overpressure and thermal radiation threat zones for risk assessment of leaking of hexane as hazardous chemical from its storage tank to environment in sunflower oil production factory by using software application which is ALOHA version 5.4.7. This study was conducted under real wheather conditions by considering storage tank parameters in terms of its orientation, size and location, chemical properties of hexane gas and different three scenario simulations with selection of type of tank failure in the case of only gas cloud dispersition to environment, fire formation and explonation.

On the other hand, this type of analyzing method is rare in food industy not only in the world, but also in Turkey. Also, usage of ALOHA software in risk evaluation would be new approchment in Turkey. Because of that reasons, approachments, methods, scenario simulations of other studies conducting on different countries and sectors were considered to form efficient and succesfull investigation in food sector and Turkey in this study.

The scope of this paper is refined sunflower oil production factory located in Tekirdag, Turkey. The risk assessment of hexane storage tank located near the extraction unit in this plant was conducted by ALOHA usage and considering different hazard scenarios in the case of leakage, fire and explosion in order to identify threat areas and effects of undesirable results on environment, factory and public.

CHAPTER 2

LITERATURE REVIEW

2.1 Sunflower Oil Production in the World and Statistics

Sunflower (*Helianthus annuus* L.) is the most essential crop for edible oil manufacturing in soils. Sunflower seed is cultivated mainly in these four suppliers which are Ukraine, Russia, European Union and Argentina according to Figure 2.1. with production volume of sunflower seed (USDA, 2022).

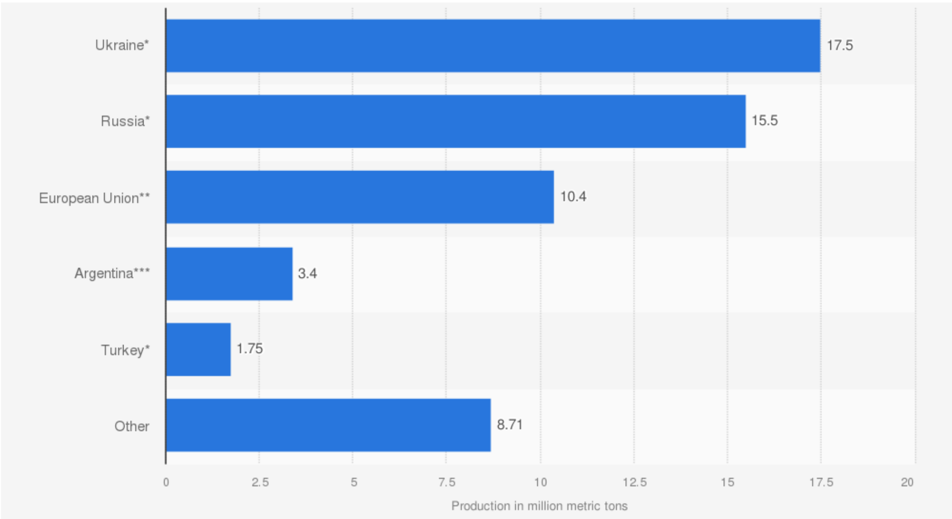


Figure 2.1. Sunflower seed production in major manufacturer countries in 21/22

(Worldwide; US Department of Agriculture; USDA Foreign Agricultural Service, 2022)

Figure 2.2. indicates import amount of major vegetable oils worldwide in 2021/2 and also shows that sunflower oil is the second major vegetable oil as 12.15 million metric tons in 2021/22 among import volumes of vegetable oils (USDA, 2022).

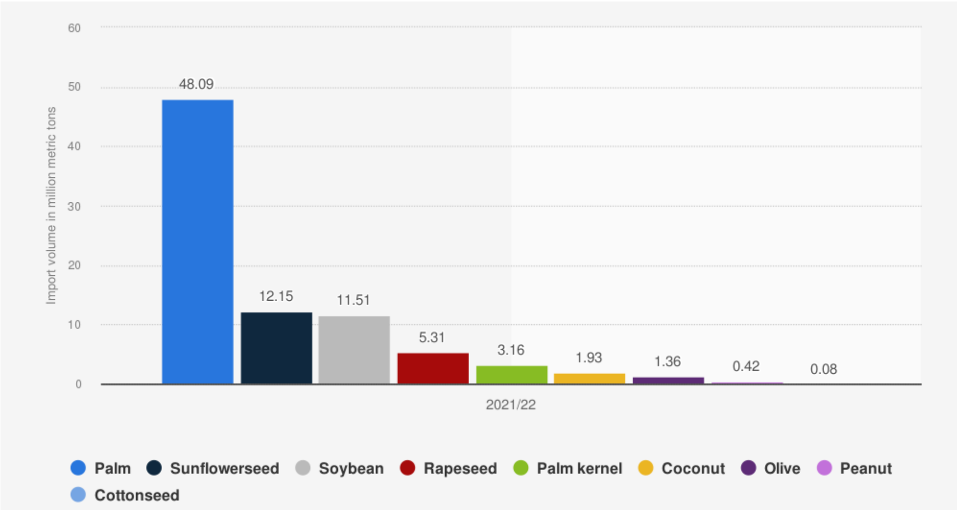


Figure 2.2. Import volume of major vegetable oils worldwide in 21/22

(Worldwide; US Department of Agriculture; USDA Foreign Agricultural Service, 2022)

When Figure 2.3. which is sunflower oil production amount worldwide from 2012/13 to 2021/22 implies that manufacturing of sunflower oil generally increases from year to year and its production in 2021/22 is 22.07 million metrics tons as the most highest value for the last ten years. Also, according to figure 2.4. which is export quantity of sunflowerseed oil worldwide from 2015/16 to 2021/22, Ukraine has the highest export amount as between 6,000 and 8,000 thousand metric tons worldwide. Then, Russia follows Ukraine as closing 4,000 thousand metric tons statistically. This emphasizes that both of them are the major sunflower oil suppliers in the world.

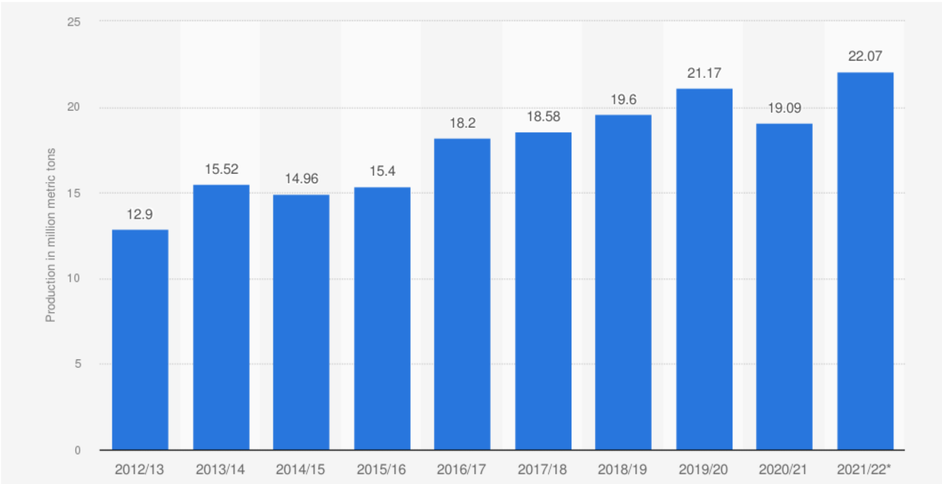


Figure 2.3. Sunflower oil production worldwide from 2012/13 to 2021/22

(Worldwide; US Department of Agriculture; USDA Foreign Agricultural Service, 2022)

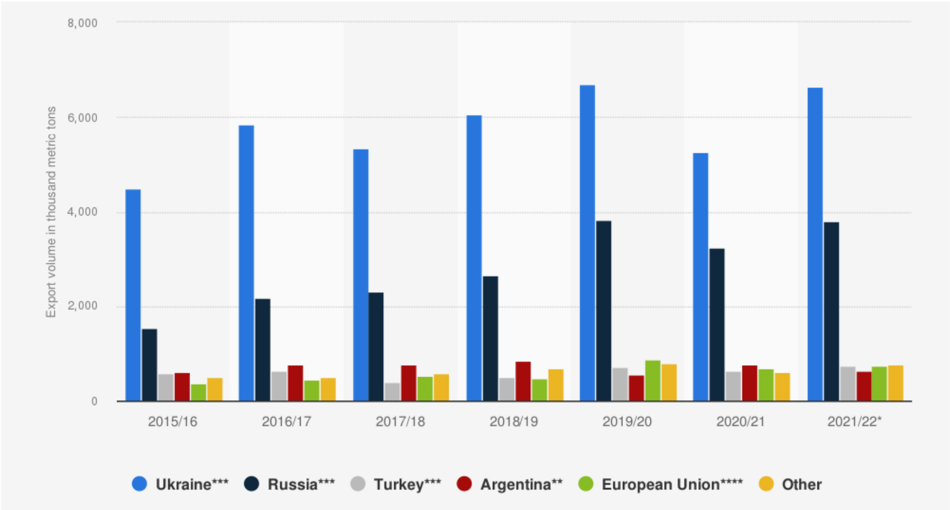


Figure 2.4. Export volume of sunflowerseed oil worldwide from 15/16 to 21/22

(Worldwide; US Department of Agriculture; USDA Foreign Agricultural Service, 2022)

2.2 Sunflower Oil Production Sector in the Turkey & Statistics

Among the oilseeds in Turkey, sunflower is the first rank in terms of cultivation area and production volume (Aydın et al., 2021). Table 2.1 is related with sunflower data in Turkey ranged from 2015/16 to 2019/20. This shows that although manufacturing volume increases year by year, import amount also boosts especially in 2019/20 due to inceasing amount of domestic usage (Tarim Orman, 2021). Apart from that, sunflower seed, domestic consumption of sunflower oil of Turkey worldwide in 2021 is 1,210 thousand metric tons, showing in figure 2.5. This number makes Turkey fifth leading country for sunflower oil consumption worldwide (Index Mundi; US Department of Agriculture, 2021).

Table 2.1 Sunflower Data in Turkey (thousand tons)

	2015/16	*2016/17*	*2017/18*	*2018/19*	*2019/20*
Cultivated Area (1000 HA)	685	720	779	734	752
Yield (kg/da)	245	232	252	265	279
Production	1.961	1.671	1.964	1.949	2.100
Domestic Use	2.112	2.589	3.032	2.914	3.466
Import	2.362	2.864	2.166	2.747	3.301
Export	1.833	1.975	1.203	1.619	1.939

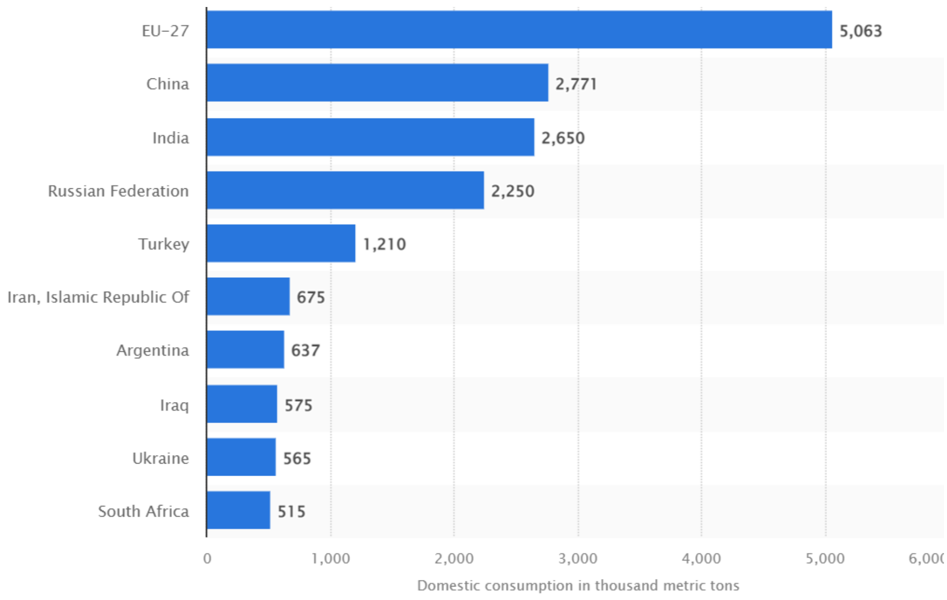


Figure 2.5. Domestic consumption of sunflowerseed oil in 2021

(Index Mundi; US Department of Agriculture, 2021)

2.3 Sunflower Oil Production Process

Sunflower oil production forms six main process which are cleaning, dehulling, grinding, pressing, solvent extraction and refining shown in figure 2.6.. After seed cleaning, impurities are removed. In dehulling process, hulls of sunflower forming 20 – 30 percentage of sunflower seed are separated from clean sunflower. Kernel region where is remained part after dehulling process are crushed into hammer mills or grooved rollers to obtain uniform materials. Then, this formed meal is heated to make it ready for pressing. In pressing, meal is extruded into screw press and oil is obtained by passing slots in this mechanism. Generally, solvents known as volatile hydrocarbons are preferred to separate oil into oil cake. Extraction of this is used to obtain maximum level of oil from oil cake and make profit in terms of yield. After solving of solvent, oil and solvent are collected separately. In this step, solvent is gained by evaporation then condensing of solvent while oil is heated by steam.

Then, final stage as refining forming four steps which are degumming, neutralization, bleaching and deodorization starts to remove undesirable materials such as phosphatides, free fatty acids, and pro-oxidants (Agrifarming, 2019). In refining process, crude oil is converted into refined oil to make it proper for human consumption. In degumming, phospholipids are removed, and this process is occurred by acid as phosphoric or citric acid or water by depending on presence of hydratable phospholipids. Neutralization is followed to separate free fatty acids (FFA) in oil with base as caustic soda by decomposing of pigments, phosphorus compounds, trace metals, proteins, and oxidizing materials. As this is alkali treatment, soaps form and separated by centrifuging. In bleaching, bleaching earth is applied to get rid of color pigments. Winterization also known as dewaxing helps to remove long chain waxes. Final step of refining is deodorization eliminating undesirable odors and flavors into oil with usage of high temperatures (Gotor & Rhazi, 2016).

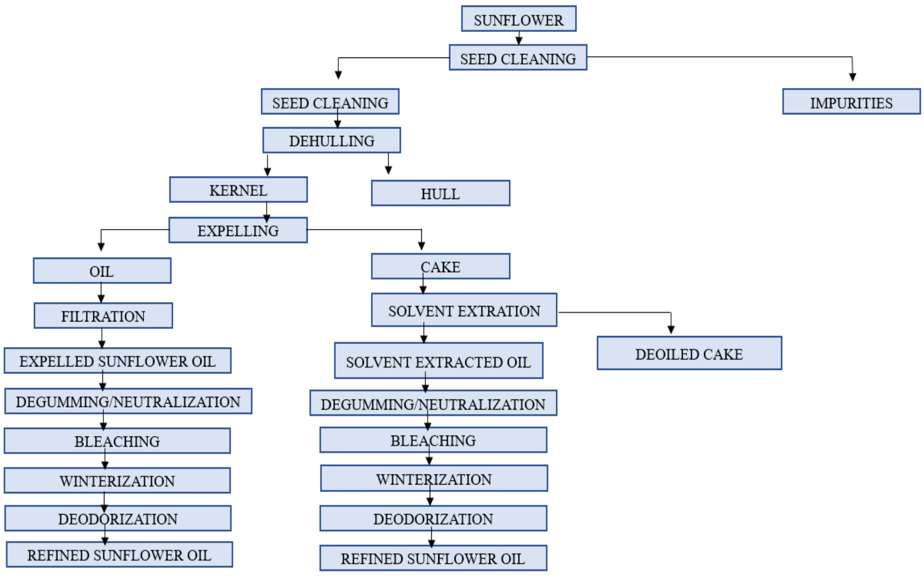


Figure 2.6. Flow chart of sunflower oil

2.4 Detailed Sunflower Oil Extraction Unit

Sunflower oil is obtained from oleaginous material with less than 30% oil by weight. Oil content in oleaginous material can be decreased 1 % by weight by solvent extraction to make yield maximum.Additionally, solvent extraction can be divided into two group as direct and prepress extraction. When the oleaginous material has less than 30 % oil by weight shown in figure 2.7. such as soybean, rice bran, mechanical and thermal preparation are applied before solvent extraction process, known as direct solvent extraction. Besides, if oleaginous material has more than 30 % oil by weight shown in figure as sunfloweer, nuts, mechanical and thermal preparation are also applies shown in figure 2.8, solvent extraction starts after the material is deoiled until 20 % oil by weight, called as prepress solvent extraction. In this stage, although various solvents as carbon disulfide, benzene, alcohols and hexane have been used in history, the hexane is common now commercially (Hamm et al., 2013).

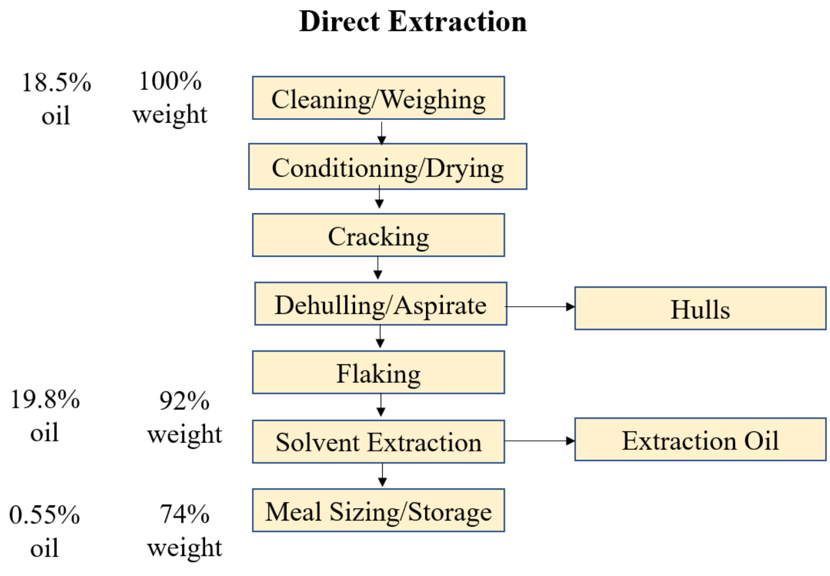


Figure 2.7. Direct Extraction Scheme of Soybean oil

(AOCS Lipid Library,2021).

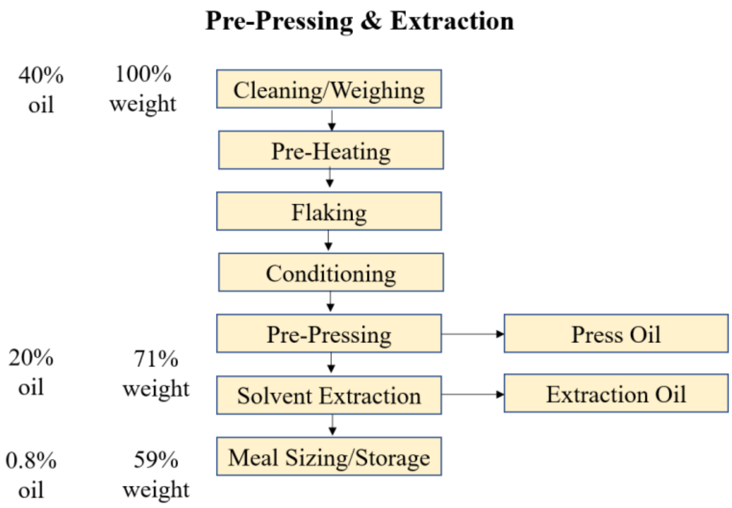


Figure 2.8. Pre-Pressing and Extraction Scheme of Sunflower oil

(AOCS Lipid Library,2021).

2.4.1 Types of Extractors

The extractor is defined as equipment where the oil is removed from oleaginous material during solvent extraction by dissolving oil in solvent (Hamm et al., 2013).

2.4.1.1 Batch Solvent Extractors

Batch extractors supply the simplest and the most common usage and are useful for small scale production. Also, it is beneficial for cake with low oil content such as olive pomace and oleaginous material to form fine particles for extraction. Besides, batch solvent extractors have some difficulties during discharging of extracted residue. Although internal stirrers are added into batch extractor to overcome this problem, they requiring high power are not economical (Bernardini, 1976).

This extractor works with reserve flowing principle, solvent being supplied from condenser is sprayed and accumulated on oleaginous material. Then, solvent is evaporated, and the evaporated solvent condenses in the condenser and is collected into collection collector. Then, it passes into the indicator after removing from water. When oil content of material decreases until 1%, miscella forming oil and solvent enters distillatory to separate solvent from miscella and evaporated solvent is condensed to be used again (Basoglu, 2017).

2.4.1.2 Continuous Solvent Extractors

Continuous solvent extractors are divided into two group as immersion extractors and percolation extractors based on their working principle.

2.4.1.2.1 Immersion Extractors

Immersion extractors shown in figure 2.9. have a continuous process with diffusion intensely. To be extracted materials are dosed from dosing unit (A) to equipment. This type of extractor includes two regions which are top and lower area. Top area is settling part for the miscella while lower area is part where extraction is occurred. Homogenous and close contact between substance and solvent is supplied in the screw stirrer (C) preventing packaging of substance before starting the extraction while climbing up and falling by gravity. After, to be extracted materials are moved by the metering screw conveyor (B), meal part of them known as meal is taken and removed in the elevator (D). Then, remaining part meets with solvent by the countercurrent principle (Bernardini, 1976).

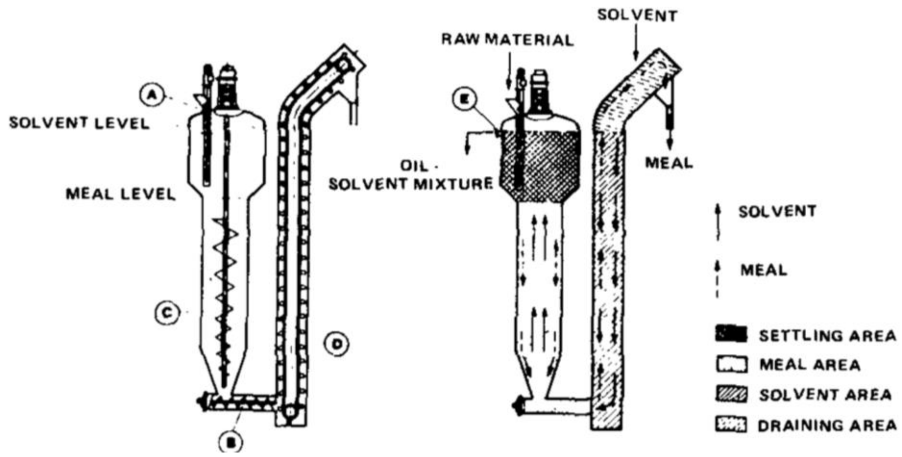


Figure 2.9. Cross section of the immersion extractor

(Bernardini, 1976)

2.4.1.2.2 Percolation Extractors

In the percolation extractor including ferris wheel with basket type, the substance to be extracted is located in the moving container and passes through the solvent continuously by applying counter-current flow and co-counter flow at the same time (Basoglu, 2017).

According to figure 2.10., the substance enters the system in the feed hopper (1) while its level is arranged by volumetric device. Substances are put into the baskets. Then, solvent is mixed with them and extraction starts and continues multiply under the countercurrent conditions (Bernardini, 1976).

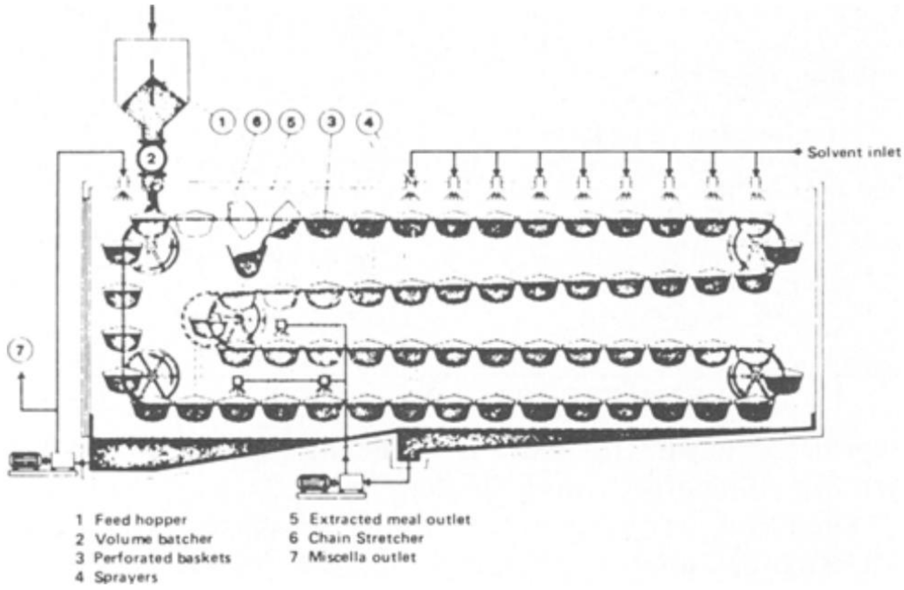


Figure 2.10. Sectional view of the percolation extractor

(Bernardini, 1976)

2.4.2 Extraction Solvents

Solvents used for oil extraction are based on petroleum fractions by dividing into four groups as pentane type 31.1 – 36.1 °C, hexane type 63.3 – 68.9 °C, heptane type 90 – 98.9 °C and octane type 101.7 – 128.9 °C based on their boiling values. Due to their properties as over production, low price, and reuse, they are utilized during extraction. However, their usage is managed with care owing to their hazardous, flammable and explosive properties (Gokalp et al., 2001).

The most widely used solvent is hexane with the boiling point 64- 68 °C for extraction because of being easy availability in Turkey and the world. Apart from that, as its hazardous way as flammable and combustible liquid, the most significant risk of fire an explosion exists in the storage tank and extraction unit (Akkoyun, 2013).

The extraction solvent for extraction follows some properties (Basoglu, 2017):

- Being chemically pure.
- Not having toxic vapor
- Not having low fire and explosion risk.
- Not being chemical reaction with oil.
- Being easy dissolving into oil.
- Not leaving any bod odor and residue into the oil.
- Having boiling point lower than 100 °C and freezing point lower than 0 °C.
- Not having harmful effects on process equipment.
- Being recyclable.

2.4.2.1 Hexane

Hexane is a straight chain alkane type. According to the Turkish Food Codex Communiqué on extraction solvents used in the Production of Foodstuffs and Food Ingredients, hexane is commercial product with acidic saturated hydrocarbons containing 6 carbon atoms and distilled between 63 and 69 ºC (Sahin, 2019). Its substance descriptions are summarized in table 2.2. Additionally, while its hazard identification is explained in table 2.3., some precautions in terms of fire are explained in table 2.4.

Table 2.2 Substance Description of Hexane (Chevron Philips, 2019)

Substance Description	
Name	*n*-hexane
CAS-No	110-54-3
EINECS-No	203-777-6
Molecular Formula	C_6H_{14}
Molecular Weight (g/mol)	86.2 g/mol
Concentration (wt%)	95-99 %
Boiling Point (°C)	67-69°C
Flash Point (°C)	-23 °C
Vapor Pressure (PSI)	5,60 PSI at 37.7 °C
Relative Density	0.66 at 15.6 °C
Density	662.7 g/L
Relative vapor density (air = 1)	3.0
Use	Solvent

Table 2.3 Hazard Identification of Hexane (Chevron Philips, 2019)

Hazard Identification
Classification of Substance
• Liquid form • Colorless • Milk hydrocarbon odor • Flammable liquid and vapor • Damaging skin corrosion/irritation • Causing toxicity • Aspiration hazard • Short/Long-term aquatic hazard • Causing drowsiness or dizziness

Table 2.3. (Cont'd)

Labelling

Precautions
• Follow specified orders/ regulations/ emergency plan • Prevent touching/forming heat, hot surfaces, flames. • No smoking • Storage closed container, cold and well-ventilated area • Use explosion-proof and non-sparking materials • Do not breathe • Wash skin after handling • Use well-ventiled area • Prevent leaking to the environment • Wear protection eqipments for eye, skin and face protection

When the precautions explained in table 2.3 are detailed in terms of exposure controls and personal protection, some issues are considered. After analyzing airborne exposure limits, suitable protection measurements should be supplied. Because of that, a suitable ventilation system is supplied to make exposure lower than Airborne Exposure Limits. However, in terms of personal respirators when this value of exposure is higher than standards, and engineering control is not sufficient, personal protective equipment (PPE) should be used. Breathing apparatus are preferred for breathing to supply quality air in the case of emergency. On the other side, while proper PPE such as boots, gloves, lab clothes, etc. for skin protection, chemical safety goggles or full shield are preferred for eye protection. Also, eye wash fountain is located at dangerous units (Baker, 2009).

Table 2.4 Firefighting Precautions of Hexane (Chevron Philips, 2019)

Firefighting Precautions
• Although alcohol-resitant foam, carbon dioxide and dry chemical are suitable for extinguishing, high volume water jet is not suitable.
• While stopping fire, entering drains or water of it is avoided and wearing self-contained breating personel protective equipment.
• Contaminated fire extinction water is separeted and stored separetly into closed container and not dropped into the sewage.
• Take precautaions to avoid static electricty discharge.

2.4.2.1.1 Regulations and Exposure Limits of n-Hexane

There are regulations related with n-Hexane based on its flammable and combustible liquid group and its occupational exposure levels based on Turkey and global standards. According to the Regulation on the Protection of Buildings from Fire in Turkey, in the fourth chapter defined as flammable and combustible liquids, a flammable liquid containing liquids with a flash point below 37.8 ºC and vapor pressure at 37.8 ºC not exceeding 276 kPa are considered is named as Class I divided into three group as Class IA liquids, Class IB liquids and Class IC liquids. Since Class IB refers to liquids with a flash point of less than 22.8 ºC and a boiling point of 37.8 ºC or higher, *n*-hexane with -23 ºC flash point and boiling point of 69 ºC is in Class IB flammable and combustible liquid group (Regulation on the Protection of Buildings from Fire, 2007).

According to Regulation Health and Safety Measures in Working with Chemical Substances, occupational exposure limits of chemicals are specified in Annex 1 of this regulations with a table. *n*-hexane with European Inventory of Existing Commercial Substances (EINECS)' number as 203-777-6 and chemical abstract numbers (CAS) as 110-54-3 has time weighted average (TWA) value for 8 hours which is 72 mg/m^3 at 20 ºC and 101,3 KPa in 1 m^3 of air amount of substance in milligrams and 20 ppm meaning 1 m^3 of air amount of substance in millimeters (Regulation Health and Safety Measures in Working with Chemical Substances, 2013).

According to the National Advisory Committee for Acute Exposure Guideline Levels (AEGLs) of Hazardous Substances has been released to detect and identify relationship between toxicologic and other scientific data and collect various data to improve AEGLs. AEGLs demonstrates main exposure limits for all public by considering emergency exposure intervals between 10 minutes to 8 hours. There are three stages as AEGL-1, AEGL-2, and AEGL-3 for each exposure periods which are 10-minute, 30-minute, 1 hour, 4 hours, and 8 hours.

AEGL-1 is the described as the airborne concentration with per million (ppm) or milligrams per cubic meter (mg/m^3) of a material. It includes all public with susceptible people, anon-sensory impacts, irritation, etc. After exposure is over, its impacts will finish, this shows that its effects are reversible. Also, AEGL-2 is the identified as the airborne concentration with per million (ppm) or milligrams per cubic meter (mg/m^3) of a material by considering public with susceptible individuals. Its impacts cause irreversible and serious health outcomes and inability to escape. AEGL-3 has same definition as AEGL-2 and AEGL-1. However, it causes life-threating health outcomes and death. Its AEGL values depends on its classification are shown in table 2.5. (National Research Council, 2011).

Table 2.5 AEGL Values for n-Hexane (National Research Council, 2011)

Classification	10 min	30 min	1 h	4h	8h
AEGL-1 (nondisabling)	NR*	NR*	NR*	NR*	NR*
AEGL-2 (disabling)	4,000 ppm	2,900 ppm	2,900 ppm	2,900 ppm	2,900 ppm
AEGL-3 (lethal)	12,000 ppm	8.600 ppm	8.600 ppm	8.600 ppm	8.600 ppm

*NR: Not recommended due to insufficient data

On the other hand, the exposure limit is 500 ppm for 8-hr TWA according to OSHA protecting and regulating health and safety standards. Besides, National Institute for Occupational Safety and Health (NIOSH) conducting respiratory devices by evaluating them and offering regulations to OSHA guides these limits as 50 ppm for 10-hr TWA. Lastly, this limit is arranged 260 ppm, 2,900 ppm and 8,600 ppm as PAC-1, PAC-2 and PAC-3 respectively by Protective Action Criteria (PAC) founded by the Department of Energy and relying on AEGLs and Emergency Response Planning Guidelines ERPGs to prepare emergency planning in the case of releasing of hazardous chemicals (NJHealth, 2012).

When the three concepts which are AEGLs, ERPGs, and TEELs are compared, the main result is that all of them has same purpose to supply data for PAC. However, they have principal differences in terms of development style. While AEGLs belong to the "general population", ERPGs and TEELs belong to "nearly all individuals". Additionally, while AEGLs have five-time intervals, TEELs are described for 15-minute interval, and ERPGs are defined as exposure duration with 1 hour (Emer, 2008).

2.5 Occupational Accidents Storage Tanks in the World & Turkey

2.5.1 General Information About Accident Occurrence

There are various types of chemical accidents as solvent mainly leaking and intoxication considered as low development, stable energy, fire, and explosion considered as rapid growth, and unstable energy. At this point, the more destructive accidents in the storage tank have various indicators such as the source of hazard, chemical properties of dangers such as vapor concentration, direct impacts caused by humans, poor operational conditions, preventions, management, and environmental effects as topography issues, location of the company closing to urban (Wang et al., 2018). In conclusion, the accident mainly has effects on staff, properties, and the environment. According to figure 2.11., releasing chemical materials leads to environmental pollution and creates economic damage. When this releasing material is toxic, poisoning causes reputational loss. On the other hand, if the leaking substance is flammable, sufficient energy pushes fire and explosion. After them, personnel loss such as injuries and deaths, property harm, substructure damages, and environmental effect are observed because of waves of huge explosions and thermal radiation (Kong et al., 2018).

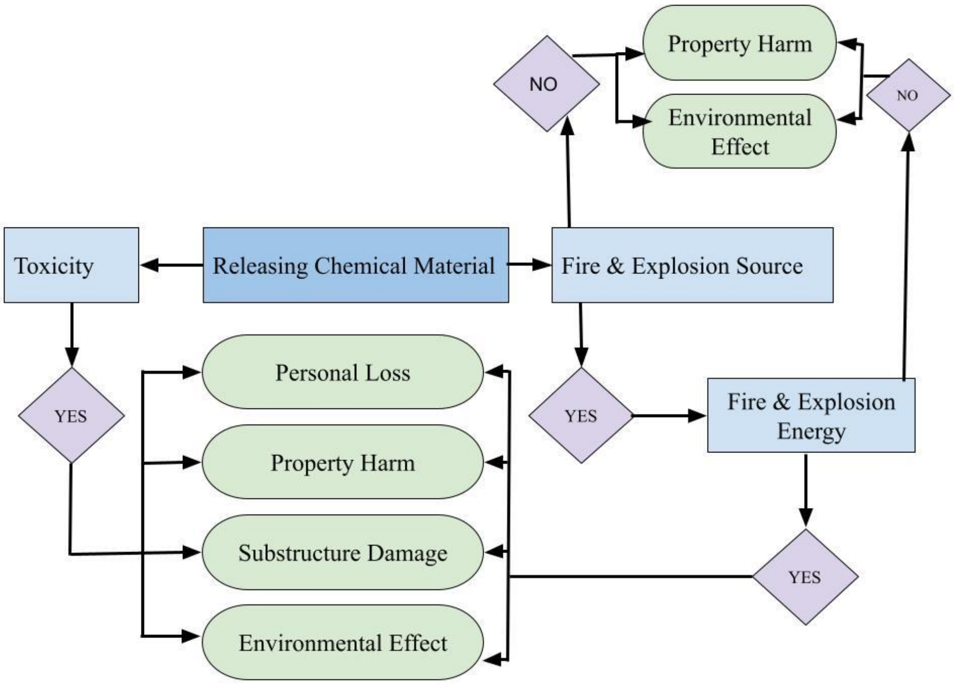


Figure 2.11. Presentation of accident occurance

2.5.2 Accident Examples in Storage Tank in the World and Turkey

Chemicals generally cause accidents in different industries during transportation, storage, and process. According to Table 2.6, solvents have second rank among three sectors which are chemical Production, sales warehouse and food & drink solvents such as n-heptane cause chemical accidents in general chemical matter production, wholesale and retail sale warehouse (Yavuz, 2016).

Table 2.6 Distribution of chemicals causing accidents by sectors (Yavuz, 2016).

Sector	*LPG*	*Cl_2*	*NH_3*	*Solvents*
Chemical Production	8	7	1	5
Sales Warehouse	7	1	0	3
Food & Drink	0	0	5	2
Total	15	8	6	10

Table 2.7 shows real occupational accident examples related with storage tank and their sources raged between 1997 and 2022. As this table is analyzed, generally accidents are common in chemical and petroleum industries. Leaking of hazardous chemical from storage tank, vapor cloud formation and dispersion, hazardous chemical puddle after leakage of it with formation of fire or explosion in the presence of ignition source and flame are main reasons of accidents resulting in evacuation of people, deaths, injuries, massive properties damage, environmental hazard and pollution.

Storage tanks include flammable liquids, and explosive air-vapor mixtures, etc. substances. Their chemical properties leading to accidents represent in figure 2.12. Flammable is the first rank. Then, while toxic flows it, explosive is third rank. Therefore, these chemical properties are considered in the case of accidents (Yavuz, 2016).

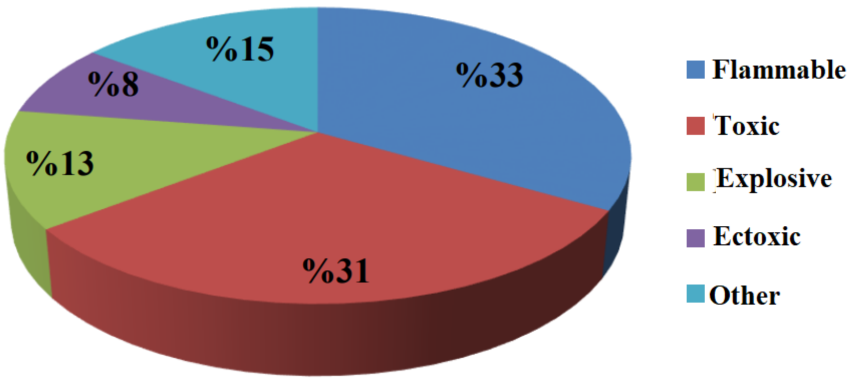


Figure 2.12. Types of chemicals that caused the accident

(Yavuz, 2016)

In table 2.7, real cases related with storage tank accidents occurred in different regions and industries with various results and reasons is shown. According to this table, leaking, bending, overfilling, static electricity formation, gas cloud formation, etc. are the main reasons of this kind of accidents.

Table 2.7 Table 2.6 Occupational accident examples in storage tank

(Tausessef etal.,2018), (Ozturk, 2011) & (CSB, 2022).

Accident 1: HPCL Refinery	
Location	India
Year	1997
Reason	Leaking from fuel storage tank creates a vapor cloud causing many explosions
People Died	80
People Injured	180
Results	Discharge of several people

Table 2.7 (Continued)

Accident 2 : Samir Mohammedia Refinery	
Location	Morocco
Year	2002
Reason	Bended roof of tank causes mixing of oil into drainage which makes fire and explosion
People Died	2
People Injured	2
Results	Morocco had to import fuels for several months.
Accident 3: Conco Phillips Tank Farm	
Location	USA
Year	2003
Reason	Overfilling of tanks damages tanks, causing fire and explosion.
People Died	-
People Injured	-
Results	After discharging of several people, schools are closed for 2 days
Accident 4: Oil Storage and Transfer Depot, Buncefield	
Location	UK
Year	2005
Reason	Vapor cloud creates explosion, which causes fire damaging 23 large storage tanks.
People Died	-
People Injured	43
Results	Massive property damage and 2000 people are discharged.

Table 2.7 (Continued)

Accident 4 : Barton Solvents	
Location	USA
Year	2007
Reason	Static electricity forms stark and causes explosion engulfing
People Died	-
People Injured	12
Results	Properties as buildings located at living space are damaged and discharging of people is occurred.
Accident 5: ConAgra Foods Facilities	
Location	Garner, North Carolina
Year	2009
Reason	Explosion occurred due to flammable vapor formation after ammonia leakage from storage tank
People Died	3
People Injured	71
Results	Properties as buildings and equipment were damaged.
Accident 6: Indian Oil Corporation terminal	
Location	India
Year	2009
Reason	Vapor cloud is formed after leaking and causes fire and explosion.
People Died	5
People Injured	150
Results	Large number of people are discharged

Table 2.7 (Continued)

Accident 7 : Petrol Ofisi Filling Factory	
Location	Turkey
Year	2011
Reason	While measuring gas on the empty ethanol tank, formed vapor cloud causes explosion
People Died	2
People Injured	-
Results	Storage tank is damaged
Accident 8: Amuay Refinery	
Location	Venezuela
Year	2012
Reason	Gas leak from pump causes fire damaging 11 other tanks.
People Died	41
People Injured	80
Results	3400 properties as building of school, restaurant is damaged.
Accident 9: Freedom Industry	
Location	Charleston, WV
Year	2014
Reason	Chemical mixture was released from storage tanks to local water source..
People Died	-
People Injured	-
Results	West Virginia residents did not access to clear drinkable water.

Table 2.7 (Continued)

Accident 10 : Millard Refrigerated Services	
Location	Theodore, AL
Year	2015
Reason	Dispersion of ammonia cloud from pipe of storage tank to the environment
People Died	-
People Injured	130
Results	Not only members working at factory but also people living around it exposure and hospitalized
Accident 11: MGPI Processing plant	
Location	Atchison, Kansas
Year	2016
Reason	Improper connection between storage tank and chemical delivery truck caused chemical leakage.
People Died	-
People Injured	120
Results	Public and workers are hospitalized because of the toxic chemicals.
Accident 12: AB Specialty Silicones	
Location	Waukegan, IL
Year	2019
Reason	Hazardous chemical was overflowed while loading of it from outside source due to open lip of storage tank.
People Died	-
People Injured	-
Results	Huge explosion and fire were formed due to chemical puddle.

Table 2.7 (Continued)

Accident 13 : Aghorn Operating Waterflood Station	
Location	Odessa, TX
Year	2019
Reason	Leaking of hydrogen sulfide from the pump.
People Died	1
People Injured	-
Results	Deaths were observed due to fire.
Accident 14: Chemical Storage Area	
Location	Gaziosmanpasa, Istanbul
Year	2022
Reason	Releasing of sodium hypochlorite storage tank to environment
People Died	-
People Injured	2
Results	Two people were injured.

2.6 Gas Explosion

An explosion is described as unexpected and quick change by increase of volume and energy release based on high temperature and pressure. These explosions could be classified as electrical, mechanical, and chemical failure which is burning of premixed clouds causing sudden climbing of pressure (WHS, 2022).

Although numbers of gas explosion are few, its severity is terrible in terms of buildings, living spaces and the environment. Generally, chemicals forming chemical accidents are threat for gas explosions, fires, and separation of toxic chemicals during their production and storage. In terms of chemical accidents shown in table 2.8, its higher percentage as % 42 of it forms vapor cloud explosion. Then, fires, explosion, other and wind follow this percentage as % 35, % 22 and %1. Also, when table 2.9 is analyzed, this represents that these accidents are resulted with not only most destructive, but also economic loss (Terzioglu, 2007).

Table 2.8 Percentages of chemical accidents' type (Crowl and Louvar, 1990)

Type	*Percentage*
Vapor cloud explosion	%42
Fires	%35
Explosion, other	%22
Wind	%1

Table 2.9 Comparing of three chemical accidents as high, intermediate, low according to some results and probabilities (Crowl and Louvar, 1990)

Type	*Probability of occurrence*	*Potential for fatalities*	*Potential for economic loss*
Fire	High	Low	Intermediate
Explosion	High	Intermediate	High
Toxic Release	Low	High	Low

2.6.1 Gas Explosion

Gas explosion could be happened in outer spaces, confined areas by a part of equipment such as pipes, vessel. According to figure 2.13 demonstration of what happening after releasing of combustible gas or evaporating liquid into the atmosphere. When their releasing is without ignition, fire is not formed due to disappearing of gas cloud. On the event of sufficient ignition immediately, fire is started. Apart from them, the most destructive scenario is occurred by formation of combustible pre-mixed gas cloud like fuel-air with sudden ignition cause (Bjerketvedt et al., 1997).

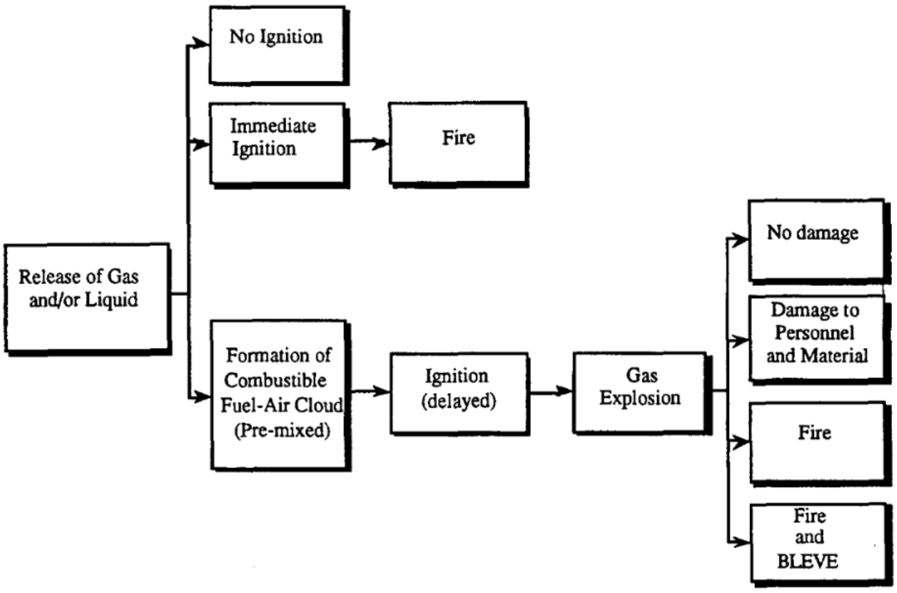


Figure 2.13. Event tree resulting of releasing of combustible gas/ evaporating liquid (Bjerketvedt et al., 1997).

2.6.2 Confined Gas Explosions

Confined gas explosions shown in figure 2.14 are defined as explosion taking place inside the process equipment as pipes, vessels, culverts, drainage. Size of mixture gas cloud is critical parameter if rapid formation of pressure increases. Since this size is higher, this is resulted with high pressure and explosion (Bjerketvedt et al., 1997).

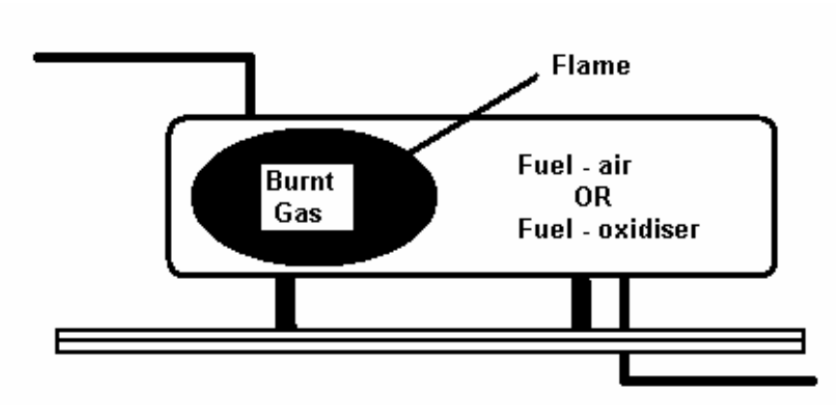


Figure 2.14. Confined explosion within tank
(Terzioglu, 2007)

For confined gas explosions, there are various places and equipment where the accidents happen. They will be explained in following part:

2.6.2.1 Closed Vessels

Vessels with small opening helps to release pressure from pipes or disks. While small releasing of this pressure, vessels' environment behaves as closed system, causing explosion (Terzioglu,2007).

2.6.2.2 Pipes

According to figure 2.15, the inside of the pipes with channel and tunnels forms pressure. Therefore, increasing of pressure in system from other sides causes formation of explosion. Also, after explosion, pressure formation is continued by flame spread. While flame is separated to the other parts, ahead of the flame forms turbulent boundary layer causing increase of burning rate (Terzioglu,2007).

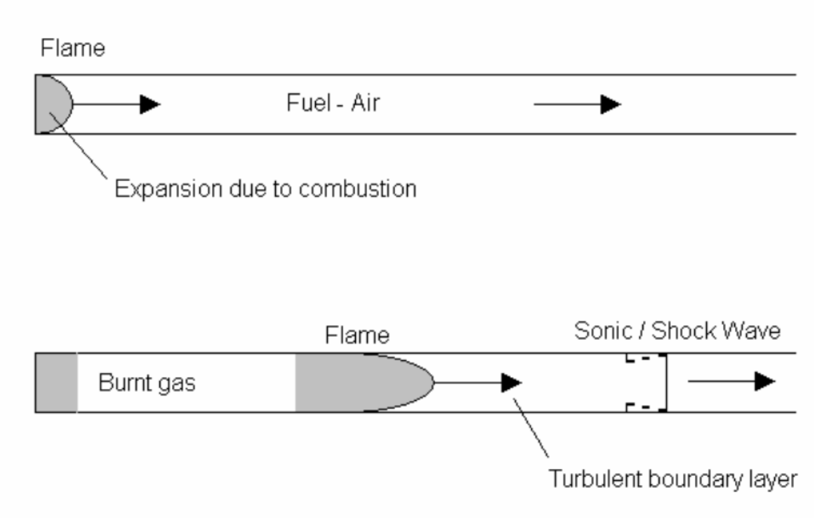


Figure 2.15. Flame acceleration in pipe
(Bjerketvedt et al., 1997).

2.6.3 Partly Confined Gas Explosion

Partly confined gas explosion is occurred at partially open areas such as compressor rooms after fuel is released immediately shown in figure 2.16. In partially open areas, ventil systems are essential to prevent accumulation of gas cloud and make explosion severity weak (Terzioglu, 2007).

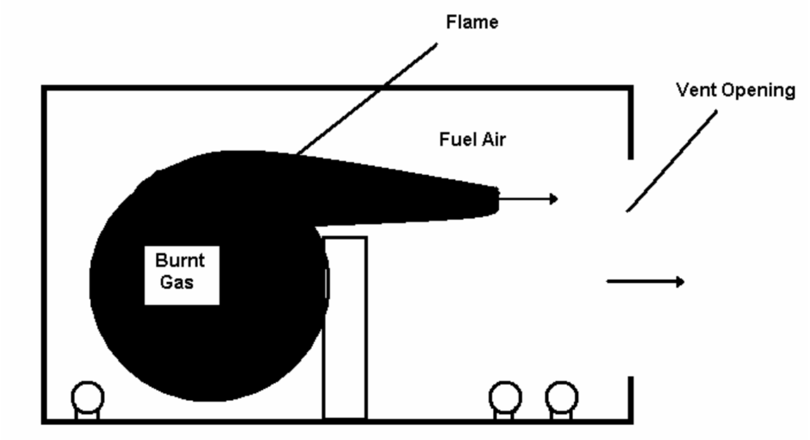


Figure 2.16. Partly confined gas explosion with equipment
(Bjerketvedt et al., 1997).

2.6.4 Unconfined Gas Explosions

Unconfined gas explosions are defined as explosion occurring in open area or open spaces to environment shown in figure 2.17. There are critical parameters for this type of explosion. Density of fuel is one of them. If its density is lower than air, gas is raised and dispersed quickly. On the contrary, if its density is heavier than air, known as dense gas, it forms a threat due to separation and accumulation on the ground (Terzioglu, 2007).

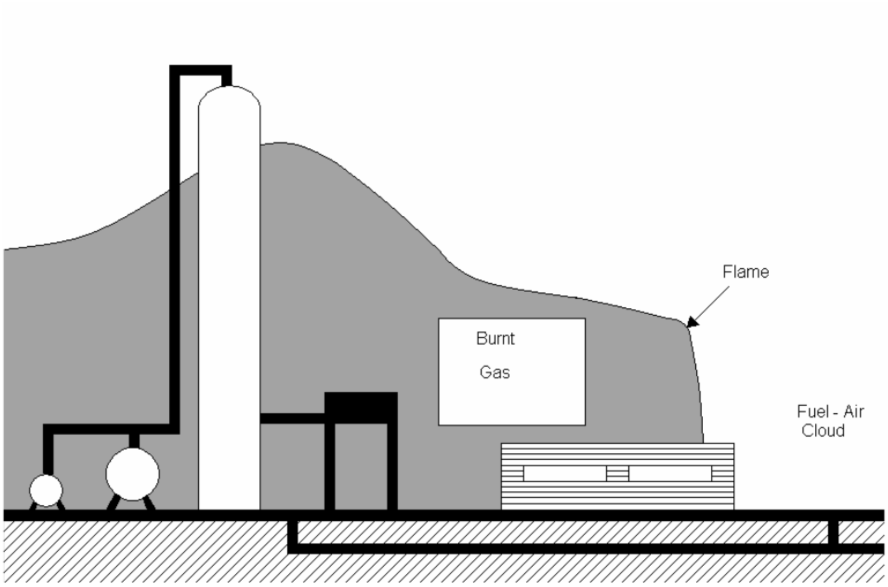


Figure 2.17. Unconfined gas explosion in open area

(Terzioglu, 2007).

2.6.5 BLEVEs

BLEVE is an acronym for Boiling Liquid Expanding Vapor Explosion. It is started by liquid flash under failure high vapor pressure in vessel and causes external fire shown in figure 2.18. When leak material is fuel, very large fire balls are formed shown in figure 2.19. Although figure 2.18 and 2.19 are related with tank car accident examples, the same situation is observed in the factory (Bjerketvedt et al., 1997).

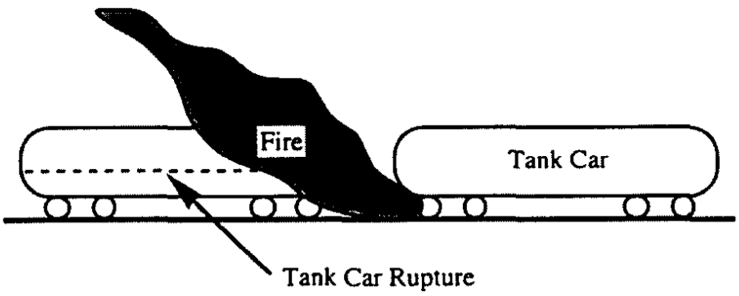


Figure 2.18. A state causes a BLEVE

(Bjerketvedt et al., 1997).

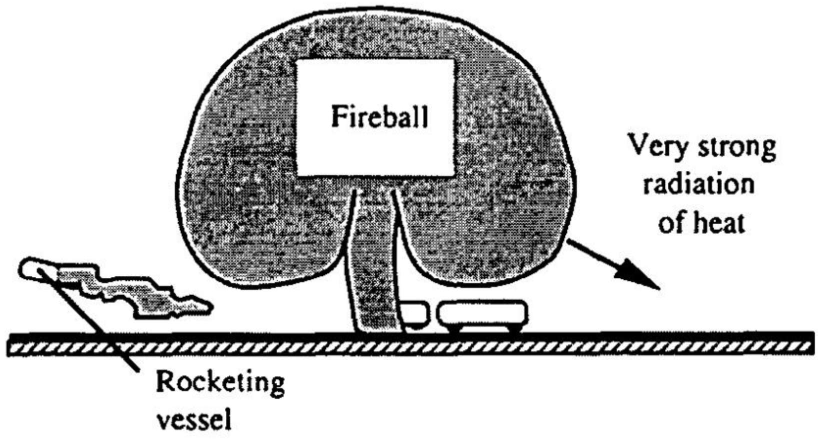


Figure 2.19. Fire balls and rocketing vessel are main threat for a BLEVE (Bjerketvedt et al., 1997).

2.7 Fire

Fire is described as burning process as combustion in the presence of three conditions as oxygen, heat, and fuel. Also, it has four forms as flash fire, jet fire, pool fire and secondary fire (Disaster Management Industry (DMI), 2022).

2.7.1 Flash Fire

During flash fire shown in figure 2.20, the act of starting to burn is combustible gas and air formation. In the presence of ignition sources, fire is started by this mixture. Its burning rate depends on atmospheric conditions such as wind direction and its velocity, and the number of flammable substances into this mixture. The length of time that flash fire lasts is short, and it results in damages which are thermal radiation and reduction of oxygen level (DMI, 2022).

Figure 2.20. I Flash fire example

(DMI, 2022)

2.7.2 Jet Fire

If flammable substance is ignited after its releasing from part of equipment such as vessel, pipe, a jet fire shown in figure 2.21 is happened by stable long flame forming releasing of pressure from one side of process. The form of flame depends in terms of length depends on amount of flammable material in the tank or process, flow rate of flammable gas or liquid and atmospheric parameters as wind speed (DMI, 2022).

Figure 2.21. Jet fire example (DMI, 2022)

2.7.3 Pool Fire

Releasing of flammable liquid accumulates on the ground and forms puddle like a pool. This accumulated and flammable pool forms pool fire shown in figure 2.22 in the presence of ignition sources. Its burning speed is related to the amount of heat required for the combustible and its evaporation. If the area of accumulation of flammable liquid as pool is large, it is very difficult to control. Generally, this kind of big pool size is observed in the storage tanks (DMI, 2022).

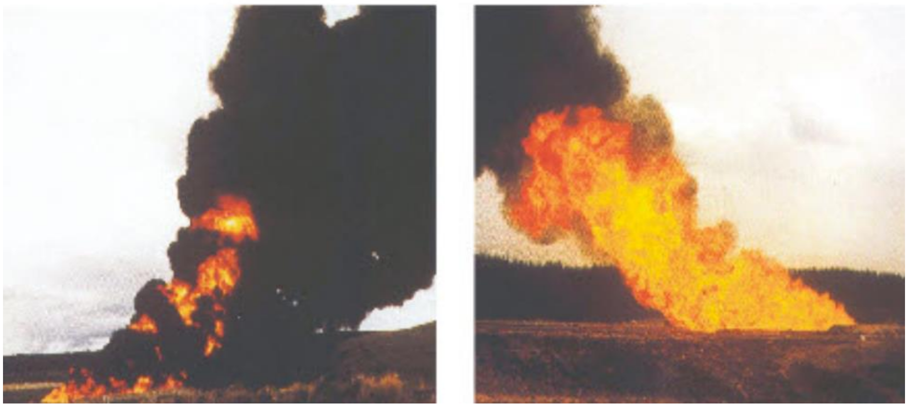


Figure 2.22. Pool fire example
(DMI, 2022)

2.7.4 Secondary Fire

A secondary fire is occurred by combustion secondary materials such as packaging materials, raw materials, insulation of process and building materials etc. In order to prevent this kind of fire, essentials precautions such as elimination of combustible materials for building, isolation or raw materials etc. are taken (DMI, 2022).

2.8 Explanation and Comparison of Dense Gas dispersion Models for Risk Assessment

There are six common dense gas dispersion models which are TRACE, PHAST, CAMEO/ALOHA, HGSYSTEM, SLAB and SCIPUFF (Hanna et al., 2014). Additionally, KORA is present risk evaluation software in Korea (Lee et al., 2018).

- The **SLAB** model is discovered by Environmental Protection Agency (EPA) in 1980 (Hanna et al., 2014). This application is used for releasing of denser substances than air from source to the environment by simulation of three different scenarios such as pool fire, jet fire and gas dispersion (Ermak, 1989).
- The **HGYSYSTEM** developed by Shell Research Ltd. in UK and based on HF chemistry and thermodynamical model helps detection of accidents causing pollution after releasing of pollutant substance which is denser than air under simulation of different cases as jet dispersion, heavy gas dispersion (American Petroleum Inst., 1995).
- The **SCIPUFF** is an acronym for Second-order Closure Integrated Puff. It gives information about combination of rate of dispersion and turbulent speed of wind (Sykes et al., 1996).
- The **TRACE** is the most common used dispersion cloud model with source emission for approximately or twenty years (Hanna et al., 2014).
- The **PHAST** is an acronym for Process Hazard Analysis Software Tool and the most widely used model among European countries. This model software is enriched by various model options. Also, it helps to analyze possible accidents from the beginning point of first leakage to huge regional gas distribution by considering impact of hazardous chemicals in terms of toxicity, flammability, and gas vaporization.

Additionally, its accidental scenario simulations such as fire types as pool, jet fire, tank roof damage, leakage from tank or tank equipment as pipe, vessel, and changing weather conditions. By examination of these scenarios, this model gives some patterns as burst pressure domain, thermal radiation domain etc (Pandya et al., 2008).

- The **ALOHA** is an acronym for Areal Location of Hazardous Atmosphere and designed as a part of CAMEO by the National Oceanic and Atmospheric Administration's. It is related with emission source and cloud dispersion model for releasing of dangerous chemicals from source to environment (Hanna et al., 2014). ALOHA gives opportunities to evaluate different dispersion and leakage scenarios and supplies visual outcomes to make comparison among scenarios (Jani et al., 2016). Besides, it comprises various chemicals such as solvents, colorless and hazardous chemicals. By using these chemicals, gas cloud dispersions separating less than six miles are modeled (Ilic et al., 2018). Moreover, ALOHA is multidiscipline software linked with chemistry, toxicology, and meteorology. Also, firefighters make a prediction relationship between leakage hazardous chemical and its hazards in terms of fire formation and health (Cherradi et al., 2018). Not only firefighters but also other users make guess whether the flammable/toxic chemical in the selected location causes fire or explosion (Beheshti et al, 2018). When required data are selected and entered, threat zones are obtained. These results are taken based on two dispersion models which are Gaussian plume model (GPM) and heavy gases model (HGM). The GPM defines dispersion of buoyant gas with same density as air (Shamsuddin et al., 2017). On the other side, HGM is useful for has with denser than air (Li et al., 2015). By depending on selected material properties, ALOHA specifies model to identify gas dispersion by drawing points where gas concentration higher than level of concern (LOC). In this point, LOCs provides information about flammable and toxicity threat of selected hazardous chemical (İlic et al., 2018).

On the other hand, ALOHA has some disadvantages. ALOHA does not include impacts of mixtures, chemical reactions etc. Additionally, it is not used for closed areas, some weather conditions such as snow or rain, less than one hour duration of releasing, more than six miles distances from releasing point (U.S. EPA and NOAA, 2007).

- The **KORA** is an acronym for Korea Off-site Risk Assessment and applied by Korea Chemicals Control Act. This application was created due to that there were not clear separation between industrial sites and public areas. It works according to Gaussian Model by analysis of damage area of hazardous chemicals (Lee et al., 2018).

Table 2.10 Comparing of three software modes which are ALOHA, KORA and PHAST (Lee et al., 2018).

Parameters	*ALOHA*	*KORA*	*PHAST*
Gaussian atmospheric diffusion	✓	✓	x
Discharge Model	x	x	✓
Multicomponent Extension Model	x	x	✓
Numbers of Chemicals	1.000	1.000	1.000
Mixed Chemicals	x	x	✓
Usage	Several	Korean Regulation	Commercial Usage
Mapping	Google Earth	V-world	Google Earth

When three models as ALOHA, KORA and PHAST are compared in table 2.10, they have same similarities and differences. Apart from them, each software has pros and cons. In terms of advantages, while ALOHA and KORA supply free access with quick results for usage, PHAST provides results in three-dimensions (3D). however, they have some disadvantages. ALOHA has some limitations which are unable 3D modeling of outcomes, inefficient for chemical reactions and non-usage for indoor cases. For KORA, it is unable to give outcomes in 3D concentration separation while its accuracy decreases based on seasonal parameters. Lastly, for PHAST it has very high price (Lee et al., 2018).

2.9 Risk Assessment Studies on the Storage Tank By using ALOHA

According to Tseng et al. (2012), ALOHA was chosen as a software tool to make risk assessment of toxic chemical release scenario. This study was conducted on three factories located at Twain with three toxic substances which are chlorine, epichlorohydrin and phosgene. Also, after direct leakage of these hazardous chemicals from storage tanks by changing parameters which are wind speed and total duration was selected ALOHA, these two outputs were compared by considering their simulation graphs to detect threat areas, showing that phosgene at Plant C had the largest threat area. Additionally, there were no big differences between summer and winter season’s threat zoned in terms of ERPG and IDLH values. Consequently, this study showed that different hazardous chemicals were analyzed by changing atmospheric conditions. Sometimes, the same results could be obtained based on locations, chemicals and meteorological parameters.

Patel and Sohani in 2015 made a risk evaluation on storage tank storing hazardous chemical located at oil refinery in India. In this research, scenarios were changed based on stored hazardous materials which were naphtha, butane, propane and kerosene, leakage size such as 2,3,6 and 15 meter, type of storage tanks as vertical / horizontal cylindrical and sphere, pressurized and unpressurized.

After that, pressurized butane leakage scenario storing in sphere tank under jet fire had the worst results with the longest threat zones as red, orange and yellow. On the other hand, unpressurized kerosene leaking from vertical cylindrical tank under pool fire had the smallest threat areas when comparing to other scenarios. This shows that type of chemical, whether the chemical leakage from tank is accomplished by pressure or not and type of fire or explosion were critical parameters affecting outcomes of accidents.

Fatemi et al. (2016) made a study to analyze the impacts of chemical accident occurred at storage tank on residential areas close to factories. The case in this paper was occurred in chlorine warehouse in Iran. The leakage of chlorine from storage tank was its scenario based on different seasons by changing atmospheric conditions where are temperature, relative humanity, wind speed, atmospheric stability class. After entering required information, while the maximum destructive result affecting 25,400 people and 6.5 km threat zone was happened in autumn, the minimum negative outcome impacting 24,100 people and 8.8 km threat zones.

According to Anjana et al. (2018), ammonia leakage scenario was conducted by using ALOHA. In this study, like others, atmospheric parameters were changed as summer and winter. After analyzing of four scenarios with different wind speed, temperature and humidity, results represented that distance of toxic hazard of ammonia was maximum in scenario 1 in winter with the highest wind speed. On the other hand, minimum thereat zone was occurred in scenario 4 in summer due to the lowest wind speed, the highest temperature, and the lowest humidity. Also, their impacts after exposing this hazardous chemical were explained. This represented that ALOHA helped users to obtain information related with exposure limits in specified thereat zones to make emergency planning in the case of leaking scenarios.

Kim and Byeon in 2017 made a study to compare two inputs of ALOHA and KORA software during hydrogen fluoride (HF) accident. It had two scenarios based on leakage scenario of HF by changing only wind speed.

Results obtained from ALOHA and KORA were close each other. Similarly, Kim et al. in 2018 made same investigation by using different chemicals which are ammonia, hydrogen chloride hydrofluoric acid and nitric acid to compare outputs of ALOHA and KORA. Also, same leakage scenarios were valid by changing weather conditions which were air temperature, wind speed, humidity, and atmospheric stability. Additionally, the Statistical Package for the Social Sciences was used to measure sensitivities of changed variables. According to this program, while effected area was the most vulnerable to atmospheric stability, not the most sensitive to humidity. Among other parameters, it was also more sensitive to air temperature than wind velocity for ALOHA and KORA. Additionally, ALOHA software was more sensitive than KORA in terms of weather variables. This showed that ALOHA was more useful than KORA to examine impact of weather parameters. This study demonstrated that KORA used widely in South Korea was compared with ALOHA to understand their advantages and disadvantaged in terms of cases, chemicals and threat zones. Similarly, in South Korea Lee et al. in 2018 made same investigation to compare three software s which were ALOHA, PHAST and KORA by considering five hazardous chemicals which were nitric acid, hydrogen chloride, ammonia, sulfuric acid, and formaldehyde in the case of releasing of them from storage tank to the environment, and changing weather conditions. After taking their results, ALOHA was the most suitable software among other for releasing of nitric acid and ammonia. While KORA was the most efficient for hydrogen chloride, and sulfuric acid, PHAST was the most beneficial for formaldehyde. These investigations showed that different software applications such as PHAST, KORA and ALOHA were used to compare their results and design efficient preparation in the case of accidents.

Anandhan et al. in 2019 made risk assessment of LPG storage tanks by using ALOHA with different scenarios which were BLEVE, jet fire in Tamilnadu, India. The results gave some predictions related with flammability, thermal radiation, and toxicity by detect threat zones while releasing of LPG from its storage tank.

This study indicated that this kind of study started to matter in India to get under control of hazardous chemical dispersions.

According to Orozco et al., 2019, the releasing of ammonia from its storage tank located at industrial region in Matanzas by using different scenarios, and the graphs which were Toxic Vapor Cloud, Flammable Area and Vapor Cloud Explosion were obtained. The outcomes represented that toxic cloud formation was the worst scenario for public and environment.

Yang et al. studied leaking scenarios of propylene storage tank which were gas cloud dispersion and steam cloud explosion as BLEVE type on ALOHA software in 2019. After evaluation of their graphs, and their effects on the environment and people, some suggestions which were evacuation action and preparation of emergency plan in the case of accidents were formed.

Siddiki and Ahmed in 2020 prepared a study related with chlorine and ammonia dispersion scenarios from their storage tanks in Khulna , Bangladesh by simulating atmospheric conditions on ALOHA. After analyzing, level of toxicity of both was highlighted based on AEGL-1, AEGL-2 and AEGL-3 in terms of duration of exposure as scenario I. Apart from dispersion of them, in the presence of ignition source, this flammable gas cloud was formed BLEVE under pressurized sudden release, only for ammonia. Then, their threat zones were detected based on their scenarios.

Iskender made a risk evaluation for an acetone storage tank in 2021 located at chemical factory in Istanbul, Turkey by simulating various cases which were toxic gas cloud formation, flammable gas cloud with fire, vapor cloud explosion, pool fire formation after accumulation of acetone on the ground and leakage of acetone storage tank. Then, after their threat areas were examined, essential precautions were explained according to regulations applied in Turkey.

Barjoee et al. prepared a study related with benzene leakage in coking and tar Refining Kerman, Iran in 2021. This leakage scenarios were based on changing seasonal conditions which are winter, autumn, summer, and spring by simulation of dispersion of toxic cloud and pool fire formation. After evaluation of threat zones with AEGL and LEL limits, the maximum hazardous area was observed in autumn. This showed that different seasons had effects on results of releasing accidents.

According to Ozay et al. (2021) , the paper had risk evaluation on methane explosion in biogas industry in Turkey by using ALOHA and PHAST. There were two separated cases for ALOHA which were direct dispersion of flammable methane from environment and releasing it from storage tank. On the other hand, there were two different scenarios for PHAST which were explosion cases as leaking and rupture of storage tank. When results of ALOHA's cases, while the first case had 200 m threat area with building damages, injuries, the second case was resulted with only glass breaking of buildings in 22 m threat area. In terms of PHAST outcomes, threat zones of different atmospheric conditions did not have big differences into scenarios. Also, catastrophic rupture scenario was the most destructive effects when other cases were considered. Consequently, this study represented those different cases were analyzed and evaluated by using many different software to detect results of methane explosions.

As a result, after mentioning related studies in the risk assessment of leakage scenarios of hazardous chemicals by using ALOHA software, various type of chemicals used in different industries such as petroleum, chemical and biogas could be analyzed When entering and selecting the essential parameters and scenarios' inputs on the programs, threat zones are obtained . Generally, scenarios are arranged by changing atmospheric parameters based on seasonal differences, wind speed, humidity etc. Apart from them, selection of scenarios based on leaking conditions which are hazardous chemical dispersion from storage tank to environment, forming puddle of chemical leakage from storage tank resulting in pool fire, BLEVE and jet fire formation in storage tank due to pressurized leakage of flammable substances.

Additionally, changing of capacity of chemicals stored in the tank, size and shape of leaking area, flow rate of leakage materials, size of fireballs before BLEVE type fire are other parameters to simulate cases. The usage of this program has been the subject of recent research currently for four or five years in Turkey, Iran, and India. In terms of South Korea, the increasing population makes residential areas close to industrial sites. Thus, new regulations were established to protect public in the case of any accident in terms of chemical storage tanks occurring factories located around the residential region. Then, KORA was formed according to needed this country in order to make emergency preparation program and make undesirable results of accidents on individuals living city or working factories minimize. Thus, this program is compared with other software such as ALOHA, PHAST to make KORA more efficient.

2.10 Scopes & Limitations of ALOHA

Generally, by using ALOHA programs, some basis for safety could be summarized as avoiding explosive mixtures and hindrance of ignition sources during usual storage and process condition comprising starting stage, production process, and shutting down period. Apart from that, ALOHA software also has some limitations in some situations that decrease atmospheric mixing and some effects detailed in the lower part (Tauseff et al., 2017).

- **Extra Low Wind Velocity:** When the wind speed is lower than 3 miles/hour, the pollutant clouds could not be contaminated rapidly with the air in the surrounding. At that point, especially around the source, ALOHA could not give reliable results in terms of gas concentration in the chemical cloud. In reality, its concentration in the gas cloud could be higher than the results predicted by ALOHA (NOAA, 2022).

- **Very Steady Atmospheric Situations:** In terms of atmospheric situations, stability classes as E and F happen on nights and bright and early and may be implied by situations such as low-lying fog. At that point, the gas concentration in the pollutant cloud could be higher than the source (NOAA, 2022).
- **Concentration Patchiness:** This is applied for some conditions where the gas concentration could not be drawn as a bell-shaped curve. Concentration patchiness happens in every cloud located at a close distance from the source. At this point, since ALOHA is based on average concentrations, they are forecasted as underestimation or overestimation. If the average concentration is accepted as accurate, the cloud must move windward to the source to mix gas and air by forming eddies. This distance affects various parameters such as wind velocity, release details and atmospheric stabilities. When the maximum interval to the toxic level of concern (LOC) concentration is lower than 50 m, threat zones could not be represented (Tauseff et al., 2017).
- **Waste products and particles coming from fire, explosions, and chemical reactions:** ALOHA does not have the ability to consider by-products of fire, explosion, and chemical reactions such as smoke. For instance, smoke is lifted up direction by heating effects during combustion although it is transported downwind after rising. At this point, ALOHA could not take into account this first-up direction rise. In this software, this is assumed a dispersed cloud does not react with atmospheric substances like oxygen, water vapor, etc. on the other hand, some chemical materials could make reactions with these substances or other chemicals. Due to that, since chemicals could be dispersed in different patterns from their containment, this causes unreliable results supplied by ALOHA. Apart from that, ALOHA could not consider particular dispersion from processes such as radioactive particles (NOAA, 2022).

- **Chemical Mixtures:** Although ALOHA has information related to the chemical library including pure chemicals and little-selected solutions, it is not valid for chemical mixtures (NOAA, 2022).
- **Wind Shifts and Steering Effects:** During chemical releasing, wind speed and its directions are assumed as constant in ALOHA. Apart from that, the ground under the cloud dispersion is expected as straight by ALOHA. However, in rural areas, wind speed and directions could change according to the shapes and directions of valleys and hills. On the other side, wind shifts and speeds are affected by building and their edges in urban areas. This also impacts the forms and movement of the gas cloud. At this point, ALOHA does not account for these impacts to form threat zones (Tauseff et al., 2017).
- **Terrain:** Tough the releasing area from the source is not flat, ALOHA assumed that the ground is straight. In terms of liquid forms, ALOHA considers that releasing scenarios of them occurs in all directions at the same flow rate. However, it does not account for the accumulation of depressions during liquid spreading out. This causes a bigger puddle amount and release rate (NOAA, 2022).
- **Hazardous Crumbs:** When there is an explosion during releasing of gases or liquids, there are rubbles sourced from properties or storage tanks. At this point, ALOHA could not draw orbits of dangerous crumbs such as flying debris (NOAA, 2022).

2.11 How accurate is ALOHA?

According to the Office of Response and Restoration in 2022, it claims that accuracy of ALOHA software is based on a rule of thumb by depending on expert judgment. For instance, ALOHA gives some interval for the concentration of dispersed gas at the location between 75 – 150 parts per million (ppm). As the exact concentration at that point is 100 ppm, this shows that ALOHA's result is correct. Apart from that, outcomes of PHAST and ALOHA were compared for butanol released from its storage tanks by using real cases. This shows that threat zone distances are less than 19 m in ALOHA software, PHAST gives exact numbers depending on different concentrations. However, the effective distance is more or less in a similar range of +/- 10%, which is acceptable. On the other hand, the same study demonstrates that ALOHA software is so basic to operate and necessary fewer inputs by some assumptions designed by considering practical real scenarios.

Additionally, although PHAST gives exact numbers, this software could be used only for scenarios of flash fire and fireball; but it could not be applied for other scenarios such as pool fire, jet fire, etc. (Bhattacharya and Kumar, 2015). Additionally, a real case which was an LPG truck tanker accident in India was examined in a study with different types of fire by using ALOHA and PHAST software. In a fireball scenario on an LPG accident, the maximum threat diameter of ALOHA and PHAST was 146 m and 149.44 m respectively. This shows that PHAST and ALOHA give similar results (Bariha et al., 2015). Consequently, when ALOHA is compared with other software such as PHAST, ALOHA has so high accuracy and speed to calculate and form models. Also, this software reduces user errors to supply the most reliable and accurate complete results (Mehrabani & Ghiyasi, 2018).

2.12 ALOHA Approach as Proactive and Reactive

ALOHA has both proactive and reactive approaches. This demonstrates that the ALOHA program is used in both cases, to take precautions before an accident and to respond quickly and accurately to the accident after an incident. ALOHA is applied to identify the concentration of dangerous substances at any location from the source of release and to make hazard evaluation by obtaining easy, fast, and accurate outcomes of heat load distances in the worst cases (Patel and Sohani, 2015).

Similarly, ALOHA supplies adequate replies in the case of hazardous chemical leaks. In this way, before any release to the environment, these replies to as proactive approaches by reducing the negative effects on the environment. Additionally, hazardous chemicals form toxic vapor clouds in the case of any leakage. These clouds could cause overpressure waves and heat radiation in the case of an accident. Due to that, people working at the factory and living around the factory impact these outcomes. Though there is risk management for hazardous chemicals, some desirable and destructive events could not be avoided for industries (Calixto and Larouvere, 2010). Because of that, emergency planning for the evacuation has a significant and critical role to make minimizing the results of accidents to hinder injuries and deaths, preserving surroundings, and passing to normal operation after the accident. If this plan is formed before the accident, it could be defined as a proactive approach. However, this could be classified as reactive usage of ALOHA because an emergency plan will be formed or recreated by considering ALOHA's results after the accident (Hosseinnia et al., 2018).

Additionally, the estimation of fluid behavior after the leakage and its separation into the environment are significant to make predictions of possible scenarios. By using possible scenarios in ALOHA, increasing awareness for maximum safe orbital in the case of fire, explosion, and toxic cloud dispersion. This is also a proactive approach by using ALOHA (Mehrabani & Ghiyasi, 2018).

In summary, ALOHA is preferred to form an emergency response plan. After preparing the emergency plan for affected regions by considering threat zones obtained from ALOHA, the team related to the emergency evacuation response specifies the safest evacuation procedure through a map created based on graphical outcomes from Google Earth (Ahmed, 2020). Additionally, the corporation of safety evacuation strategy in the Malaysian chemical industry advises ALOHA usage for a proactive approach to foresee losses (Ramli et al., 2018). Additionally, ALOHA software could be applied for educational and practical aims to develop the ability of forecasting and quickly management of emergency events (Poluyan et al., 2017).

2.13 Air Dispersion Models Used in ALOHA

Since the release of hazardous chemicals from its source to surrounding creates danger, air dispersion models use for this software to make prediction for threat zones by centering the source of releasing and calculation of concentration of pollutant with various parameters such as time and position. ALOHA uses two semi-empirical air dispersion models which are the Gaussian model and the Heavy Gas model.

2.13.1 The Gaussian Model

While the Gaussian model is suitable for pollutants which are not influenced by gravity, the Heavy Gas model is proper for pollutant cloud whose density is heavier than the ambient air and influenced by the gravity. Also, the Gaussian model is preferred for the passive pollutants not be influenced by air flow and gravity. The estimation of concentrical distribution of neutrally buoyant gas under steady state distribution is made according to approach of Gaussian distribution with enhancement of down-wind distance. This model is based upon empirical evaluations.

Due to that, increasing in measurement times forms the Gaussian distribution shape as well as widen spatial distribution. Also, the exact concentration of separation could alter at any single momentary in time. This method is useful for sudden and permanent cases lasting up to one hour (Jones et al., 2013).

2.13.2 Heavy Gas Dispersion

Heavy gas model for ALOHA usage is formed to consider the gravitational impacts on dispersed clouds whose density value is higher than air known as dense substances. When the evaporation rate from accumulated leakage is not huge amount and formation of dispersed cloud is ruled by the wind and thermal transmission in the atmosphere, the gravitational influence could be unimportant for dense substances. Additionally, the Gaussian model could be preferred for this kind of materials like Heavy Gas Model. However, the Gaussian model is proposed for pollutant clouds with less density than air (Jones et al., 2013).

In terms of ALOHA, there is a default section to select suitable algorithm for the Heavy Gas and Gaussian Models. In this point, Richardson's Number (Ri_C) plays critical role to make this decision whether the dispersion is passive or non-passive. If the calculate value of Ri_C is less than 1, the software decides that this material is passive. Unless the decision is changed by user, ALOHA makes calculations by using the Gaussian dispersion model. This value is based on the density of dispersed substance, the wind speed, and its release rate as it seems in the below equation (Spices and Havens, 1989).

$$Ric = \frac{H*g'}{U^2}$$

where the reduced gravity as g' is $g' = \frac{g\ (\rho - \rho_{a})}{\rho_a}$

ρ is the chemical density,

ρ_a is the ambient air density,

g is the acceleration of gravity,

U* is the wind's friction velocity

H is called as the characteristic dimension of the source, depends on the types of sources which are instantaneous dispersion, puddle, continuous sources (Jones et al., 2013).

CHAPTER 3

METHODOLOGY

ALOHA software is used as computantial risk assessment method for hexane storage tank located at open area and near the extraction unit in refined sunflower oil production factory in this study by simulation of three cases which will be analyzed detailly in this chapter.

3.1 Study Area

The refined sunflower oil company analyzed in this case study is located in Tekirdag, Turkey and close to the living space shown on picture 4. This factory was installed in this location due to its proximity to raw material source as sunflower oil seed and produces refined sunflower oil. Its total area contains others unit such as butter production unit, extraction unit, refinery unit etc. There are green space, farm land and residental areas within a distance of min 2 km. In terms of weather conditions, it has warm and clear summer and cold, partly cloud and snowy winters. Its temperature values are ranged between 0°C and 28.3°C (Wheather spark, 2022). By using Google Earth Pro, location of the stud shown in figure 3.1. and hexane storage tank is marked and its information is entered ALOHA at Sitedata as location shown in figure 3.2.

Figure 3.1. Location of study area

(Google Earth Map, 2022)

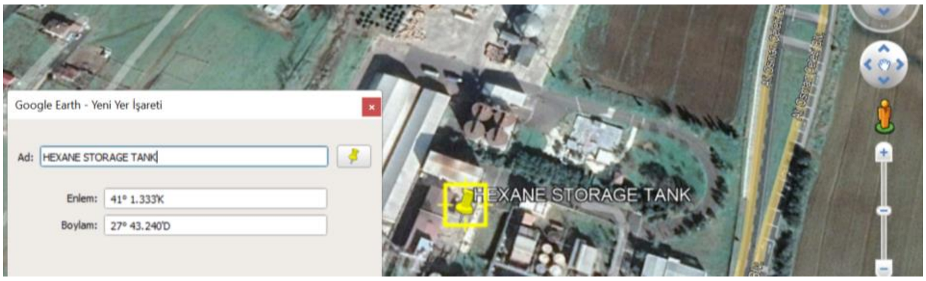


Figure 3.2. Location of Hexane Storage Tank on Google Earth Pro

3.2 ALOHA Software

ALOHA developed by some instutions which are United States Environmental Protection Agency (USEPA), Chemical Emergency Preparedness and Prevention Office (CEPPO), and National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA) is decribed as an air dispersion model to simulate dangerous chemical cases and identify footprint of hazardous chemicals in the case of any leakage (Tseng et al., 2012). Its latest version as 5.4.7 was updated in September 2016 and used in this study.

This software supplies some advantages to users as making and comparing some extra alternative cases for leak and visualization of them what may occurred (Jani et al., 2016). In this software, as there is a list about dangerous chemicals, ALOHA is also related with other areas such as chemistry, toxicology, health and meteorology. Also, it gives some information about fire. Toxin and hazard level of leakage of hazardous chemicals and results of this leak as fire or explosion also are estimated by using ALOHA. After required data which are chemical information, case study location, meteorological conditions as wind speed and direction, temperature etc, are entered on ALOHA, it gives results which are atmospheric dispersion rate, separation way of gas cloud from accident source such as pipe, tank or other part of equipment. Additionally, it gives visual results of dispersion models on the figures based on Gaussian model which are useful to define motion and expanse of a neutrally floating gas and a heavy gas model known as the Dense Gas Dispersion Model (DEGADIS) which are useful heavy gas separation (Cherradi, et al., 2018).

3.3 Data For Modeling

Source data containing storage tank properties, chemical data including hazardous chemical properties, atmospheric data with meteorological data and scenario design with three cases will be explained in this part.

3.3.1 Source Data

The source data involves storage tank properties in terms of type, orientation, diameter, length and capacity and physical state and storage temperature of storage hazardous chemical which is n-hexane.

Stainless steel vertical tank explained in table 3.1 with 13-meter diameter and 10-meter length contains liquid n-hexane at ambient temperature. When its fill rate is assumed as 80 %, n-hexane volume in hexane storage tank is 1,061.60 m^3.

Table 3.1 Technical data of n-hexane storage tank

Parameter	*Unit*
Tank Type	Stainless Steel
Tank Diameter	13 m
Tank Length	10 m
Tank Volume	1,327 m^3

3.3.2 Chemical Data

ALOHA includes chemical data containing physical and chemical properties of them. When chemical is selected as n-hexane, its properties shown in table 3.2.

Table 3.2 Properties of n-hexane on ALOHA

Parameter	*Unit*
Chemical Name	n-hexane
CAS Number	110-54-3
Molecular weight	86.18 g/mol
AEGL-2 (60 min)	2900 ppm
AEGL-3 (60 min)	8600 ppm
IDLH	1100 ppm
LEL	12000 ppm
UEL	72000 ppm
Normal Boiling Point	155.7 º F
Freezing Point	-139.6 º F

3.3.3 Weather Information

Meteorological conditions during accident have impact on separation of toxic cloud (Chakrabarti & Parikh, 2011). Especially, while atmospheric turbulence and wind are critical factors on separation of gas cloud. Although temperature and humidity are less critical parameters, thermal inversion has significant point for dispersion of heavy gas clouds (Inanloo and Tansel, 2015). On the other hand, since heavy gas cloud as n-hexane gas is close to ground while dispersion of air, low-level reversals does not affect it (Joaquim, 2008). Additionally, tough time and meteorological conditions of accident could not be estimated exactly, stability class gains significant role to estimate threat zone size for distribution of gas cloud. Because of that reason which supplying stability class on ALOHA software based on principle of Pasquill's six stability classes (Anjana et al., 2018). This stability class is identified by ALOHA software automatically after entering required weather information. Since dispersion of gas cloud is influenced by speed and direction of wind, they are considered as a critical parameter while determination of the weather conditions. Risks on human health and severity of the accident are increased excessively by increasing of wind speed (Terzioglu and Iskender, 2021). According to the information, the weather conditions were selected by considering real conditions for each season as spring, summer, autumn, and winter. The atmospheric conditions based on some parameters such as air temperature, wind speed, direction, humidity, cloud cover, etc. were obtained from real values by considering the real location of the storage tank between November 2021 and October 2022, showing in table 3.3 (Weather online, n.d.).

Its model of release is the Heavy Gas Model. After entering of inputs, the ALOHA software recommends that this dispersion model due to that its Richardson Number (Ri_C) is calculated as higher than 1 automatically.

Table 3.3 Weather Conditions of Selected Area (Weather online, n.d.)

Parameters	*Season*			
	Spring	*Summer*	*Autumn*	*Winter*
Air temperature (ºC)	11.8	24.1	19.4	7.1
Relative humidity (%)	74	64	70	79
Wind speed (m/s)	2.78	3.69	3.03	2.86
Wind direction	NNE *	NE**	NW***	NW***
Elevation of wind speed measurement (m)	10	10	10	10
Ground roughness	Open Country	Open Country	Open Country	Open Country
Atmospheric stability class	C	C	E	E
Cloud cover (0-10)	4	3	4	5
Model of release	Heavy gas	Heavy gas	Heavy gas	Heavy gas

*NNE: North- Northeast Wind

**NE: Northeast Wind

***NW: Northwest Wind

3.3.4 Topography

Topography has critical impact on contaminant dispersion. As wind blows on these forms, wind turbulent is affected (Anajana et al., 2018). In terms of ALOHA, it has three options as ground roughness which are open country, urban or forest and open water. In this study, topography has been chosen as open country.

3.3.5 Assumptions

- In this study, leakage of hazardous chemical as n-hexane from a 10 cm circular opening at the bottom of the storage tank to atmosphere.
- The tank filling capacity is assumed as 80 % full of hexane.
- Weather conditions for each season as spring, summer, autumn and winter are taken from real average values.
- The opening diameter is taken as 10 cm at the bottom of the storage tank for hexane leakage from tank.
- Maximum puddle size is assumed as unknown for second scenario simulation while entering data on ALOHA software.
- In third scenario, percentage of mass in the fireball is assumed as 100 % and %50 respectively and them their results are compared.
- Release model is selected by ALOHA software as the Heavy Gas Model automatically.

3.4 Scenarios for the Simulation

3.4.1 First Scenario

According to first scenario, hexane leaks out at the bottom of the storage tank. Shape of this opening is circular opening with 10 cm opening diameter. Also, the bottom of the leak is taken as zero meter above the bottom of the tank. After leakage, an evaporating puddle is formed without burning. Consequently, its tank failure type can be described as leaking vertical cylindrical storage tank with unpressurized flammable liquid without chemical burning by creating an evaporating puddle. This scenario is happened under the selected conditions for each season.

3.4.2 Second Scenario

According to second scenario, same conditions and leakage parameters mentioned in the part of first scenarios are occurred in this simulation. Apart from first scenario, pool fire takes place in leaking tank with chemical burning after leak. Also, this scenario arises from selected states.

3.4.3 Third Scenario

According to third scenario, same leakage conditions and data highlighted on first scenario are valid in this scenario. BLEVE type of explosion is happened in this part. After formation of fireball by chemical burning, tank explodes and BLEVE develops. Simulation conditions for this scenario is designed according to two cases which are 100 % and 50 % percentage of mass in the fireball.

CHAPTER 4

RESULTS & DISCUSSION

4.1 First Scenario: Hexane Leaks from the Storage Tank by Moving on Environment without Chemical Burning

4.1.1 The Toxic Threat Graphs for the First Scenario

The results for the first scenario which is hexane leakage from the tank at the circular opening area with a 10 cm diameter without fire formation and its dispersion to the environment are taken from ALOHA software by considering different weather conditions based on seasonal differences such as spring, summer, autumn and winter. Also, distances of its gas cloud formation are detected according to its threat zones. Additionally, the graphs of toxic area of the vapor cloud based on values of Acute Exposure Guideline Levels (AEGL) and Protective Action Criteria for Chemicals (PAC) represent the toxic area of this hazardous chemical after distribution to the environment and are shown in figure 4.1 (A), for spring, figure 4.2. (A) for summer, in figure 4.3. (A) for autumn, and figure 4.4. (A) for winter season respectively.

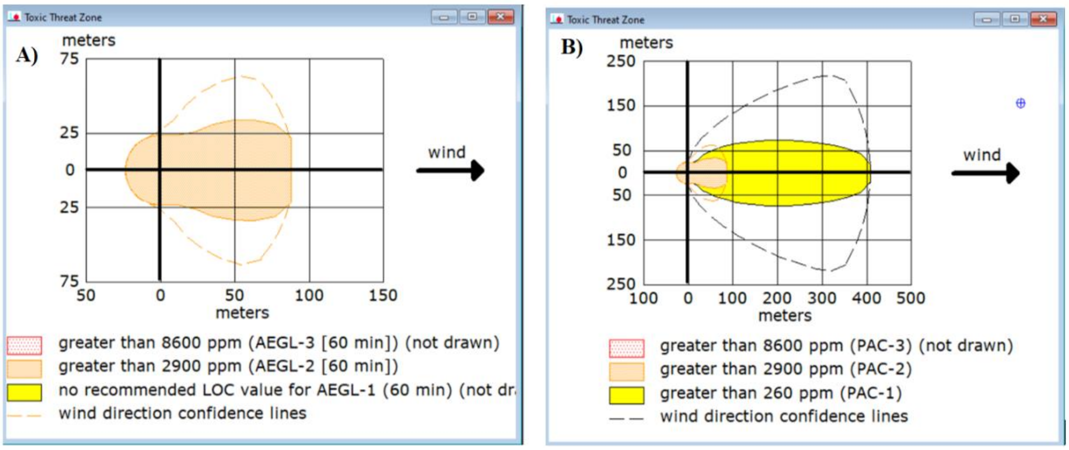


Figure 4.1. Graphical representation of toxic threat zone based on AEGL (A) and PAC (B) values for spring season

(ALOHA software, 2022).

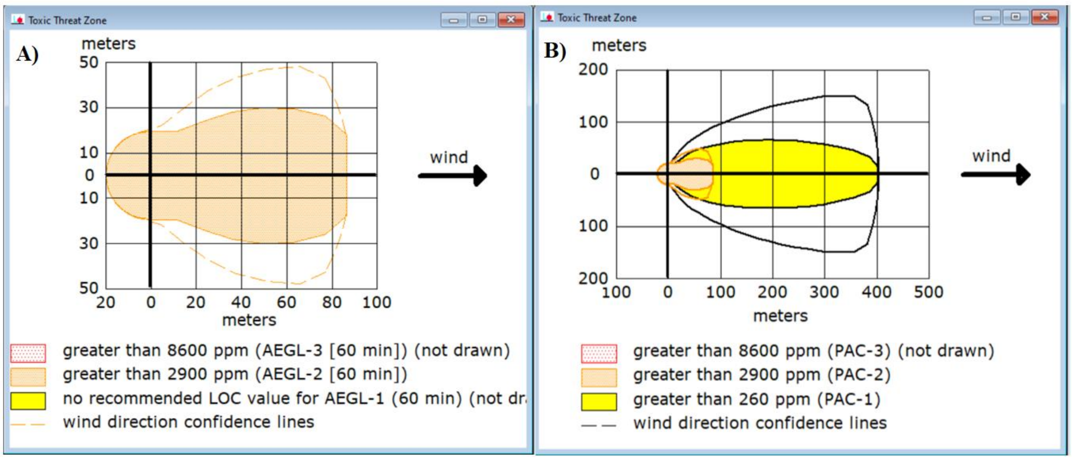


Figure 4.2. Graphical representation of toxic threat zone based on AEGL(A) and PAC (B)values for summer season

(ALOHA software, 2022).

According to toxic threat zones based on AEGL shown in the figure 4.1. (A), figure 4.2. (A), figure 4.3. (A) and figure 4.4. (A), while there are two areas with red and orange colors for autumn, there is only range region for another season.

When the results demonstrated in table 4.1, while the maximum distance for the toxic gas cloud region is approximately 121 m in the autumn season drawn by the orange color on the graph, its red region is 58 m.

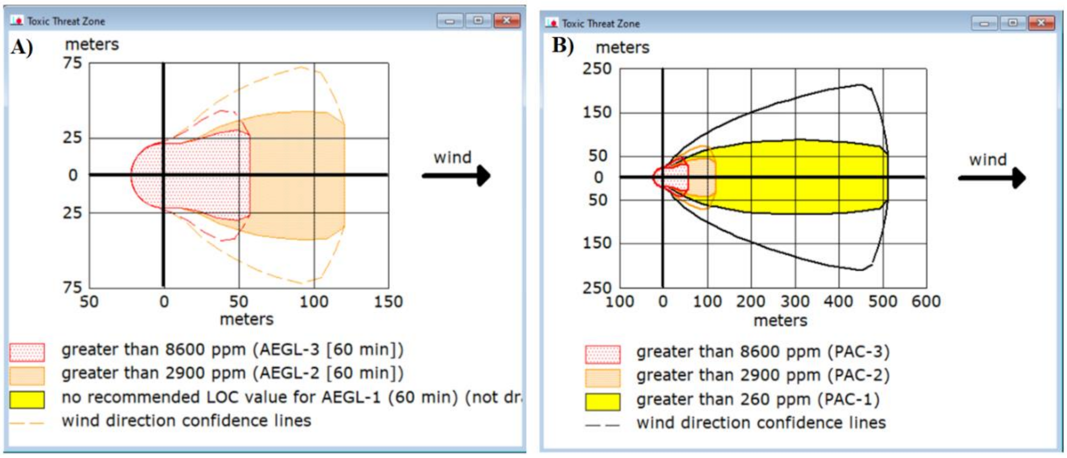


Figure 4.3. Graphical representation of toxic threat zone based on AEGL (A) and PAC (B) values for autumn season

(ALOHA software, 2022).

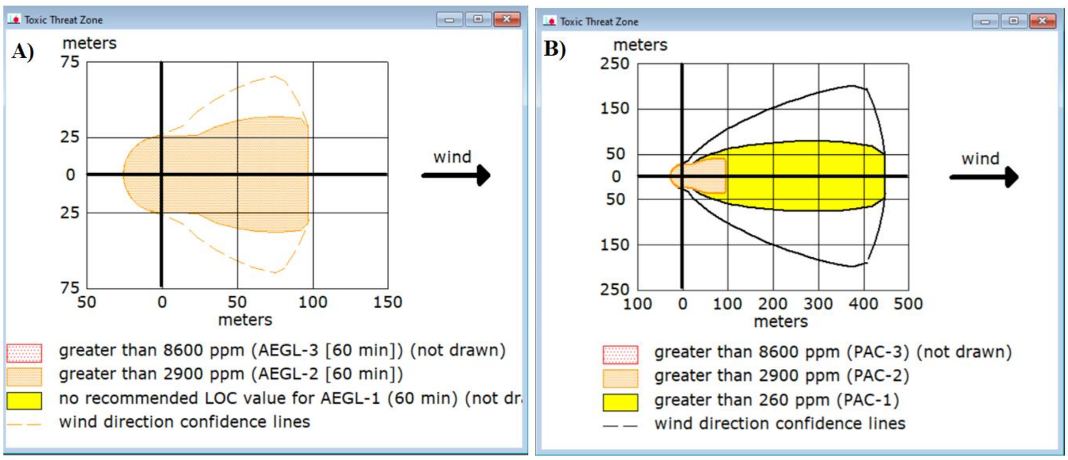


Figure 4.4. Graphical representation of toxic threat zone based on AEGL (A) and PAC (B) values for winter season (ALOHA software, 2022).

Table 4.1 Results of scenario 1 for toxic threat zones based on AEGL in terms of seasons

	Toxic Threat Zone		
Season	*Threat Zones*	*Concentration (ppm)*	*Distance (m)*
	AEGL-3	>8.600 (Red)	39
Spring	AEGL-2	>2.900 (Orange)	88
	AEGL-1	NI* (Yellow)	-
	AEGL-3	>8.600 (Red)	39
Summer	AEGL-2	>2.900 (Orange)	87
	AEGL-1	NI *(Yellow)	-
	AEGL-3	>8.600 (Red)	58
Autumn	AEGL-2	>2.900 (Orange)	121
	AEGL-1	NI* (Yellow)	-
	AEGL-3	>8.600 (Red)	44
Winter	AEGL-2	>2.900 (Orange)	98
	AEGL-1	NI *(Yellow)	-

*NI: No Information

The orange zone demonstrates AEGL-2 which exposes a concentration of greater than 2900 ppm and was dispersed to 88, 87, 121, and 98 m from the source in spring, summer, autumn, and winter, respectively. On the other hand, the red zone demonstrates AEGL-3 which expose concentration of greater than 8600 ppm and was dispersed to 39, 39, 58 and 44 m from the source in spring, summer, autumn and winter, respectively. This represents that the maximum distance for red region in AEGL-3 is 58 m from the source in autumn. Though there are red and orange regions, yellow region is not drawn on this graph. The reason for the unknown value of AEGL-1 on the application is less reliable dispersion prediction for short distances.

Also, though there is red region in autumn season with maximum threat zone, other season is deprived of this red region due to same reason as untrustable separation estimation for short distances.

Table 4.2 Results of scenario 1 for toxic threat zones based on PAC in terms of seasons

		Toxic Threat Zone	
Season	*Threat Zones*	*Concentration (ppm)*	*Distance (m)*
Spring	PAC-3	>8.600 (Red)	39
	PAC-2	>2.900 (Orange)	88
	PAC-1	>260 (Yellow)	409
Summer	PAC-3	>8.600 (Red)	39
	PAC-2	>2.900 (Orange)	87
	PAC-1	>260 (Yellow)	405
Autumn	PAC-3	>8.600 (Red)	58
	PAC-2	>2.900 (Orange)	121
	PAC-1	>260 (Yellow)	516
Winter	PAC-3	>8.600 (Red)	44
	PAC-2	>2.900 (Orange)	98
	PAC-1	>260 (Yellow)	449

Apart from graphs toxic threat zones for AEGL values, also graphs toxic threat zones for PAC were obtained for each season in the figure 4.1. (B), figure 4.2. (B), figure 4.3. (B) and figure 4.4. (B), while there are three areas with yellow, orange, and red colors for autumn, other season is without red color exhibition on their graphs. When the results represented in table 4.2., the maximum distance for the toxic gas cloud region is 516 m in autumn season drawn by the yellow color on the graph. Yellow region shows PAC-1 which exposes a concentration of greater than 260 ppm and was dispersed to 409, 405, 516, and 449 m from the source in spring, summer, autumn, and winter respectively.

On the other hand, the orange region demonstrates PAC-2 which expose concentration of greater than 2.900 ppm and was separated to 88, 87, 121, and 98 m from the source in spring, summer, autumn and spring, respectively. These values shows that while the maximum value is 121 m for this threat region in autumn, its minimum value is 405 m in summer season. Besides, PAC-3 with red zone which expose concentration of greater than 8.600 ppm was 39, 39, 58, and 44 m from the hexane storage tank in spring, summer, autumn and winter respectively. This shows that its maximum distance is 58 m in autumn season.

When two graphs shown on figure 4.1., 4.2., 4.3. and 4.4. with (A) and (B) are compared, impact area of (B) graph has bigger than (A) graph. The reason of this is that since database of PAC comprises three base public exposure guidelines which are AEGLs, Emergency Response Planning Guidelines (ERPGs) and Temporary Emergency Exposure Limits (TEELs), it has wide ranges with various possibilities (NOAA, 2022). When the figures were analyzed, (A) graphs do not have yellow region due to limitations of AEGLs dataset. On the other side, since PACs database also includes other public exposure guidelines, it has a value for yellow region. Additionally, values of orange and red regions are same. This means that data of PACs includes AEGLs dataset for orange and red region.

A) B)

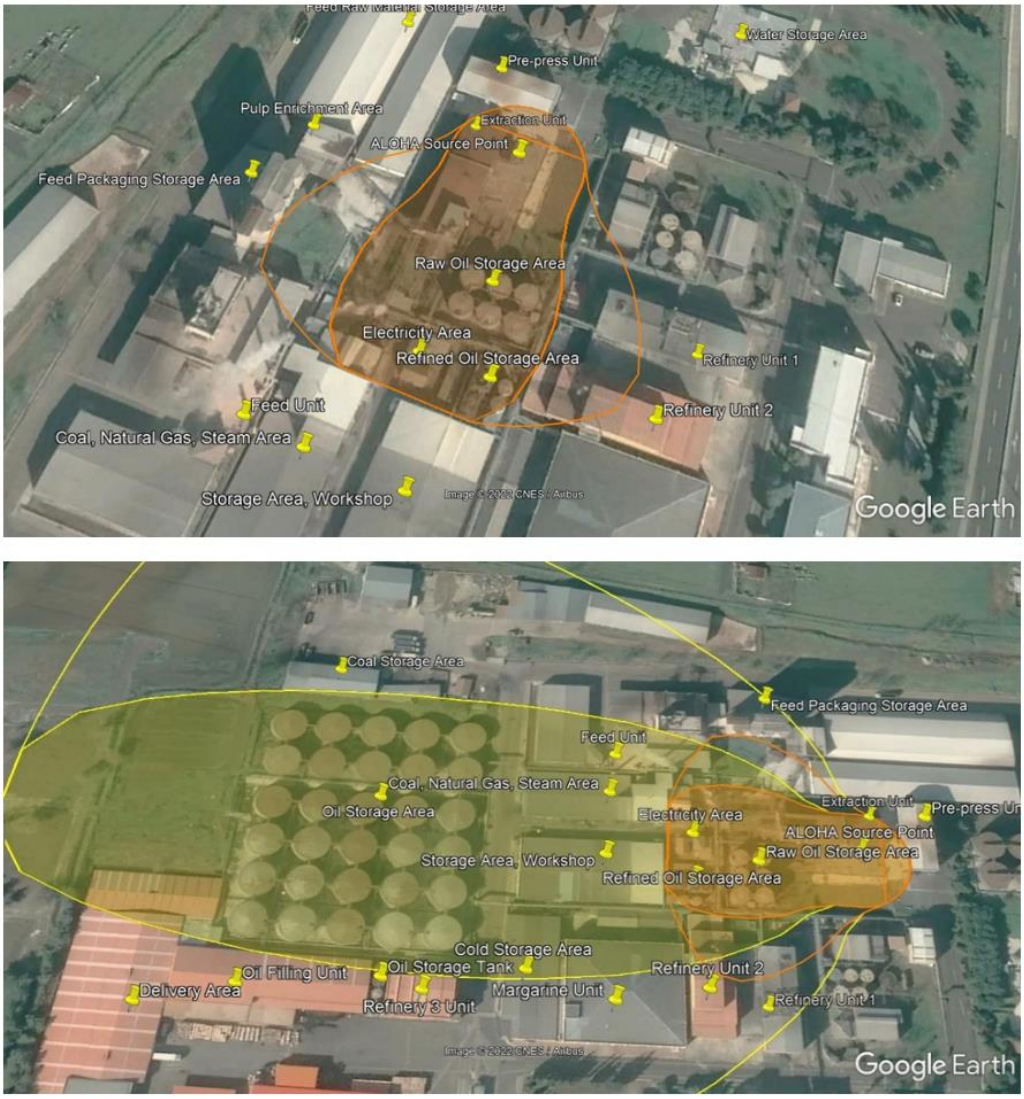


Figure 4.5. Visual representation of toxic threat zone graph with AEGL (A) and PAC (B) values for spring, respectively

Google Earth Pro (Google Earth Pro, 2022).

When the visual presentation of toxic threat zones graphs in spring season with AEGL and PAC values shown in figure 4.5. (A) and (B), respectively is analyzed, the effects area of figure 4.5. (B) are bigger than figure 4.5. (A) with AEGL. For figure 4.5. (A) with orange threat region with AEGL-2 value including vulnerable individuals and people who could be faced with undesirable, unalterable and serious health damage, and impaired capability to get away from the place, its threat region comprises extraction unit, few sides of pre-press unit, raw oil storage area, electricity area and refined oil storage area. In this scope, the numbers of people working at these areas are few because of the existence of storage areas, the dispersed gas will not affect a lot of people. Though few people located at this area, an emergency action plan should be prepared by considering impacts of AEGL-2 region on people health. During accidents, people could be access green and open areas away from the critic area. According to this factory, its assembly area for people working at the extraction unit is the area around the steel silos of sunflower oil raw material located at easily accessible open area. This shows that its location is proper for this season. In terms of figure 4.5. (B) with PAC values, when the yellow region as PAC-1 is considered, it comprises huge area as feed unit, steam producing area, storage area, cold storage area, some parts of margarine unit, and oil storage area. Since PAC-1 region includes people who could have temporal health effects during accident providing more time to move away from this yellow area, people locating at this region will have a chance to escape harmful effects of dispersed cloud during accident. Also, there are some green and open areas near the yellow region, provides easy evacuation from dangerous area. In the case of emergency, its assembly area for that region is located around the vehicle maintenance or near the weighbridge area. While two assembly areas are sufficient to cover the people in the threat area of this size supplying a safe area, they also provide an alternative with easy access to all segments. In terms of PAC-2 with orange color, its threat zone includes some units as extraction unit, raw and refined oil storage area.

As PAC-2 range involving not only people but also susceptible individuals has a higher hexane concentration than PAC-1 region, irreversible and critical health impacts on people during accident could be observed, which weakens protective measure. Therefore, people locating at these units should be evacuate immediately. Additionally, if the ventilation system of close area as an engineering solution is weak, the protective equipment protecting from hazardous chemical dispersion should be supplied for these people easy access. Moreover, red region as PAC-3 is not represented in figure.4.5. (B). Its reason is that its visualization on the map does not give reliable results due to the short distance. Additionally, since this PAC-3 area has life-threating health impacts, deaths and serious damages are vulnerable. Due to that, its outcomes should be considering especially in extraction unit and oil storage areas. People working at region should be evacuated immediately from this red region and in the case of inability to move away from there, also the protective equipment should be supplied to gain more time to escape. In terms of factory, there are limited personal protective equipment in these units. Thus, their numbers should be increased, and their trainings should be given immediately.

A)

B)

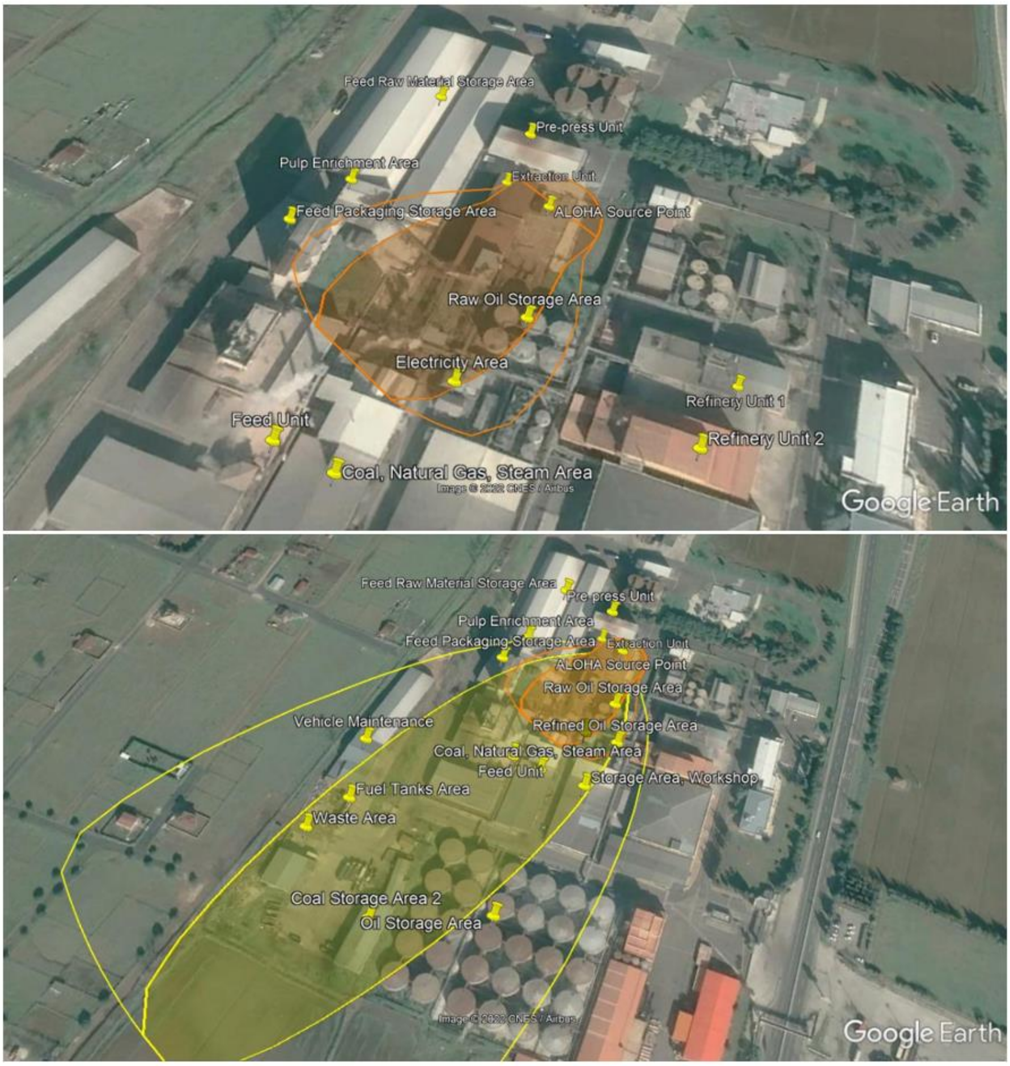


Figure 4.6. Visual representation of toxic threat zone graph with AEGL (A) and PAC (B) values for summer, respectively Google Earth Pro

(Google Earth Pro, 2022).

When visual graphs of toxic threat zones in summer shown in figure 4.6 (A) for AEGL and (B) for PAC are analyzed, the first difference between spring and summer is their affected areas. The main reason of that is wind direction. Though other parameters such as are similar As their wind directions as NNE and NE for spring and summer, respectively, there are some differences in terms of influenced units.

The domains differing from spring in terms of AEGL-2 are some parts of feed raw material storage area, pulp enrichment area, and feed unit. Because of that, people working at feed unit should be in alarm in the case of any hexane gas dispersion especially in summer. Also, as the number of people locating at feed unit is higher when compared numbers in spring, the numbers of affected people in this season are increased. Because of that and destructive impacts of orange area as AEGL-2 on human health, measurements should be taken carefully and perform a military exercise by supporting training. On the other hand, figure 4.6. (B) represents PAC values with two regions colored by orange and yellow. Also, there are not similar with summer season due to different wind direction. Their differences between spring and summer are that parts mentioned above for orange part as feed unit and feed unit, some storage areas as cool, oil and some materials, waste and fuel tank areas and vehicle maintenance area.

A) B)

Figure 4.7. Visual representation of toxic threat zone graph with AEGL (A) and PAC (B) values for autumn, respectively Google Earth Pro

(Google Earth Pro, 2022).

In terms of autumn season, its outcomes shown in figure 4.7. (A) for AEGL and (B) for PAC, respectively, each region as red, orange, and yellow is drawn on the maps when comparing autumn with summer and spring. Since the values of each threat regions for autumn is higher than summer and spring, its each areas are drawn on the maps. Its cause is atmosheric stability.

The atmospheric conditions in terms of wind speed, direction and temperature, etc. supply more stable class as E when making compasion with summer and spring as C stability class. Additionally, when comparing other seasons as spring and summer, impact area of autumn is different. For figure 4.7. (A), it has two color region as red and orange area. In terms of red region as AEGL-3, it comprises not only extraction , but also margarine silo and some parts of refinery unit. This makes increase the numbers of effected people, and gives the more undesirable outcomes in terms of death and injures. Because of that, evacuation plan and immediate action plan should be carefully planned, applied after accident. For AEGL-2 region as yellow, its affected area also is different with other units as refinery 1 and refinery 2 unit, some parts of administrative building. Also, the main reason for this differences for impact area is wind direction. Also, when wind directions of other seasons as spring and summer with NNE, NE are considered, autumn has different direction as NW. Apart from AEGL, PAC has three regions with red, orange and yellow. Its red and orange regions are similar to AEGL's red and orange regions. It has a yellow region. When the affected area for PAC-1 is analyzed, it includes administrative building, quality control and laboratory building, security area, parking area, some parts of margarine unit and road. Since the autumn has the biggest thrat zones among other seasons, proactive measurements should be increased in this season.

A)

B)

Figure 4.8. Visual representation of toxic threat zone graph with AEGL (A) and PAC (B) values for winter, respectively Google Earth Pro

(Google Earth Pro, 2022).

When winter season is considered, its ALOHA outputs shown in figure 4.8. (A) for AEGL and (B) for PAC, its impact areas include same units as autumn season due to same wind direction as NE. Though they have similar impact area, their values of threat distances have similar differences. Additionally, this area also comprises more people working at this area. Therefore, this area also should be detected and prepared in the case of accident.

Additionally, although atmospheric conditions of autumn and winter were compared in terms of humidity, wind direction, and atmospheric stability are same, their threat region distances are different, and the autumn one is bigger than winter. The main reason for that is differences as air temperature and wind speed. This provides that the higher value of wind speed and temperature cause bigger threat regions.

In summary, after analyzing all season for scenario 1 in terms of the toxic threat graphs and their visual presentations on map based on AEGL and PAC values, when two values from AEGL and PAC are compared, the obtained threat region from the hexane storage tank in autumn has the highest value among other seasons. When the results obtained from a similar study which is the benzene leakage scenario in the refining industry in Iran are compared with these results, also same results have seemed. Similarly, the predicted threat zone for this study in refining industry has the most extensive area for autumn. This shows that atmospheric conditions have critical impacts on dispersion. According to weather parameters, a gas or pollutant cloud could be dispersed, separated, or transformed by air patterns. At this point, wind velocity and atmospheric stability are critical parameters (Zhang et al., 2015). Also, according to solar radiation between heating air and ground, atmospheric stability plays significant role in mixing and turbulence movements in the atmosphere (Mao et al., 2020).

Summary, the result of this study points out that maximum and minimum range of gas cloud happens in autumn and summer. In terms of atmospheric stability in autumn and summer, it is in E and C for autumn and summer, respectively. This indicates that dispersion of a heavy gas as hexane has higher in stable atmospheric conditions than in unstable one. The reason for this is that while there is presence of slow air motion in the perpendicular axis to the ground, there is easy dispersion of pollutants in the horizontal axis to the ground (Pourbabaki et al., 2018). Thus, existence of stability in autumn causes rise of separation of hexane toxic vapor cloud.

Apart from stability, wind speed is significant factor while drawing figures. If the wind speed is low, dispersion of gas cloud could not be sure which patter it should follow. Because of that, while the dashed lines on figures are close each other for high wind velocity, the distances between dash lines are increased for low wind velocity. In this study, the highest wind speed is observed in summer and its distances between dash lines are the biggest among dash lines of other figures. On the other hand, spring season has the lowest value for wind velocity, and its dash lines are seemed as a pie with big radius. This big area between dash lines indicates that wind could move the cloud in any direction (U.S. EPA and NOAA., 2007).

In terms of wind parameters, wind direction has an importance on dispersion of hexane toxic vapor cloud (Hassoon et al., 2019). In this study, the wind direction of the region in spring, summer, autumn and winter was NNE, NE, NW and NW, respectively. As these direction of the wind affects directions of gas dispersion, this also impresses whether the public living around the factory is affected or not.

When inputs of ALOHA for scenario 1 with the toxic threat regions, by depending on the season, different parts and units of factory are affected by toxic cloud. Generally, the red threat zones include extraction unit, pre-press unit, some parts of oil silos, refinery units and feed silos. Because of that, when considering these close regions around the hexane storage tanks, these areas should be prepared in the case of any leakage scenarios in terms of toxicity. Some emergency action plan should be prepared to identify evacuation plan, supply protective equipment, and train people working in this region.

4.1.2 The Flammable Threats Graphs for First Scenario

Flammable threat zone graph with Lower Explosive Limit (LEL) defined as minimum amount of gas or vapor of hazardous chemical to create fire when the necessary conditions such as spark, ignition source are met of first scenario is obtained from ALOHA software shown on figure 4.9. (Barjoee et al., 2021). For the first scenario, other outcomes for the hexane vapor cloud represents that total threat orbits of hexane flammable vapor cloud are smaller than the toxic vapor cloud. According to results shown in table 4.3., the threat zones of it is divided into two regions as red and yellow. In terms of red region with 60 % LEL exposing more than 7200 ppm concentration, it is separated to 45, 45, 66 and 50 m from the storage tank in spring, summer, autumn, and winter, respectively. On the other side, yellow area with 10 % LEL exposing more than 1200 ppm concentration, it is dispersed to 157, 154, 206 and 174 m from the hexane storage tank in spring, summer, autumn, and winter, respectively. These outcomes show that the most dispersion of flammable hexane vapor happened in autumn like the toxic threat graphs.

Table 4.3 Results of scenario 1 for flammable threat zones based in terms of seasons

	Flammable Threat Zone		
Season	*Threat Zones*	*Value (ppm)*	*Distance (m)*
	60 % LEL	>7.200 (Red)	45
Spring	10 % LEL	>1200 (Yellow)	157
	60 % LEL	>7.200 (Red)	45
Summer	10 % LEL	>1200 (Yellow)	154
	60 % LEL	>7.200 (Red)	66
Autumn	10 % LEL	>1200 (Yellow)	206
	60 % LEL	>7.200 (Red)	50
Winter	10 % LEL	>1200 (Yellow)	174

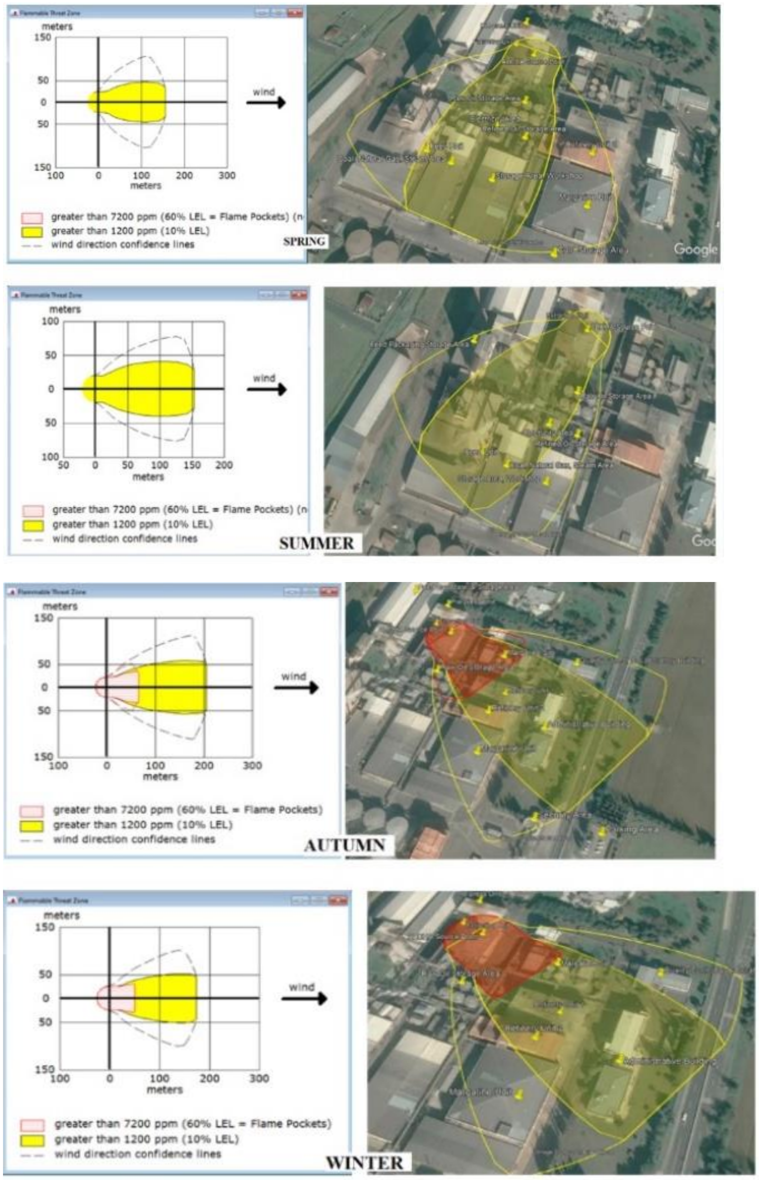


Figure 4.9. Graphical and visual representation of flammable threat zone for each season as spring, autumn, summer, and winter

(ALOHA software and Google Earth Pro, 2022).

When the figure 4.9. related with ALOHA outputs in terms of flammable threat and visual presentation on map is analyzed, it shows that the wind directions have effects on impact area. Additionally, threat areas are shaped by wind direction for other all seasons. As due to the existence of same wind direction in autumn and winter, their effected areas are same. Moreover, wind speed influences radius of dashed lines shown in the graphs. As the wind speed is increased, its size expands. Due to that, summer has the widest dash radius by comparing other seasons. Moreover, since autumn has the highest atmospheric stability among other seasons and higher wind speed than winter, its threat zones have the largest size.

When LEL limit of n-hexane is 11000 ppm, greater than 12000 ppm level creates a threat for fire. Also, 10 % LEL means that required measurements should be taken in these regions to prevent fire in the case of hexane dispersion in these regions. At that point, when the representations of each season are examined in figure 4.9., generally, yellow region comprises different areas of sunflower oil factory such as extraction unit, some storage areas as coal, refined oil, natural gas, equipment and silos, some areas of feed unit, administrative building and quality control and laboratory units. In terms of red region, extraction unit, and some parts of refinery units are the most dangerous region. Therefore, since 60 % LEL means that extreme safety conditions should be considered in this region immediately to hinder any fire or explosion risks (CAMEO Chemicals, 2022). Because of those reasons, any source of ignition and flammable substances is searched and evaluated to make a risk assessment plan. By this way, formation of fire or explosion could be hindered in the case of chemical flammable leakage, which evaluated as proactive approach. Apart from them, based on the outcomes of ALOHA for this scenario, the orbit of flammable vapor cloud is in the only private space of factory, and no threat areas are estimated in the public area. However, as there are closer unit each other near the storage tank, an ignition source causes the big damage.

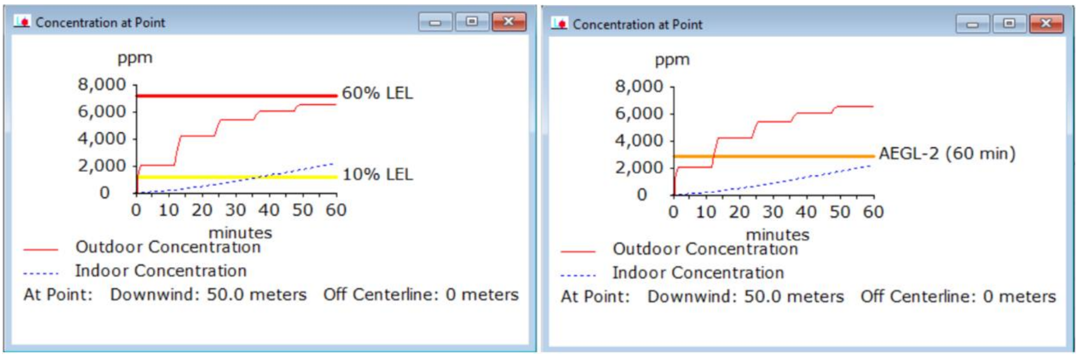


Figure 4.10. The values of exposure to hexane (B) and flammable vapor cloud (A) as a function of time in feed unit for spring

(ALOHA software,2022)

After examination of the two different types of graphs as toxic and flammable threat zones, they provide that the exposure values to hexane toxic and flammable gas cloud are a function of time in feed unit shown in figure 4.10. When affected areas for spring are considered, the greatest number of people impacted by toxic and flammable gas vapor during accident is located at feed unit and its around. Due to that reason, the coordination of this area is entered in ALOHA software and figure 4.10. for spring is obtained for this critical region. The diagram (B) reflects the concentration of the hexane toxic vapor cloud. The concentration of the hexane indoor and outdoor the feed unit are shown by dashed and stepped lines into these diagrams.

The results represented that while the hexane concentration into vapor cloud will not exceed AEGL-2 standard indoor, it will be higher than the AEGL-2 standard after 12 minutes from the start of the accident. On the other side, the outcomes of hexane concentration into flammable vapor cloud are shown in the diagram (A). While its concentration into dispersed gas cloud indoor 35 minutes after the starting point of accident exceeds the 10 % LEL norms, it does not exceed the standard 60 % LEL.

In terms of outdoor concentration, while its concentration is reached the standard level 10 % LEL, it does not reach 60 % LEL level. These values show that while making emergency action plan for threats, people should be located outside after 12 minutes not to be affected by hexane toxicity. Additionally, any ignition sources should be banned or hindered due to existence of 10 % LEL standard.

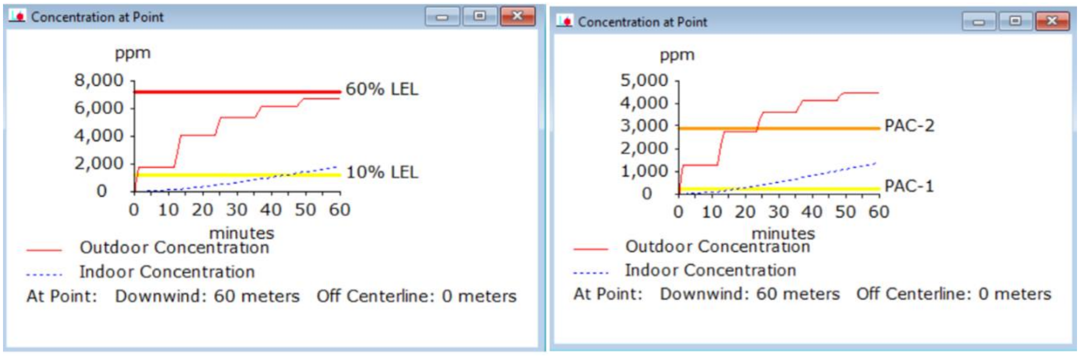


Figure 4.11. The values of exposure to hexane (B) and flammable vapor cloud (A) as a function of time in refinery unit for autumn.

(ALOHA software,2022)

After examination of the two different types of graphs as toxic and flammable threat zones, they provide that the exposure values to hexane toxic and flammable gas cloud are a function of time in refinery unit shown in figure 4.11. When affected areas for autumn are considered, the greatest number of people impacted by toxic and flammable gas vapor during accident is located at refinery unit and its around. Due to that reason, the coordination of this area is entered in ALOHA software and figure 4.11. for autumn is obtained for this critical region. The diagram (B) reflects the concentration of the hexane toxic vapor cloud. The concentration of the hexane indoor and outdoor the refinery unit are shown by dashed and stepped lines into these diagrams.

The results represented that while the hexane concentration into vapor cloud will be exceed AEGL-1 represented by PAC-1 standard after 11 minutes from the start of accident as indoor, it will not access the AEGL-2 standard presented as PAC-2 on figure 4.11 indoor. In terms of outdoor concentration, its concentration reaches PAC-1 standard at the beginning of accident and reach PAC-2 after 25 minutes after accident occurs. On the other side, the outcomes of hexane concentration into flammable vapor cloud are shown in the diagram (A). While its concentration into dispersed gas cloud indoor 37 minutes after the starting point of accident exceeds the 10 % LEL norms, it does not exceed the standard 60 % LEL. In terms of outdoor concentration, while its concentration is reached the standard level 10 % LEL after few minutes of accident, it does not reach 60 % LEL level. These values show that while making emergency action plan for threats, people should be located outside after 11 minutes not to be affected by hexane toxicity. Additionally, any ignition sources should be banned or hindered due to existence of 10 % LEL standard.

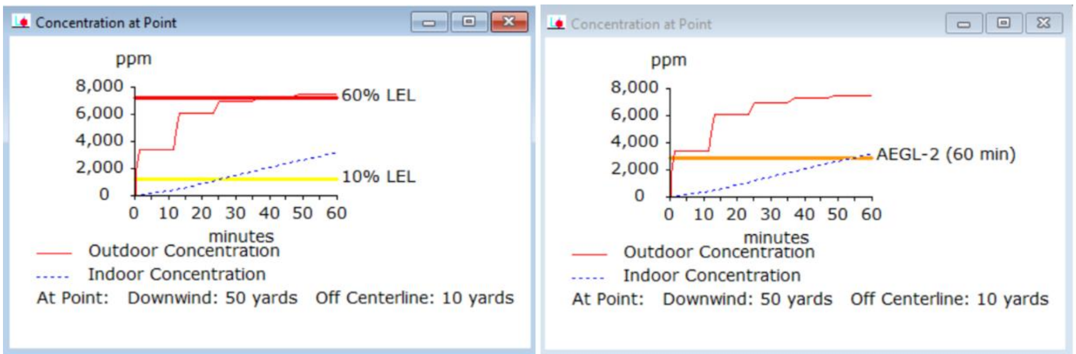


Figure 4.12. The values of exposure to hexane (B) and flammable vapor cloud (A) as a function of time in feed unit for summer.

(ALOHA software,2022)

After examination of the two different types of graphs as toxic and flammable threat zones, they provide that the exposure values to hexane toxic and flammable gas cloud are a function of time in feed unit shown in figure 4.12. When affected areas for summer are considered, the greatest number of people impacted by toxic and flammable gas vapor during accident is located at feed unit and its around. Due to that reason, the coordination of this area is entered in ALOHA software and figure 4.12 for summer is obtained for this critical region. The diagram (B) reflects the concentration of the hexane toxic vapor cloud.

The concentration of the hexane indoor and outdoor the feed unit are shown by dashed and stepped lines into these diagrams. The results represented that while the hexane concentration into vapor cloud will be exceed AEGL-2 standard after 50 minutes from the start of accident as indoor. Based on outdoor concentration, its concentration reaches AEGL-2 standard at the beginning of accident. On the other side, the outcomes of hexane concentration into flammable vapor cloud are shown in the diagram (A). While its concentration into dispersed gas cloud indoor 20 minutes after the starting point of accident exceeds the 10 % LEL norms, it does not exceed the standard 60 % LEL. In terms of outdoor concentration, while its concentration is reached the standard level 10 % LEL after few minutes of accident, it will reach 60 % LEL level after 55 minutes when accident occur. These values show that while making emergency action plan for threats, people should be located outside after 20 minutes not to be affected by hexane toxicity. Additionally, any ignition sources should be banned or hindered due to existence of 10 % LEL standard. Also, these results indicate that people have more time than other seasons to evacuate indoor in summer.

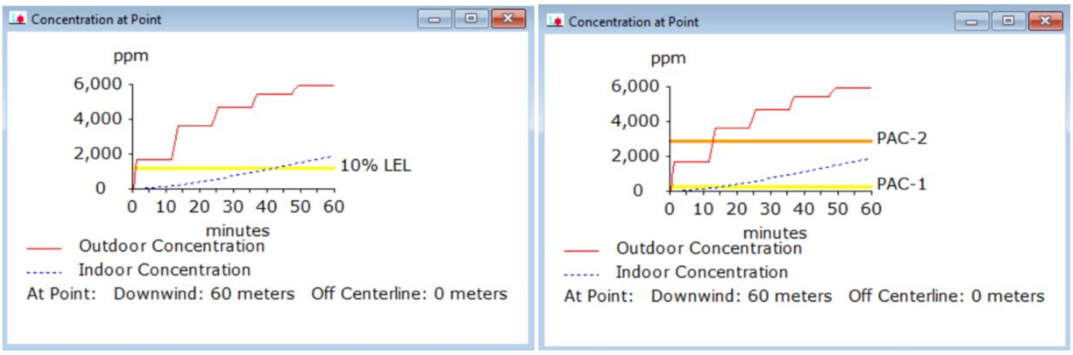


Figure 4.13. The values of exposure to hexane (B) and flammable vapor cloud (A) as a function of time in refinery unit for winter

(ALOHA software,2022)

After examination of the two different types of graphs as toxic and flammable threat zones, they provide that the exposure values to hexane toxic and flammable gas cloud are a function of time in refinery unit shown in figure 4.13. When affected areas for winter are considered, the greatest number of people impacted by toxic and flammable gas vapor during accident is located at refinery unit and its around. Due to that reason, the coordination of this area is entered in ALOHA software and figure 4.13 for winter is obtained for this critical region. The diagram (B) reflects the concentration of the hexane toxic vapor cloud. The concentration of the hexane indoor and outdoor the refinery unit are shown by dashed and stepped lines into these diagrams.

The results represented that while the hexane concentration into vapor cloud will not exceed AEGL-2 represented as PAC-2 standard, it will exceed AEGL-1 represented as PAC-1 after few minutes from the start of accident as indoor. Based on outdoor concentration, its concentration reaches AEGL-2 standard after 12 minutes from the starting of accident. On the other side, the outcomes of hexane concentration into flammable vapor cloud are shown in the diagram (A).

While its concentration into dispersed gas cloud indoor 20 minutes after the starting point of accident exceeds the 10 % LEL norms, it does not exceed the standard 60 % LEL. In terms of outdoor concentration, while its concentration is reached the standard level 10 % LEL after 37 minutes when accident occur. These values show that while making emergency action plan for threats, people in yellow region should be located outside immediately not to be affected by hexane toxicity. Additionally, any ignition sources should be banned or hindered due to existence of 10 % LEL standard after 37 minutes. Also, these results indicate that people have more time than other seasons for flammable toxin cloud in winter.

4.1.3 The Overpressure Threat Graphs for First Scenario

Overpressure threat zone graphs demonstrated on figure 4.14. for each season have two regions with orange and yellow colors. In this case, this graph would make sense in the presence of rapid change on pressure after gas cloud explosion under first scenario conditions.

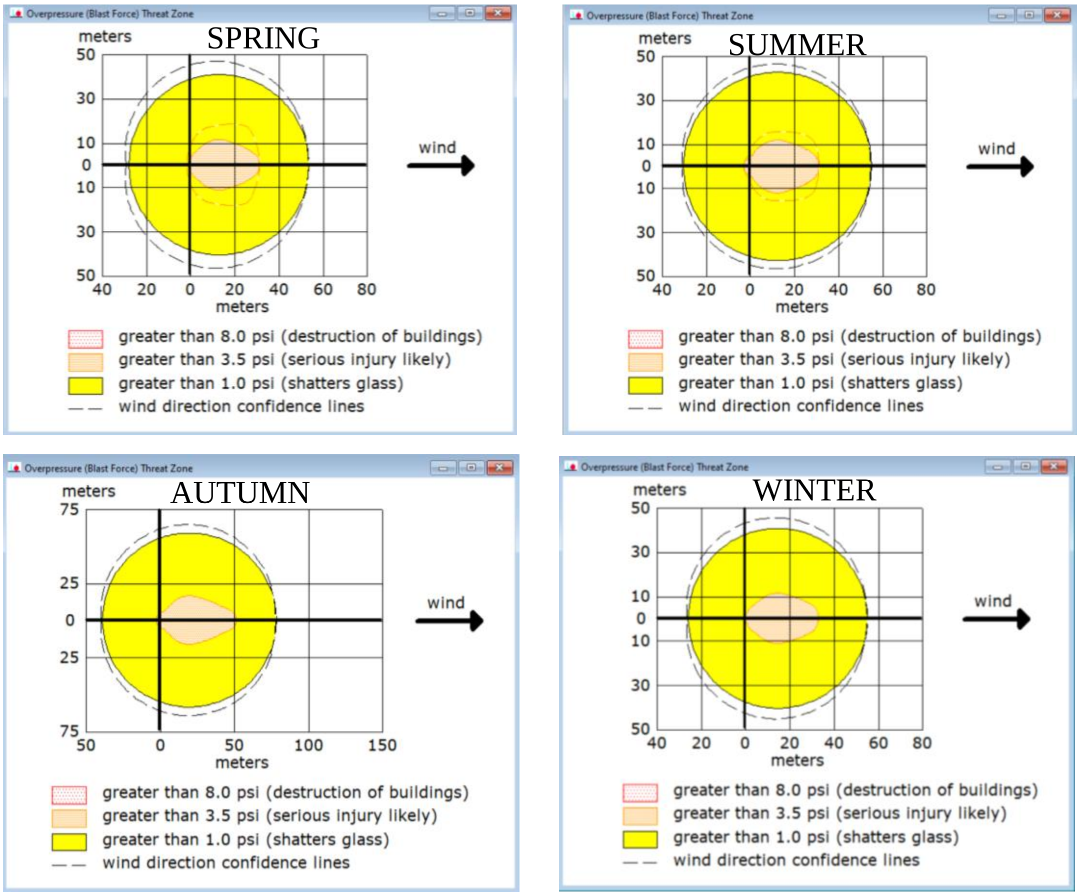


Figure 4.14. Graphical representation of overpressure threat zones for each season (ALOHA software, 2022).

When table 4.4. which are the results of each threat zones as orange and yellow is examined, the autumn season has the hugest area among other seasons. In terms of orange region with greater than 8.0 psi (55.6 kPa) which is 32, 32, 52 and 33 m in spring, summer, autumn, and winter, respectively, this region causes serious injuries. If the blast wave pressure is less than 1.0 psi (6.9 kPa), yellow region is drawn as 54, 55, 79, and 55m in spring, summer, autumn, and winter, respectively from the tank and results with breaking glass.

Table 4.4 Results of scenario 1 for overpressure threat zones based in terms of seasons

	Overpressure (Blast Force) Threat Zone		
Season	*Threat Zones (psi)*		*Distance (m)*
	>8.0 psi	Red	-
Spring	>3.5 psi	Orange	32
	>1.0 psi	Yellow	54
	>8.0 psi	Red	-
Summer	>3.5 psi	Orange	32
	>1.0 psi	Yellow	55
	>8.0 psi	Red	-
Autumn	>3.5 psi	Orange	52
	>1.0 psi	Yellow	79
	>8.0 psi	Red	-
Winter	>3.5 psi	Orange	33
	>1.0 psi	Yellow	55

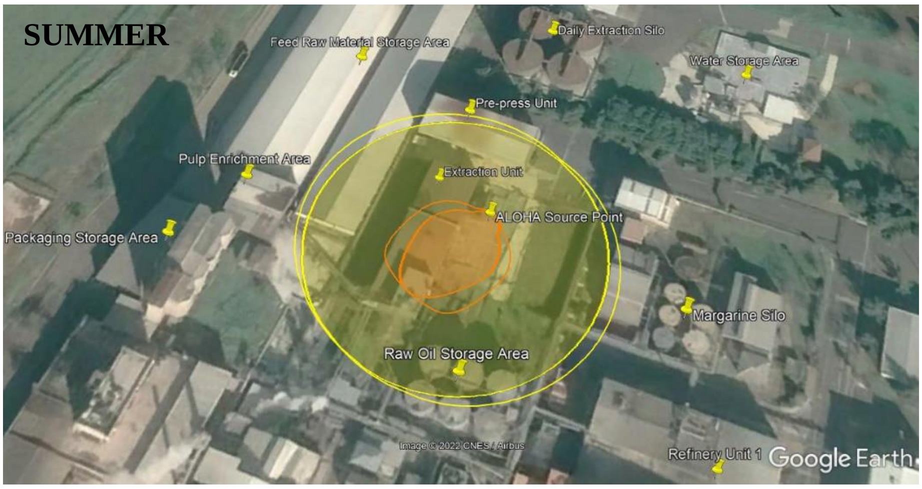


Figure 4.15. Visual representation of overpressure threat zone for spring and summer (Google Earth Pro, 2022).

When visual presentation of this graphs shown in figure 4.15. are detected, the effected regions for summer and spring are same. Therefore, there could be serious injuries in extraction unit due to excessive wave pressure. Also, there are some damages such as glass shattering in yellow parts where are extraction unit, some part of pre-press unit, raw oil storage area, raw feed material storage area, some parts of pulp enrichment area and feed unit of both seasons. Since these units include a lot of materials and machines affecting from overpressure loading, it leads serious injures due to breaking and separation of them.

According to figure 4.16. autumn has more larger area than winter in terms of orange and yellow color. While autum includes extraction unit, margarine silo, some parts of refinery units, refined oil storage area and elecricity area, winter comprises extraction unit, some parts of raw oil storage area and margarine silo. This indicates that when electricity area is damaged, fire could be formed and more damaged results could be observed.

Figure 4.16. Visual representation of overpressure threat zone for autumn and winter (Google Earth Pro, 2022).

As a result, first scenario is related with gas dispersion of hexane from opening area at the bottom of its storage tank under mentioned conditions without burning for each season as spring, summer, autumn and winter. By using ALOHA software, four graphs based on toxin threat zones in terms of AEGL and PAC values, flammable threat zones and overpressure threat and their visual presentations on Google Earth Pro application, and the diagrams with the values of exposure to hexane and flammable vapor cloud as a function of time in feed and refinery units for each season are highlighted and possible results are evaluated based on threat zones in terms of building, people, and environment. After obtaining and examination of results, atmospheric conditions have strong impact for formation and size of threat areas.

Atmospheric stability has a critical relation with threat region. If the atmospheric conditions are classified as more stable class, this makes zones of threat region increase. Wind speed and cloud cover have great impact to decide atmospheric stability. If the wind speed increases, also the radius of threat region raises. Apart from them, wind directions decide affected area during accident. If the accidents are occurred under same meteorological conditions, the affected areas are different due to different wind direction from source of the accident. After these outcomes, this scenario could be used for proactive approach to avoid accident. Also, it could be used reactive approach in the case of accident to evacuate people to safe places to make minimize the destructive effects of hazardous chemical hexane dispersion. Summerly, the autumn season has the highest impact areas among other seasons due to high atmospheric stability class determined by wind speed, wind direction, temperature, humidity, etc.

4.2 Second Scenario: Hexane leaks from storage tank by forming a pool fire with chemical burning

In the second scenario, hexane accumulation after leakage of hexane from bottom of the storage tank with 10 cm diameter opening circular area forms a hexane pool. This puddle of hexane causes burning, knowing as pool fire. On the contrary to first scenario, there are chemical burning in this scenario. Because of that, only one type graphs related with thermal radiation is obtained. After entering essential input on the ALOHA software by considering different weather conditions for spring, summer, autumn and winter, it gives these graphs to identify thermal radiation threat zones for pool fire with chemical burning. These graphs based on spring, summer, autumn and winter shown on figure 4.17. gives thermal radiation level of concern (LOC) associated with a threat level by evaluation of dangerous zone related with pool fire.

Table 4.5 Results of scenario 2 for thermal radiation threat zones based on seasons

	Thermal Radiation Threat Zone		
Season	*Threat Zones*	*(kW/(sq m)*	*Distance (m)*
	>10.0	Red	55
Spring	>5.0	Orange	79
	>2.0	Yellow	124
	>10.0	Red	53
Summer	>5.0	Orange	76
	>2.0	Yellow	120
	>10.0	Red	53
Autumn	>5.0	Orange	77
	>2.0	Yellow	122
	>10.0	Red	56
Winter	>5.0	Orange	80
	>2.0	Yellow	125

The results taken from the graphs are that there are three regions with yellow, orange, and red colors, represented in table 4.5. According to this table, the distances of yellow color with greater than 2.0 kW/ (sq m) are 124, 120, 122, and 125 m for spring, summer, autumn, and winter, respectively.

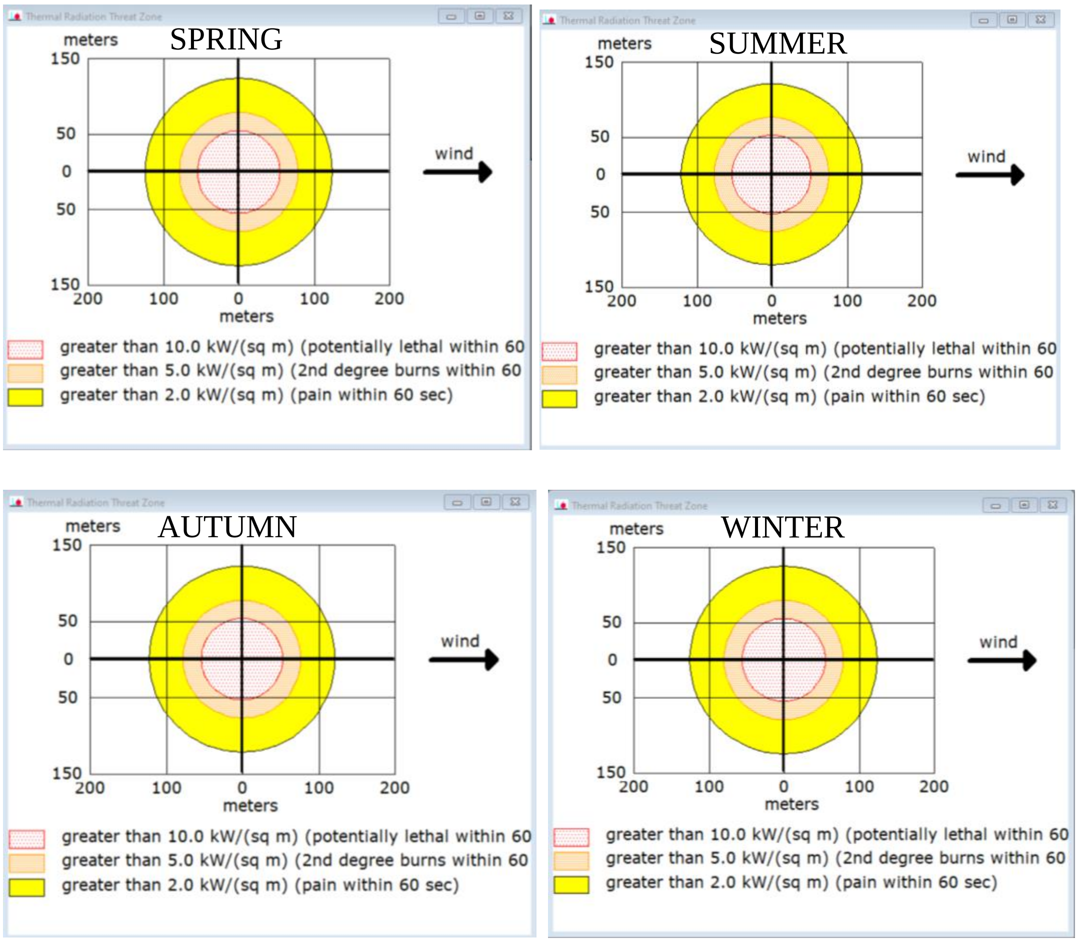


Figure 4.17. Graphical representation of thermal radiation threat zones for each season (ALOHA software, 2022).

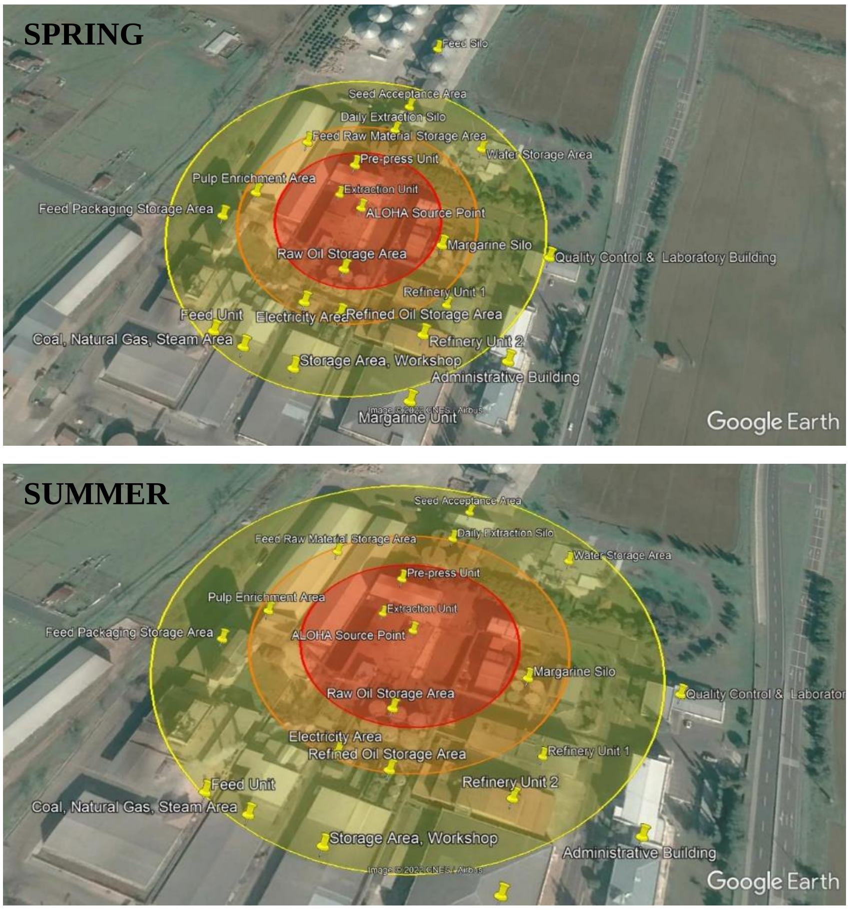


Figure 4.18. Visual representation of thermal radiation threat zone for spring and summer (Google Earth Pro, 2022).

In yellow region represented on map shown in figure 4.18 and 4.19, there is only pain within 60 seconds in this yellow threat region. However, the exposure time durations are increased as longer than one minute even at this yellow region, the serious impacts of it on people increases, and resulted with undesirable physiological outcomes (NOAA, 2022). Because of that, people within 60 seconds should reach safe shelter to protect themselves. When the visual representations of them for each season are analyzed, this threat zones comprises seed acceptance area, water storage area, some parts of refinery unit, some storage areas, steam areas, some parts of feed unit.

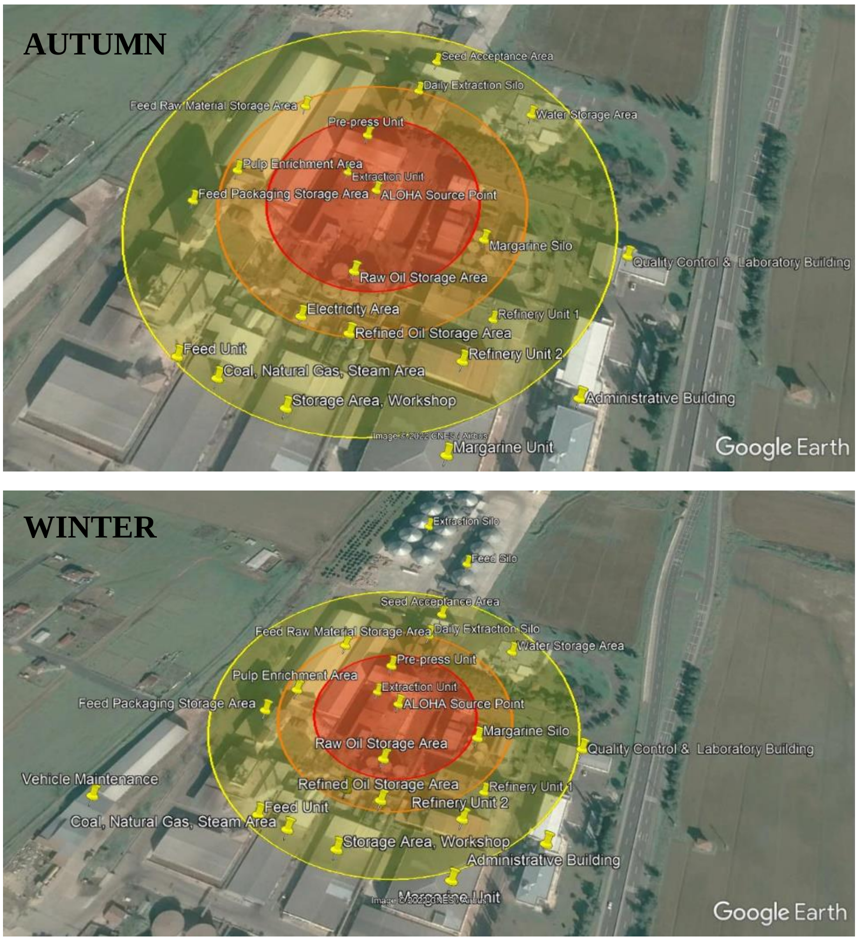


Figure 4.19. Visual representation of thermal radiation threat zone for autumn and winter (Google Earth Pro, 2022).

In terms of orange threat region with 5 kW/ (sq m), its area size is 79. 76. 77, and 80 m for spring, summer, autumn and winter. According to NOAA in 2022, severity of exposing of thermal radiation is higher than yellow one in this area. In terms of human health, second-degree burns within 60 seconds would be observed on people locating at this region in the accident. Because of that, according to visual presentation on map shown in figure 4.18 and 4.19 people working and locating at pulp enrichment area, electricity area, margarine silo, refined oil storage area, and daily extraction silo should be evacuated from this area.

The most dangerous threat area is red region with greater than 10.0 kW/ (sq m). Lethal outcomes would be seen in red threat region distance, which is 55, 55, 53, and 56m for spring, summer, autumn and winter, respectively. If the visual presentation of this graph on the google map shown in figure 4.18 and 4.19 is analyzed, the area that will be most affected by possible fire is extraction unit. Also, individuals working on extraction unit and pre-press would have fatal results due to existence of red threat zones in these units.

As a result, pool fire of hexane from hexane puddle in the case of ignition source causes thermal radiation. This pool fire impacts not only buildings but also people. Its effects are varied based on thermal radiation values and their threat zones. When moving from yellow to red threat region for each season whose threat zone values are summarized on table 4,.5., lethal cases increase. Also, not only threat zones levels but also duration time while exposure of thermal radiation is significant to minimize severity. In terms of sunflower oil factory, extraction unit is located at the critical region. Moreover, when the seasons are compared, they have similar values in terms of threat zones. This explains that the differences in atmospheric conditions are not critical parameter for size of threat zones.

4.3 Third Scenario: Hexane storage tank explodes with chemical burning in a fireball (BLEVE)

In third case, when temperature of the pressurized hexane inside the storage tank is higher than boiling point of hexane, BLEVE type of explosion occurs due to easy flammable property of hexane. If the hexane is flammable, the fire would be formed. However, only heat is not sufficient to form BLEVE. When existence of combustible vapor mixing with air in the presence of ignition source causes heating of tank, pressurized vapor inside the tank explodes due to rupture of tank.

For this case, there are two situations that percentage of mass in the fireball is assumed as 100% and 50% will be analyzed and compared respectively. Percentage of the mass in the fireball is an input of ALOHA software. For BLEVE type of simulations, this input is compulsory to get threat zone. Additionally, this parameter effects the size of threat zones, meaning if this value increases, the area of threat zones also expanded. Therefore, different values of it are detected and compared to analyze its effect in this scenario by changing atmospheric conditions as spring, summer, autumn, and winter.

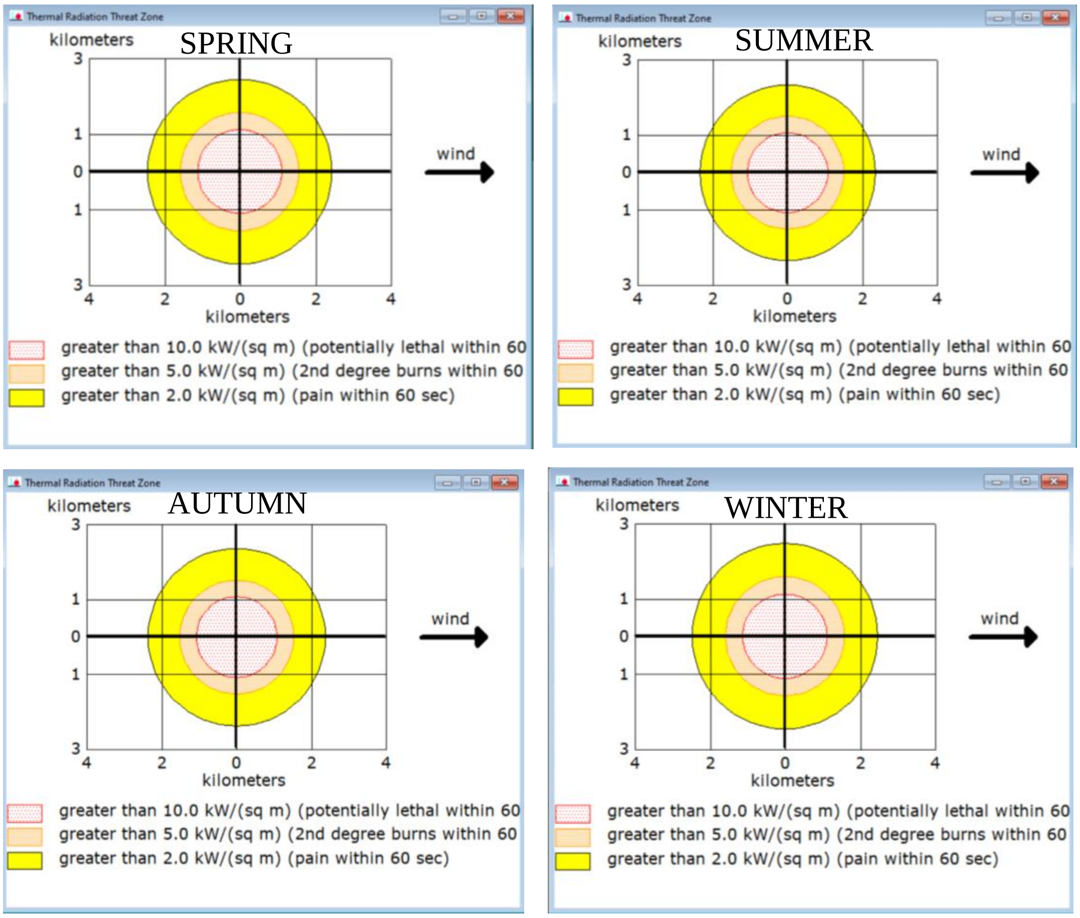


Figure 4.20. Graphical representation of thermal radiation threat zones with 100 % percentage of mass in the fireball for each season (ALOHA software, 2022).

Firstly, when this value is taken as 100 %, the graph of thermal radiation threat zone is gained and exhibited on figure 4.20. with three threat zones which are red, orange, and yellow colors for each season. Also, their exact values are shown in table 4.6. The yellow region with greater than 2.0 kW/ (sq m) is 2.4, 2.3, 2.4 and 2.5 km for spring, summer, autumn, and winter, respectively. In this region visualized on map shown in figure 4.21 for spring and summer, also in figure 4.22 for autumn and winter, this yellow region includes both people locating at factory and public.

According to its destructive results mentioned in scenario II, it impacts not only people health but also properties. In terms of properties locating in this region, there would be damage of them and producing of building debris and shattered glass. In terms of human, these kinds of dangerous particles could be injuries and deaths in the presence of constructional damage.

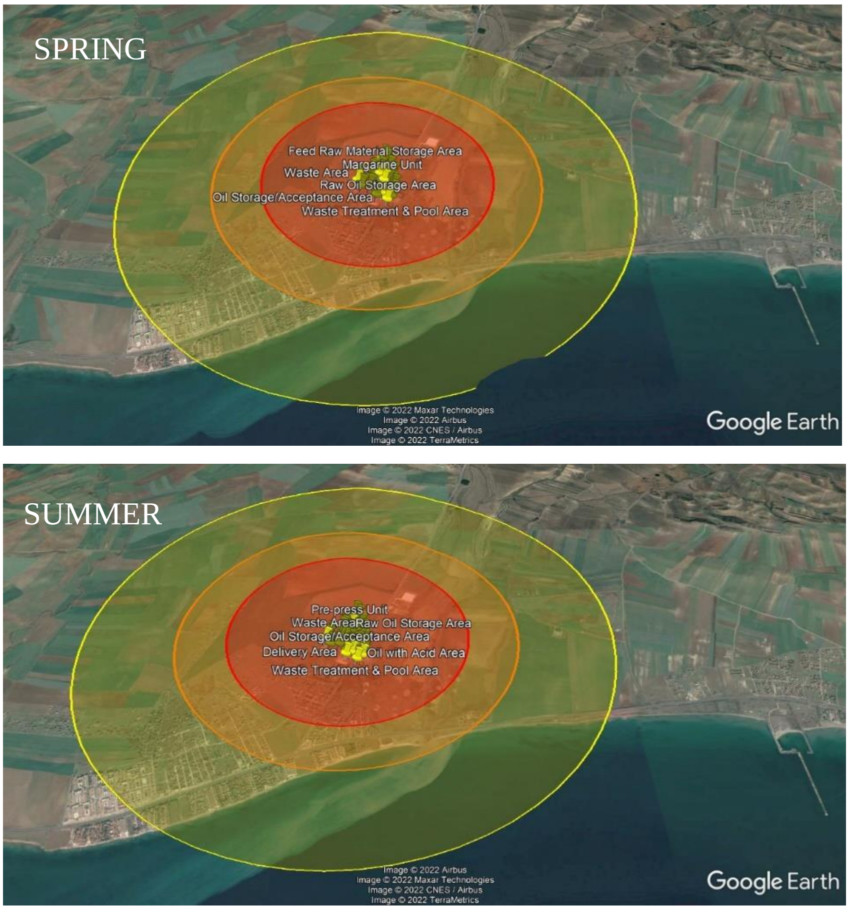
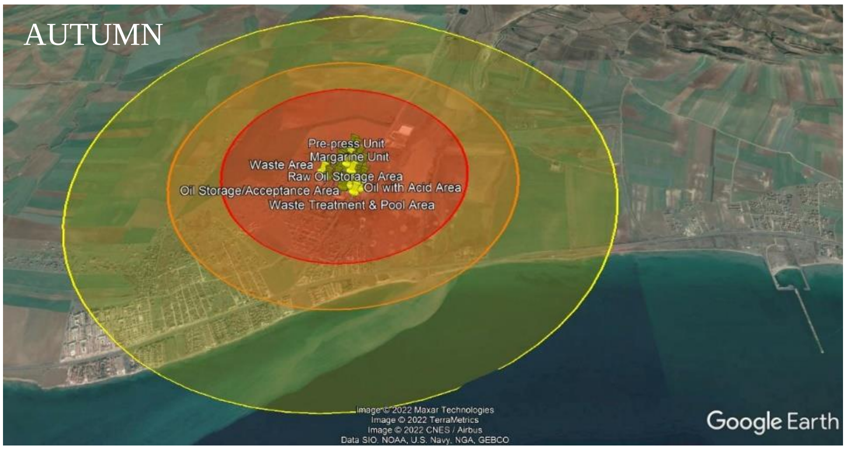


Figure 4.21. Visual representation of thermal radiation threat zone for spring and summer with 100 % percentage of mass in the fireball on Google Earth Pro (Google Earth Pro, 2022).



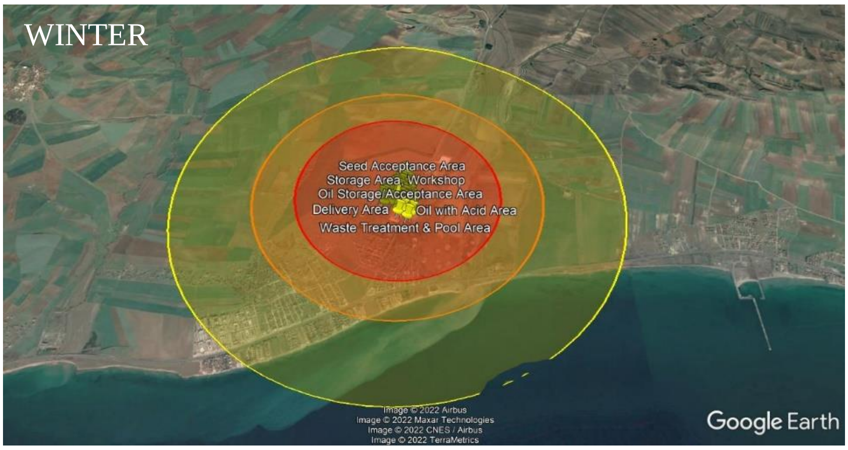


Figure 4.22. Visual representation of thermal radiation threat zone for autumn and winter with 100 % percentage of mass in the fireball on Google Earth Pro (Google Earth Pro, 2022).

Apart from that, the distance of thermal radiation for orange region with greater than 5.0 kW/ (sq m) is 1.6, 1.5, 1.5, and 1.6 km for spring, summer, autumn and winter, respectively. Orange threat zones also impacts public around the factory represented in figure 4.21 and 4.22. Based on its damaging results mentioned in scenario 2, this explosion causes demolishes buildings partially or totally, and some vehicles overturns loaded vehicles. By this way, people could be injured or death inside properties and vehicles.

On the other side as health, second degree burning is observed in this area. Finally, death and fatal outcomes are seen in the distance of red zone which is from storage tank to 1.1 km for all seasons with greater than 10 kW/ (sq m) within 60 s. When the threat zones are visualized on the map represented in figure 4.21 and 4.22, red zone also has huge region comprising not only factory area but also living spaces. This shows that all individuals living around the factory and working at the factory impact these fatal outcomes of BLEVE. In red region includes all parts of the factory and some parts of the public. Also, rapid pressure wave in red region causes direct blast effects on population (NOAA, 2022). Because of that, at this point the most critical point is that accidents should be prevented by using proactive approach to avoid these undesirable outcomes.

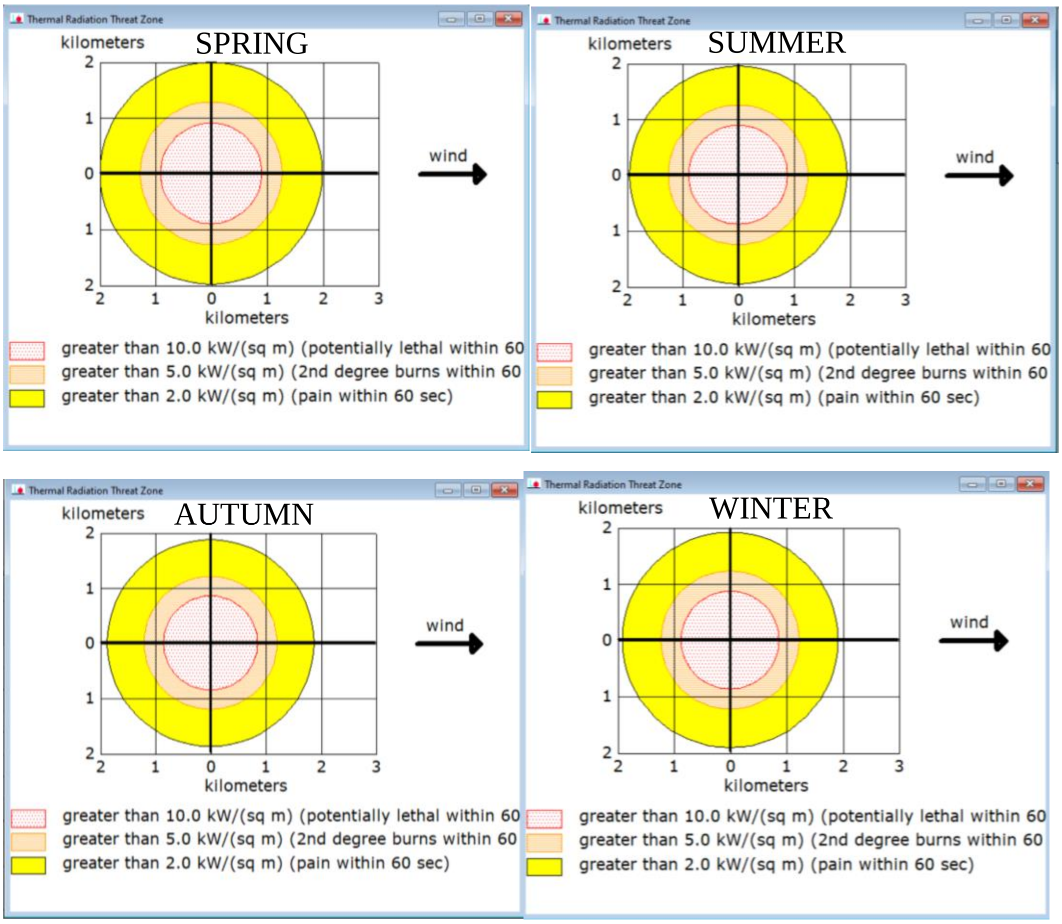


Figure 4.23. Graphical representation of thermal radiation threat zones with 50 % percentage of mass in the fireball for each season (ALOHA software, 2022).

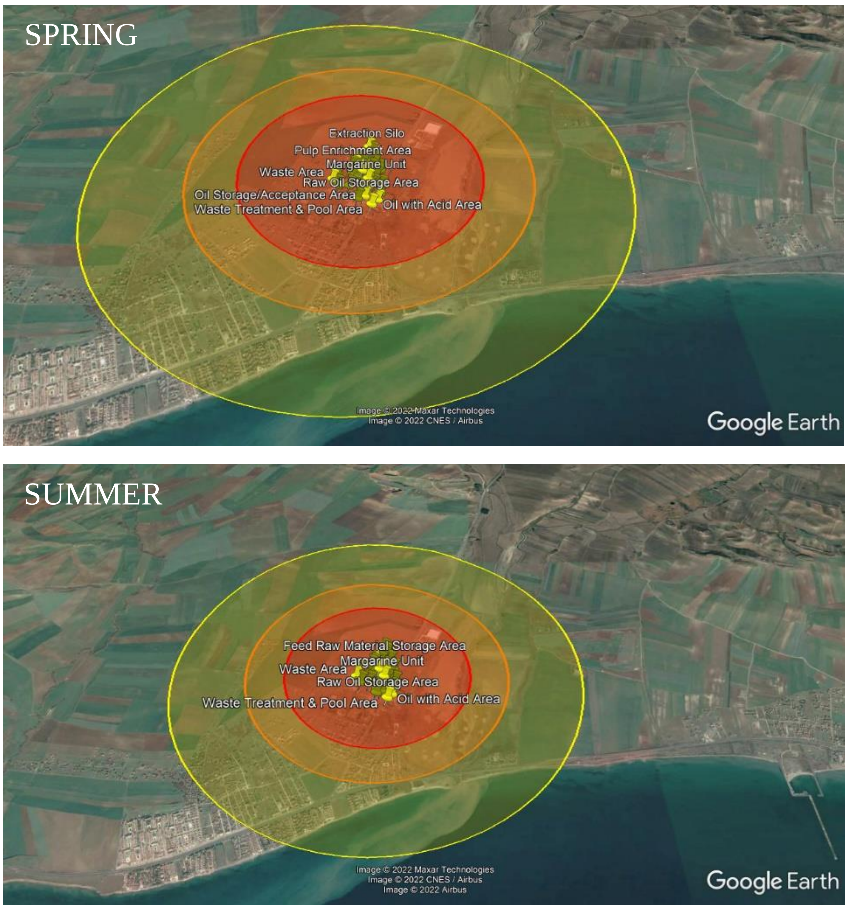


Figure 4.24. Visual representation of thermal radiation threat zone for spring and summer with 50 % percentage of mass in the fireball on Google Earth Pro (Google Earth Pro, 2022).

Secondly, percentage of mass in the fireball is assumed as 50% and analyzed to compare their results for each season. After entering this value, the outputs of threat zones shown in figure 4.23 which are red, orange, and yellow colors are 889 m, 1.3 km, and 2.0 km, respectively for spring. While these values are 885 m, 1.2 km and 1.9 km, respectively for summer, they are 866m, 1.2 km, and 1.9 km, respectively for autumn. Finally, threat areas as red, orange, and yellow colors are 901 m, 1.3 km, and 2.0 km, respectively for winter.

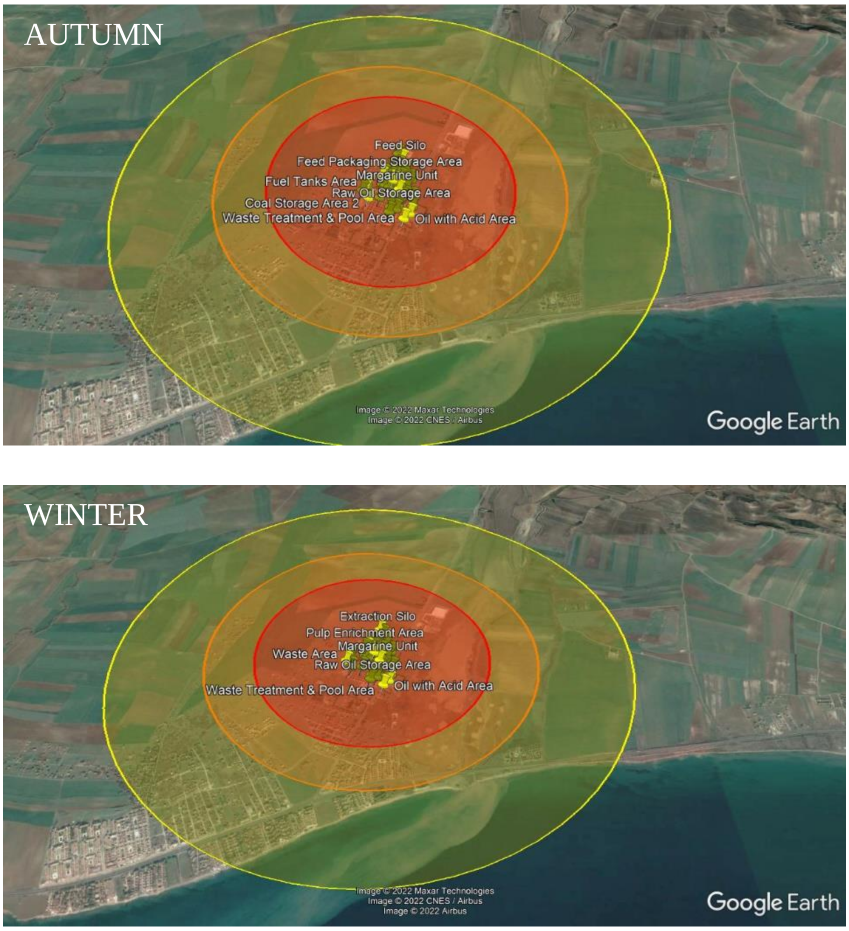


Figure 4.25. Visual representation of thermal radiation threat zone for autumn and winter with 50 % percentage of mass in the fireball on Google Earth Pro (Google Earth Pro, 2022).

When its affected areas shown in figure 4.24 and 4.25 with 50 % percentage of mass in the fireball are analyzed; though its distances are less than other with100 % percentage of mass in the fireball, they have similar impact areas. Like first input in this third scenario, it also forms a threat for not only people working on factory but also public living around the factory. Since this would convert a danger by growing population day by day and should be taken into account while design of city planning.

Moreover, when the threat zones of two inputs which are 100 and 500 % percentage of mass in the fireball are compared, the fist input as 100 % percentage of mass in the fireball has higher values than other, which obtaining in table 4.6. This emphasizes that when the percentage level of mass in the fireball increases, the threat zones also increase regardless of seasonal differences. Additionally, when table 4.6. is examined, it provides that thermal radiation threat zones are independent from season differences. For each season, they have similar and same numbers.

Table 4.6 Results of scenario 3 for overpressure threat zones based seasons

Thermal Radiation Threat Zone				
Season	*Threat Zones (kW/(sq m)*		*Distance (km) for 100 %*	*Distance (km) for 50 %*
Spring	>10.0	Red	1.1	0.889
	>5.0	Orange	1.6	1.3
	>2.0	Yellow	2.4	2.0
Summer	>10.0	Red	1.1	0.885
	>5.0	Orange	1.5	1.2
	>2.0	Yellow	2.3	1.9
Autumn	>10.0	Red	1.1	0.866
	>5.0	Orange	1.5	1.2
	>2.0	Yellow	2.4	1.9
Winter	>10.0	Red	1.1	0.901
	>5.0	Orange	1.6	1.3
	>2.0	Yellow	2.5	2.0

After all scenarios are detected, the result of this study emphasizes that while atmospheric conditions play critical role on the toxic threat zones as first scenario, they are unsignificant for thermal radiation threat zones for second and third scenarios. For toxic threat zones, atmospheric stability has a strong sign on atmospheric conditions to identify total amount of threat zones. Additionally, the wind is a critical parameter to highlight affected areas. By using these results, whether the muster points for this sunflower oil factory are proper could be checked by considering seasonal differences. Also, the whether the personal protective equipment and their usages is sufficient could be detected. After that, these data could be used as proactive approach in the case of emergency situations. For first scenario, the most affected areas are the extraction unit, pre-press unit, feed unit, and oil storage tank areas.

In terms of second and third scenarios, the weather conditions are not significant to identify size of threat zones. However, for these scenarios the existence of ignition sources and their managements play critical role to avoid accidents as proactive approach. In this point, some inspection plans and efficiency of them could be checked by reviving maintenance instructions of equipment and their requirements.

In summary, in this part of this paper, three scenarios are simulated and evaluated by considering seasonal effects. Accidents occurred by hazardous chemical results with destructive losses in terms of property, injury and death. The main reason of that accidents is not only able to prevent but also be predictable. Because of that, prediction of results and reasons on time is important (Chakrabarti and Route, 2011). Moreover, when all scenarios are compared, this shows that BLEVE type cases have more destructive effects on not only for factory but also environment due to huge effect areas with dangerous threat zones for scenario III. Also, whatever the percentage of mass in the fireball has fatal results in enormous environment. Additionally, the most destructive scenario is Scenario III which is hexane storage tank explosion with BLEVE type fire, results of thermal radiation threat zone emphasize that third scenario with BLEVE has bigger destructive outcomes and orbit than second scenario with pool fire.

Then, Scenario I which is dispersion of gas cloud from environment follows it. Also, Scenario II with pool fire formation has the least domain in terms of threat zones.

4.4 How to use ALOHA software results for sunflower oil factories?

After making analyzing using the ALOHA program, risky situations and materials causing accidents mentioned in the simulation part should be highlighted. These outcomes supply simulation of some cases in the case of hazardous chemical in storage tank. By using these results, some improving includes precautions taking after accident and in the case of accident could be planned, applied, and informed. In terms of this sunflower oil factory, the first aim is to develop proactive approach to avoid chemical dispersion hexane from storage tanks and its undesirable destructive results. Thus, the some dangerous parameters such as hexane, miscella, oils, hot surfaces, flames, and hot gases, mechanically produced sparks, electrical materials, static electricity, lightning, electromagnetic fields with between 9 kHz and 300 GHz range, electromagnetic radiation with 300 GHz and 3 million GHz, ionizing radiation, ultrasonic, adiabatic compression, shock waves, gas flow, chemical reactions should be considered to prevent and control measurements in the case of accidents in a hexane storage tank in this sunflower oil plant. In terms of prevention, these required precautions are explained and designed to hinder explosive/flammable gas-vapor mixtures and any connection with ignition sources. In a general aspect, this prevention could be applied by using engineering applications which are creating safety distances between the extraction unit and the hexane storage tank and developing ventilation conditions to make the storage process of hexane safe and its risky outcomes minimum. Also, in this factory, as the locations of the hexane storage tank and extraction unit are close to each other, any precautions designed and taken for the extraction unit also make a safe contribution to hexane storage tanks (Fediol, 2006).

4.4.1 Locations of the Extraction Unit and Hexane Storage Tank

When the ALOHA results are examined obtaining after each scenario and season, the most dangerous unit is the extraction unit. The reason of that the close distance between hexane storage tank and extraction unit. Since there is a mutual relationship between these areas during accident, and to cause accident, their locations should be arranged carefully. In this part, some precautions will be highlighted step by step to develop and check measurements.

- **Distance Between Hexane Storage Tank and Buildings:** During unloading of hexane from storage tank to extraction unit, there should be not any ignition sources around unloading area. According to Guidelines of Fediol in 2006, while the distances between these two areas as storage tank and extraction unit should be 30 m, its value between storage tank and properties should be at least 7.5 m. Since the current location between the hexane tank and extraction unit is approximately 10 m, this could be dangerous situations in the presence of ignition sources. However, as its distance from building is at least 7.5 m, it is safe for other buildings. Based on ALOHA results, min red region is 33 m and includes extraction unit. Due to presence of close-range between storage tank and extraction unit, although there is a iron wire around the storage tank, the surrounding of the storage tanks should be enclosed by fence as high wall to make its undesirable outcomes minimum during accident. In terms of this sunflower oil factory, as hexane storage tank is deprived of this fence as high wall, it will be surrounded by it. By this way, in the case of an accident, this protection high will avoid undesirable interaction between the most dangerous unit as extraction and storage tank.
- **The Properties of Unloading Area:** Materials and platforms of unloading area should be noncombustible. By this way, though existence of spark, there is no formation of fire. By this way, although there is any hexane leakage, there is not any interaction due to existence of non-combustible material.

In terms of this sunflower oil factory, there is not any specific platforms. Due to that, a proper platform should be located for unloading of hexane from vehicle to storage tank. Also, this platform should be supported with a spill containment pan, helping safety. Additionally, while unloading area, the pipe connection should be supplied with suitable automated shut off valve with earthing. Proper earthing is critical process as the hexane is static accumulating liquids. The charge formation is occurred in the presence of air flow on material surfaces or through a pipe during unloading or loading. In the case of static spark and ignition sources, static discharge with proper grounding as earthing should be applied (Saferack, 2020).

- **Storage Tank Checklist:** In the case of leakage scenarios evaluated in above parts by using ALOHA software, not only a monthly aboveground storage tank inspection checklist but also an annual aboveground storage tank inspection checklist is formed as a proactive approach. These checklists are shown in appendix part as D and E part. This monthly tank maintenance inspection checklist is applied monthly. However, as the autumn season is the most dangerous season among other season based on results of ALOHA, this checklist will be done every 15 days in this season. This checklist includes some titles such as visual inspection, ancillary equipment, and safety precautions. On the other hand, other an annual tank maintenance inspection checklist is applied annually. This includes fencing and access and roof venting. In terms of this factory, these check lists are attached in periodic maintenance plan and follow-up form with documentation no which is PB-ELK-001. After addition as hexane storage tank, it should be remarked as annual maintenance in August, monthly maintenance for each month, and every fifteen days in autumn season. By this way, it should be checked periodically.

- **Containment Area:** Since the close distance between storage tank and extraction unit, secondary contaminant area should be surrounded by wall producing same material of containment area. By this way, though around of the storage tank is fenced by iron wire, this high wall protection will prevent leakage of hexane from different units. In the case of leakage, this containment area makes easy interference, before the accident spreads or affects to other units.
- **Leak Detection:** The main reason of chemical accidents is the leakage of the hazardous chemical. Because of that, ant detection system is critical to avoid accidents as proactive chemical. In this factory, the leak detection system is not be found. According to leakage scenarios based on especially in the outer region of storage tank, the leak detection system should be established. While proper leak detection is chosen, engineered approach should be considered. Thus, the multiple parameters such as the size, location and of the storage tank, pipe systems, and cost factors etc. are critical to choose proper technology. Among the detection methods, tank gauging method is the most common for storage tanks. This is divided into two type as automatic tank gauging method and manual tank gauging method. As the manual tank gauging method is more economical than automatic one. In the first stage, manual tank gauging method could be applied at set intervals and could be repeated in the case of suspicious situations. By this way, any leakage could be detected, and accidents could be prevented. In terms of automatic method, it supplies some opportunities. All times, whether there is a leakage from storage tank could be measured automatically by giving results as temperature of liquid. By this way, the probability of vapor or gas dispersion from storage tank due to leakage is decreased by using this proactive approach (Environmental Protection Agency, 2015). In this factory, though its leak detection is made by usage of manual tank gauging method, it should be updated to automatic tank gauging method to collect data and avoid accident immediately.

4.4.2 Extraction Process

When all the threat zones shown in figure 4.26. are placed on top of each other on google maps, the intersection set is extraction unit. This shows that some precautions must be taken regardless of the types of the scenarios during accident.

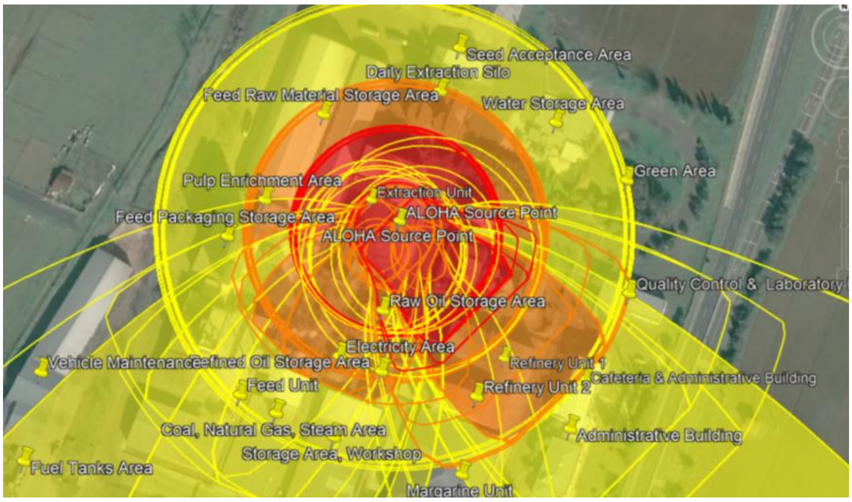


Figure 4.26.Visual representation of the intersection set of all threat zones on Google Earth Pro (Google Earth Pro, 2022).

- **Venting of Extraction Unit:** As the extraction unit is the nearest the storage tank, undesirable outcomes such as ignition, fire, or chemical gas dispersion, etc. occurred in the storage tank also directly affects the extraction unit. Due to that, the ventilation of extraction unit gains importance. The sufficient venting should be supplied to alter air volume at least six times per hour with exhaust fans (Fediol, 2006). In terms of this factory, though the extraction unit is located at enclosed building, the ventilation system is supplied under manual conditions in this. Though this provides enough ventilation during process, it is insufficient in the case of emergency situations. Due to that, mechanical ventilation system should be established immediately.

Though there is a plan for setting of this mechanical ventilation system, after this study, this preparation process will accelerate. By this way, gas dispersion or any ignition sources could be removed by this ventilation system in the case of accident by removing of undesirable air by fans and changing this air with fresh one. Additionally, the extraction process should be occurred in closed system with ventilation of outside atmosphere supporting with proper flame arrester. In terms of flame arresters in extraction unit, their locations should be controlled against freezing and arranged again to make them easy access for inspection and repair after their establishments. Moreover, emergency ventilation system should be designed for excessive accumulation of internal pressure in the presence of fire.

- **Vent Vapor Recovery System:** During vapor recovery system, all substances such as hexane vapor, water vapor, and air are into this vent header which is a common material to ventilate all equipment material for extraction process, and flow to this recovery system. Water-cooled, shell-and-tube condenser and a mineral oil absorption recovery system are parts of this vent vapor recovery system. As this system is critical parameter for hexane, its inspection and repair should be followed carefully and added into the risk assessment as proactive approach. In this step, its efficiency should be monitored. In this recovery system, temperature and pressure of this system should be controlled. If these parameters reach undesirable levels, it is resulted with fire or explosion due to existence of hexane. During accident, since this system includes hexane vapor, it should be ventilated carefully as reactive approach.
- **Wastewater Evaporator:** This evaporator is used for two purposes. The first aim is to support safety of system by removing any substances that may pose a hazard such as oils, solvents, and miscellas from wastewater. The second purpose is to supply protection in the case of spills. Because of that, also its inspection and repair should be done.

- **Conveyors:** In this factory, they are established at least 7.5 m outside of other regions or buildings. As these conveyors carry fine particles oil mixed cake and hexane, this creates a dangerous situation due to existence of hexane. Because of that, it is located at least 7.5 m from other regions. Additionally, they are enclosed and supported with noncombustible materials which have open grade floor sections. By this open grade floor sections, ventilation of conveyors is supplied to prevent separation of solvent vapors and liquids to other areas. Also, ventilation is significant parameter for conveyors to avoid accumulation and leakage of solvent. Due to that, during accident and in the case of the accident, this area also checked and followed carefully.
- **Prevention Hexane Separation to the Preparation:** Conveyors are the last part of the extraction unit, have more openings on the outer region of extraction process. Also, the highest point of these openings locating at the enter side of conveyors is 15 m. This height is sufficient to move dense solvent vapors into the preparation area. To avoid it, automatic valve should be located between these openings and preparation area. By this way, back flow of dense solvent vapors is supplied from dry feeding hopper to extractor.
- **Other Measurements:** Judgments as shutoff steam and shutdown of process materials should be applied in the case of emergency. Though the most of them is done automatically, there is some manual operations. Due to that, these applications as shutoff and shutdown should be occurred at safe distant location. However, some operations such as cooling water to condenser, fans located inside and outside of buildings and lights should be provided during accident. In this factory, there is no emergency stop buttons on the machines in extraction units. In the case of danger situations for work equipment and normal stopping process, equipment with an emergency stop system is required. This is high property to develop proactive approach. Thus, it should be applied immediately.

Additionally, interlocked system for equipment should be applied to remove material from the stopped equipment under operation. However, if there is any formation of hazardous situations, this system should not be applied. Also, alarming system should be established to inform abnormal and hazardous situations such as steam loss, failure of critical equipment, and fire, etc. Additionally, some automatic connection between temperature sensitive devices and alarms should be supplied especially at desolventizer and wastewater evaporator. Also, alarms should warn for not only temperature and pressure, but also presence of hexane. In this factory, there is some alarming systems. First system is related with hexane existence in this unit. Hexane leak detection system is available, and its periodic maintenance is applied by authorized companies once a year. The other system is related with pressure. There is some measurement devices for this alarming. Manometer is located at some critical areas which are absorption tank, tank no. 506, heater tank no. 521, 21, 18, 60-A, vacuum line, filter enter area, absorption tank no. 180, the main entrance of condenser tank, water line, steam entrance of toaster, the main steam entrance of the extraction unit, hot water tank, some pumps, etc. On the other side, there are thermal alarming system. With this purpose, some thermometers are located at different regions which are absorption tank, tank no. 506, heater tank no. 521, 21, 18, 60-A, vacuum line, filter enter area, absorption tank no. 180, the main entrance of condenser tank, water line, steam entrance of toaster, the main steam entrance of the extraction unit, hot water tank, some pumps, extractor, heater region of toasters, etc (Akay, 2019). Also, an alarm system for storage tank should be applied between solvent flow from storage tank to the work tank to avoid overflow of the tank. Moreover, apart from alarming systems, solvent water separators should be checked to prevent any hexane contamination to water side or vice versa. Besides, some precautions should be taken in the case of lightining in the places where flammable, explosive, dangerous and harmful substances are processed.

Their periodic checks should be made by a qualified person at least once a year like this factory. In the event of explosion or fire whose source is electricity, exproof electricity equipment, engines, and lighting. Electricity to be installed in dangerous places should be suitable and must be ex-proof, and its certificates and technical specifications should be fit legally. Additionally, in terms of electricity, electrical panel, installation, and electrical working body especially chassis, and protection of all machines should be grounded, and always connected with earthing being ensured that it does not break due to external and internal factors. Also, electrical grounding measurements should be made every year. By this way, the formation of static electric as source of spark source will be avoided. Finally, as the overpressure graphs show that extraction unit is the most dangerous unit, the numbers of sight glasses should be decreased to make measurements against high pressure by avoiding breakage and product damages.

4.4.3 Emergency Preparedness

According to checking, updating and formation of some emergency situations related with shutdown, shutoff or operating some critical equipment, all workers should be trained in:

- application of essential actions in the case of emergency,
- emergency exit locations,
- emergency meeting places,
- usage and limitations of fire equipment in the case of fire or explosion.

After training of them, some periodic drills should be occurred to check efficiency of trainings. Moreover, efficiency of equipment using in the case of emergency situations and procedures should be checked and tested periodically.

4.4.4 Toxic Dispersion

In the case of toxic dispersion, its levels are higher than standard intervals. In the case of not supplying suitable conditions to provide fresh air by using engineering control methods such as ventilation system, in this factory this is tried to use personal protective equipment. In the extraction unit, the suitable masks are supplied to prevent toxic effects of hexane in the case of dispersion.

In summary, this part shows that how to ALOHA results use in sunflower oil factory. By using them, the most dangerous areas are identified as surrounding of storage tank and extraction unit. Therefore, in this part the focus points are them. Apart from them, also some storage areas such as raw oil, sunflower and feed raw material, refinery units as 1 and 2, pulp enrichment area and electricity area are located at the threat regions. For these areas, to avoid accidents some situations and precautions are valid. Unlike the extraction unit, steel silo is used specially to storage sunflower oil and raw material of feed unit such as corn, barley, and wheat. There is temperature sensor for alarming if the temperature is exceeded than 35 ° C, cooling down of the silos are started to keep temperature desirable levels by avoiding fire, explosion of the silos. Additionally, there is level sensor. When the level of substances in the silos is exceed than desirable levels, this sensor gives alarming in this factory. By this way, also fire and the explosions are hindered. Besides, other precautions for emergency preparedness, venational situations in these units, toxic dispersion, exproof material, grounding system, etc. are as same as extraction unit.

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Production of edible oil gains importance due to an increasing demand on them and being essential parts of human nutrition. During extraction of edible oil especially sunflower oil, hexane is used to make its production more efficient. By reason of hazardous chemical properties of hexane, suitable storage conditions should be supplied. Thus, the aim of this study is making risk assessment on hexane storage tank at sunflower oil factory located at Tekirdağ by using ALOHA to detect threat zones based on three different scenarios.

Simulation of three scenarios was examined under different seasonal conditions as spring, summer, autumn and winter. By this way, whether the atmospheric conditions impact on different scenarios or not was analyzed. According to outputs, while atmospheric conditions affect toxic threat zones, flammable threat zones in first scenario which is hexane leakage without fire formation , they do not play critical roles on the overpressure threat zones in first scenario, thermal radiation threat zones in second scenario as puddle formation with pool fire and third scenario as BLEVEs type explosion.

When the most influenced area is analyzed by considering all scenarios and results, location of the extraction unit and hexane storage tank, extraction process, emergency preparedness, toxic dispersion are gotten importance to develop proactive approach.

5.2 Recommendations

The main recommendations for this study are listed at the bottom:

- Other software assessment method as PHAST should be examined for this paper and for the future investigations and to compare their outputs as ALOHA and PHAST.
- The emergency preparedness plan should be prepared and exercised by considering outputs of this scenarios.
- Especially, some regions where the residential areas are close to industry regions are conducted by using this software as ALOHA to prevent separation of toxic chemicals, environmental pollution and property damages.
- This paper could be used as a source of hexane releasing from storage tanks in food sector.
- A barrier could be built around the storage tank to prevent spread of flame and fire around. By this way, pool fire could be hindered.
- After the effects of wind directions are analyzed carefully, if the releasing accident of hexane is occurred, people are directed to safe areas located at the opposite direction of the prevailing wind.
- As the n-hexane is flammable, some cooling, an automatic foam injection mechanism and ventilation system should be installed.
- Health guidelines, eye and face, skin, body and respiratory protection should be supplied in the case of emergency situation by creating safety guideline.
- Methods and materials for contamination and cleaning of n-hexane should be specified.
- Some measuring devices could be established near the storage tank to get exact results for temperature, moisture, wing speed and direction and repeat this study under these conditions.

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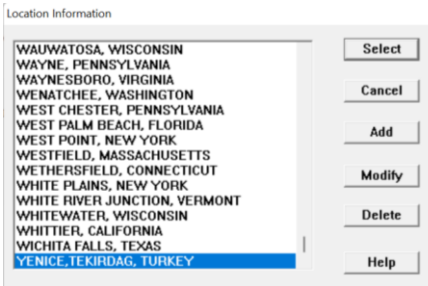
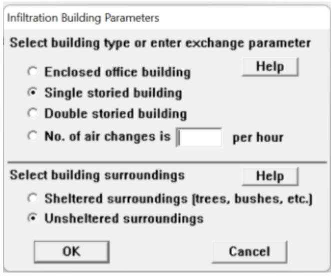
APPENDICES

A. ALOHA Inputs for Scenario I for Spring Season

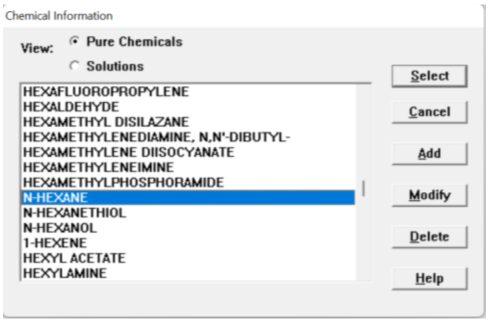
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



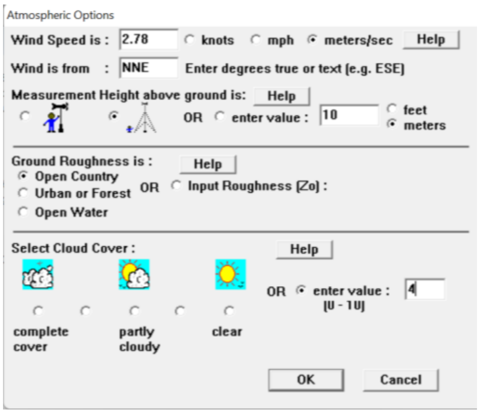
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

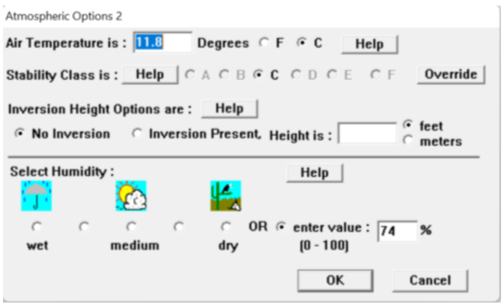


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

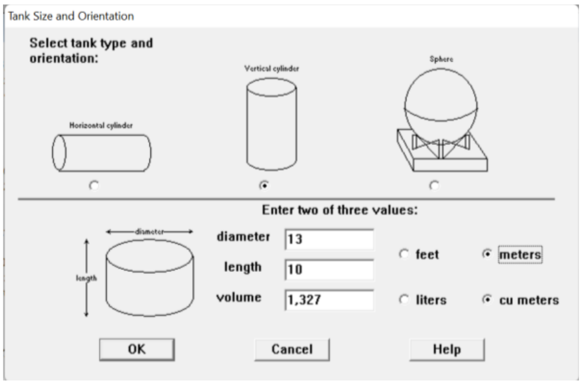


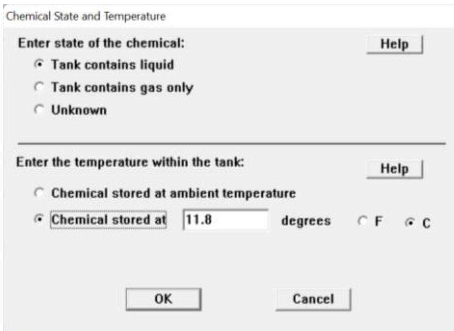
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the spring season. For the spring season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surroundings of the storage tank. Then, while the value of cloud cover was entered, the air temperature was obtained at 11.8 º C. After all, the stability of the class was selected as C automatically. When no inversion for height was selected and humidity was entered as 74 %, inputs of atmospheric parameters were finished.

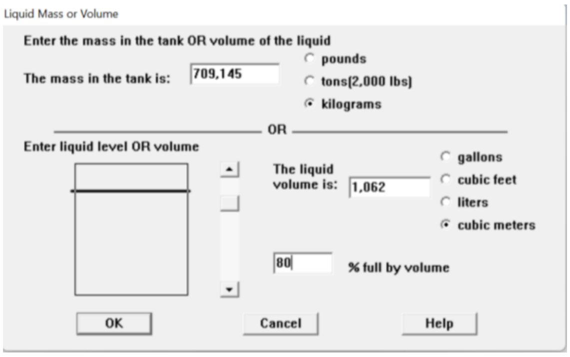




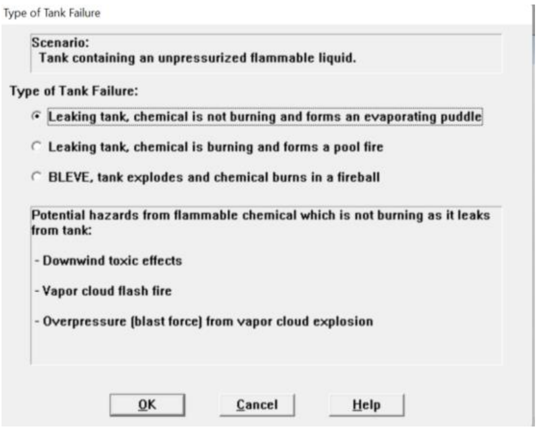
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



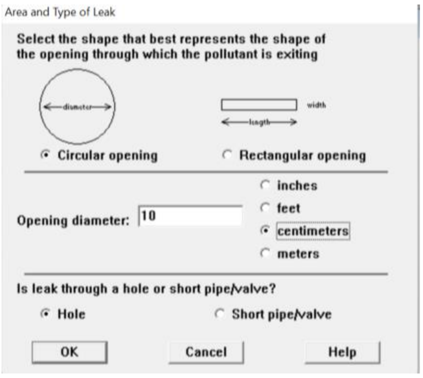


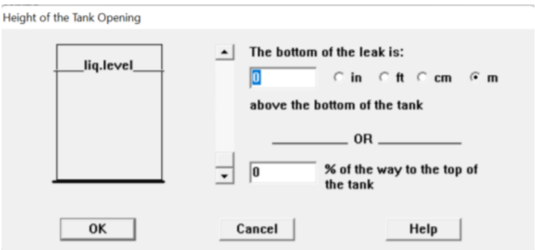


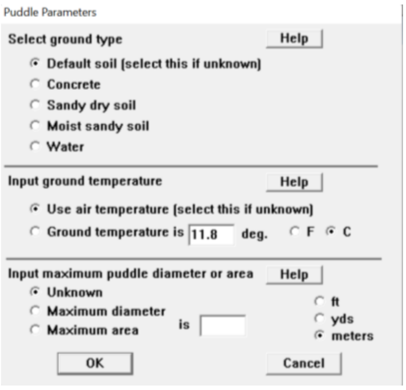
After the first scenario requirements, type of tank failure was selected as ‘leaking tank, chemical is not burning and forms an evaporating puddle’.



Based on scenario 1 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it's the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.







Threat zones as toxic area of vapor cloud, flammable area of vapor cloud and blast area of vapor cloud explosion were obtained in display part, and their toxic levels were highlighted according to thereat zones such as red, orange and yellow.

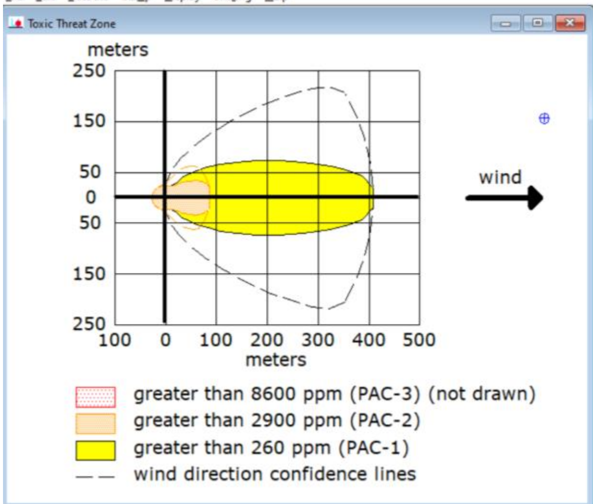
ALOHA 5.4.7 - [Text Summary]

File Edit SiteData SetUp Display Sharing Help

```
SITE DATA:
   Location: YENICE,TEKIRDAG, TURKEY
   Building Air Exchanges Per Hour: 0.56 (unsheltered single storied)
   Time: October 31, 2022  1459 hours ST (using computer's clock)

CHEMICAL DATA:
   Chemical Name: N-HEXANE
   CAS Number: 110-54-3                    Molecular Weight: 86.18 g/mol
   AEGL-1 (60 min): N/A   AEGL-2 (60 min): 2900 ppm   AEGL-3 (60 min): 8600 ppm
   IDLH: 1100 ppm      LEL: 12000 ppm      UEL: 72000 ppm
   Ambient Boiling Point: 68.7° C
   Vapor Pressure at Ambient Temperature: 0.11 atm
   Ambient Saturation Concentration: 109,247 ppm or 10.9%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
   Wind: 2.78 meters/second from NNE at 10 meters
   Ground Roughness: open country          Cloud Cover: 4 tenths
   Air Temperature: 11.8° C                Stability Class: C
   No Inversion Height                     Relative Humidity: 74%

SOURCE STRENGTH:
   Leak from hole in vertical cylindrical tank
   Flammable chemical escaping from tank (not burning)
   Tank Diameter: 13 meters                Tank Length: 10 meters
   Tank Volume: 1,327 cubic meters
   Tank contains liquid                    Internal Temperature: 11.8° C
   Chemical Mass in Tank: 709,145 kilograms
   Tank is 80% full
   Circular Opening Diameter: 10 centimeters
   Opening is 0 meters from tank bottom
   Ground Type: Default soil
   Ground Temperature: equal to ambient
   Max Puddle Diameter: Unknown
   Release Duration: ALOHA limited the duration to 1 hour
   Max Average Sustained Release Rate: 245 kilograms/min
      (averaged over a minute or more)


   Total Amount Released: 10,018 kilograms
   Note: The chemical escaped as a liquid and formed an evaporating puddle.
   The puddle spread to a diameter of 62 meters.

THREAT ZONE:
   Model Run: Heavy Gas
   Red    : 39 meters --- (8600 ppm = AEGL-3 [60 min])
   Note: Threat zone was not drawn because effects of near-field patchiness
     make dispersion predictions less reliable for short distances.
   Orange: 88 meters --- (2900 ppm = AEGL-2 [60 min])
   Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

THREAT AT POINT:
   Concentration Estimates at the point:
   Downwind: 80.7 meters                   Off Centerline: 41.4 meters
   Max Concentration:
      Outdoor: 1,610 ppm
      Indoor:  397 ppm
```

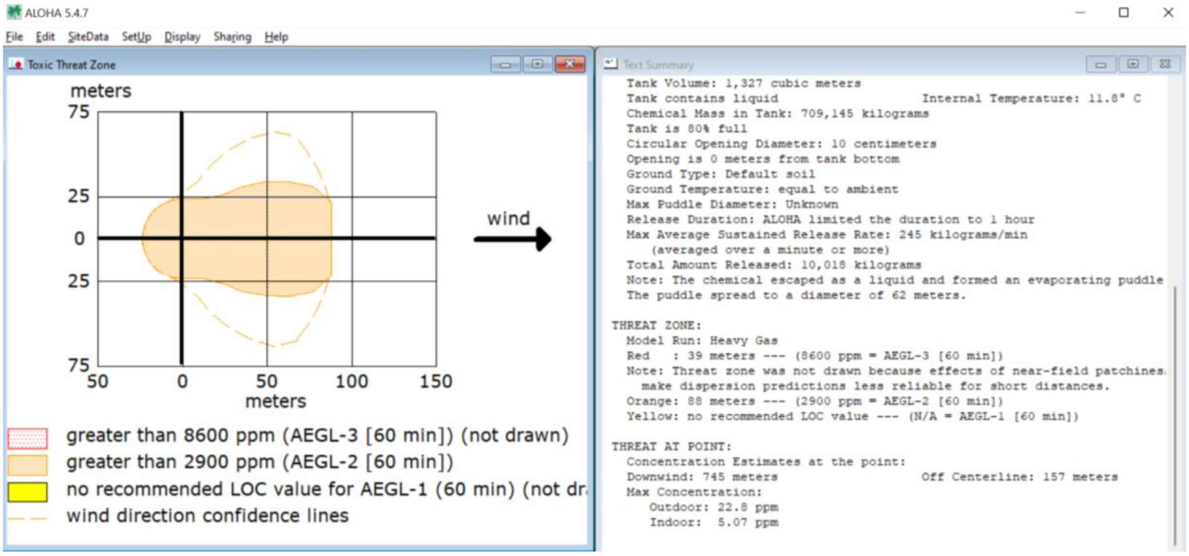
ALOHA 5.4.7

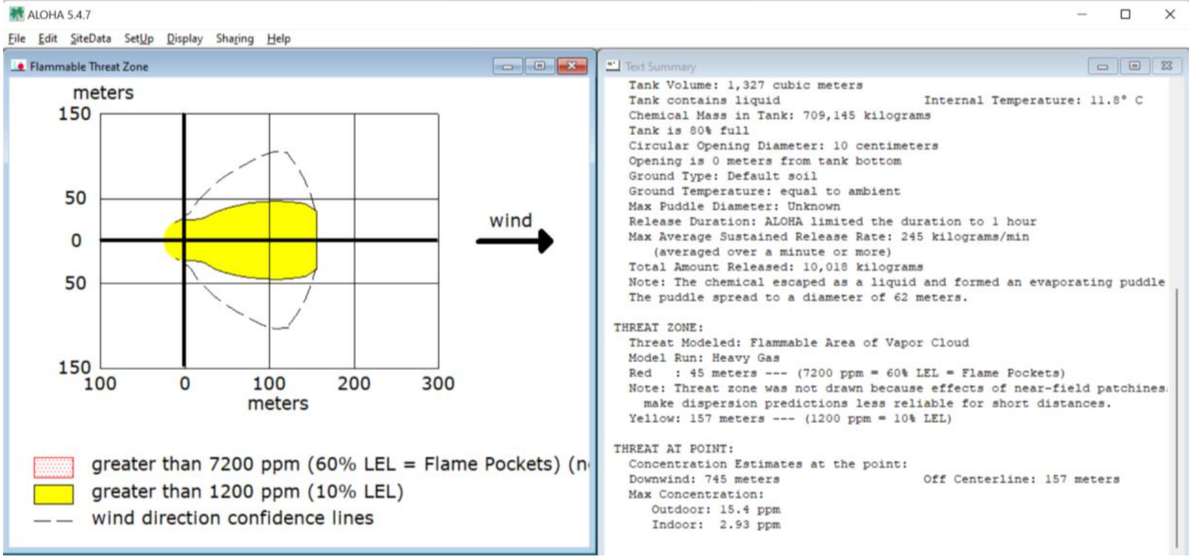
File Edit SiteData SetUp Display Sharing Help

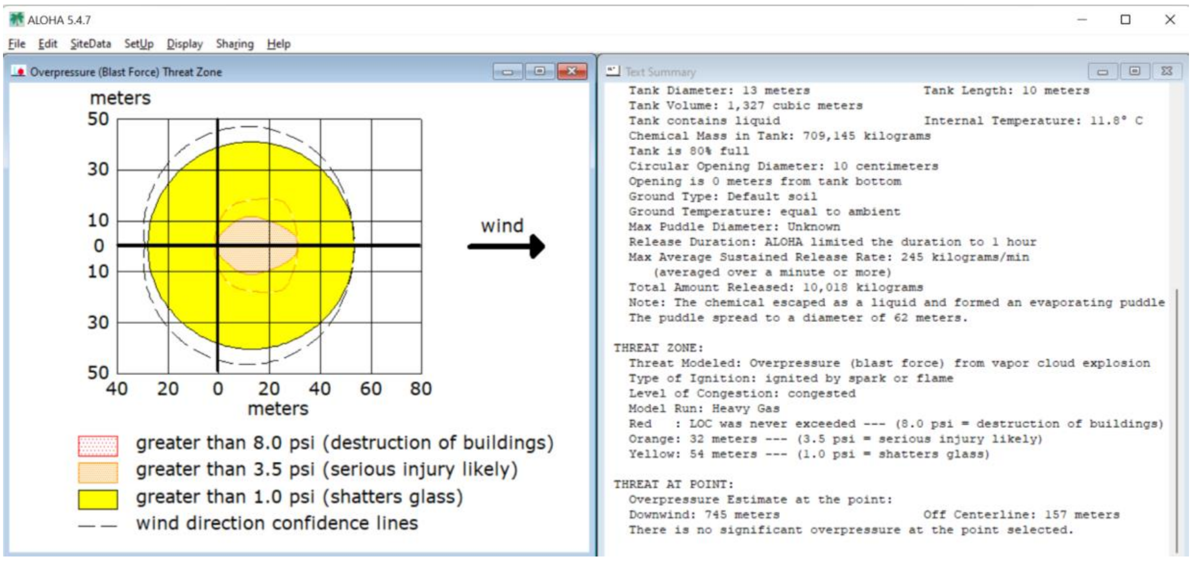


Text Summary

```
   Tank Volume: 1,327 cubic meters
   Tank contains liquid                    Internal Temperature: 11.8° C
   Chemical Mass in Tank: 709,145 kilograms
   Tank is 80% full
   Circular Opening Diameter: 10 centimeters
   Opening is 0 meters from tank bottom
   Ground Type: Default soil
   Ground Temperature: equal to ambient
   Max Puddle Diameter: Unknown
   Release Duration: ALOHA limited the duration to 1 hour
   Max Average Sustained Release Rate: 245 kilograms/min
      (averaged over a minute or more)
   Total Amount Released: 10,018 kilograms
   Note: The chemical escaped as a liquid and formed an evaporating puddle
   The puddle spread to a diameter of 62 meters.

THREAT ZONE:
   Model Run: Heavy Gas
   Red    : 39 meters --- (8600 ppm = PAC-3)
   Note: Threat zone was not drawn because effects of near-field patchines
     make dispersion predictions less reliable for short distances.
   Orange: 88 meters --- (2900 ppm = PAC-2)
   Yellow: 409 meters --- (260 ppm = PAC-1)

THREAT AT POINT:
   Concentration Estimates at the point:
   Downwind: 745 meters                    Off Centerline: 157 meters
   Max Concentration:
      Outdoor: 22.8 ppm
      Indoor:  5.07 ppm
```

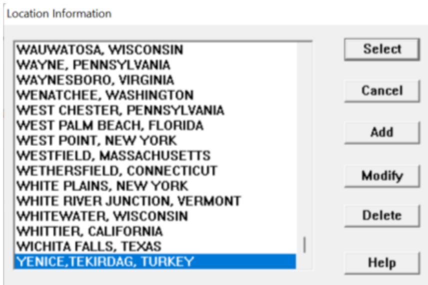

ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Toxic Threat Zone
meters
75
25
0
25
75
50 0 50 100 150
meters
wind
greater than 8600 ppm (AEGL-3 [60 min]) (not drawn)
greater than 2900 ppm (AEGL-2 [60 min])
no recommended LOC value for AEGL-1 (60 min) (not dr
wind direction confidence lines
Text Summary
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 11.8° C
Chemical Mass in Tank: 709,145 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil
Ground Temperature: equal to ambient
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 245 kilograms/min
(averaged over a minute or more)
Total Amount Released: 10,018 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 62 meters.
THREAT ZONE:
Model Run: Heavy Gas
Red : 39 meters --- (8600 ppm = AEGL-3 [60 min])
Note: Threat zone was not drawn because effects of near-field patchiness
make dispersion predictions less reliable for short distances.
Orange: 88 meters --- (2900 ppm = AEGL-2 [60 min])
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])
THREAT AT POINT:
Concentration Estimates at the point:
Downwind: 745 meters Off Centerline: 157 meters
Max Concentration:
Outdoor: 22.8 ppm
Indoor: 5.07 ppm


ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Flammable Threat Zone
meters
150
50
0
50
150
100 0 100 200 300
meters
wind
greater than 7200 ppm (60% LEL = Flame Pockets) (n
greater than 1200 ppm (10% LEL)
wind direction confidence lines
Text Summary
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 11.8° C
Chemical Mass in Tank: 709,145 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil
Ground Temperature: equal to ambient
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 245 kilograms/min
(averaged over a minute or more)
Total Amount Released: 10,018 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 62 meters.
THREAT ZONE:
Threat Modeled: Flammable Area of Vapor Cloud
Model Run: Heavy Gas
Red : 45 meters --- (7200 ppm = 60% LEL = Flame Pockets)
Note: Threat zone was not drawn because effects of near-field patchiness
make dispersion predictions less reliable for short distances.
Yellow: 157 meters --- (1200 ppm = 10% LEL)
THREAT AT POINT:
Concentration Estimates at the point:
Downwind: 745 meters Off Centerline: 157 meters
Max Concentration:
Outdoor: 15.4 ppm
Indoor: 2.93 ppm

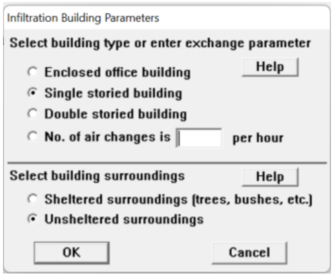


B. ALOHA Inputs for Scenario I for Summer Season

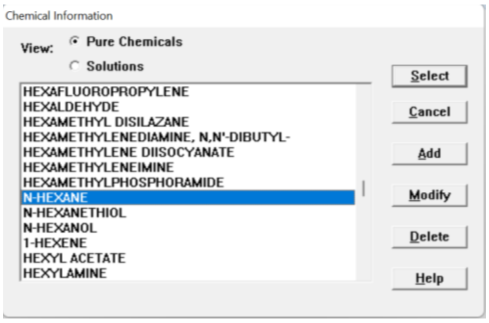
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



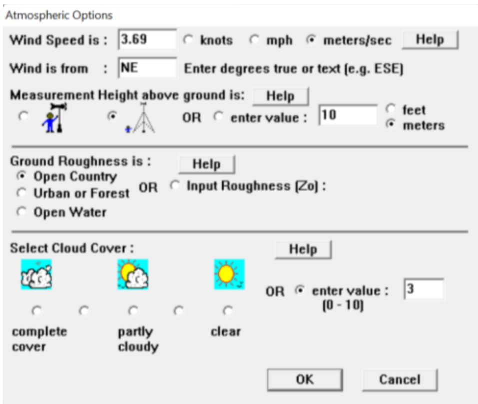
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

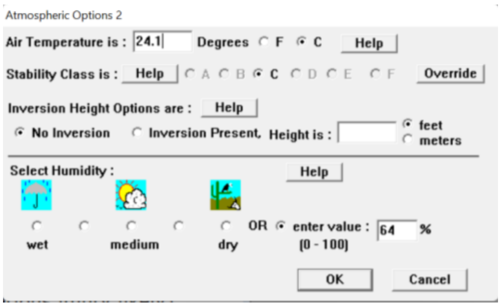


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

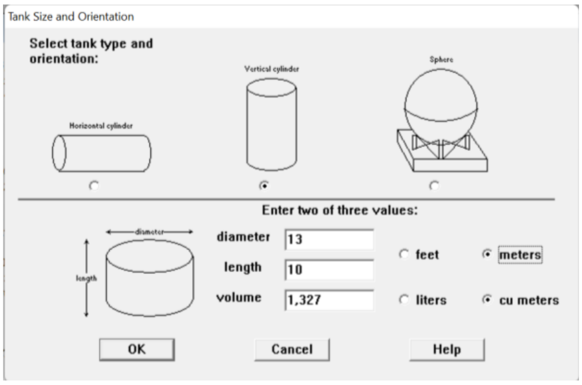


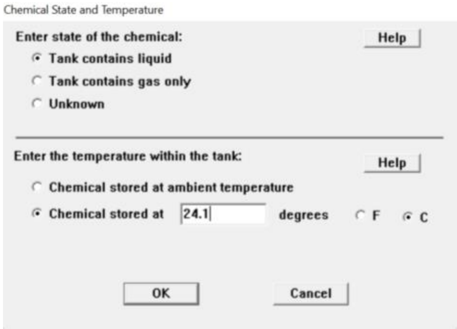
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the summer season. For the summer season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 3, the air temperature was obtained at 24.1 ^{o} C. After all, the stability of the class was selected as C automatically. When no inversion for height was selected and humidity was entered as 64 %, inputs of atmospheric parameters were finished.

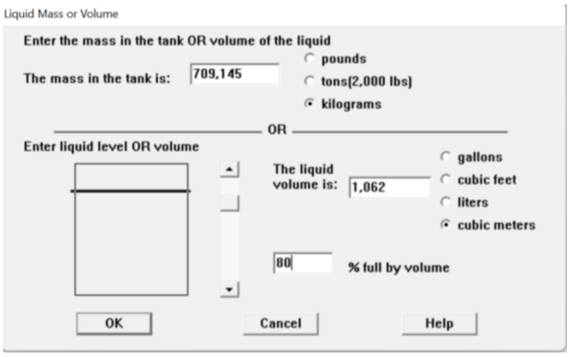




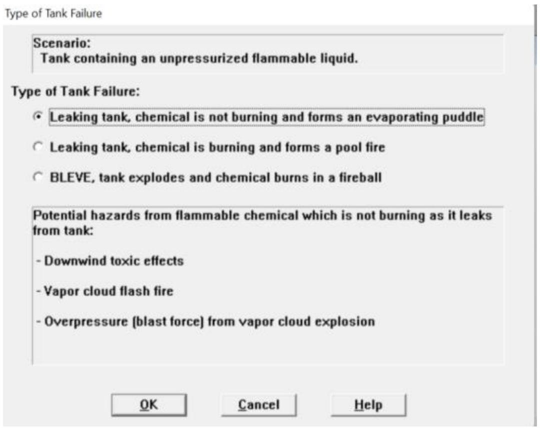
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



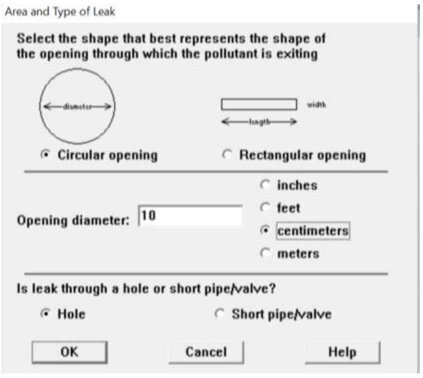


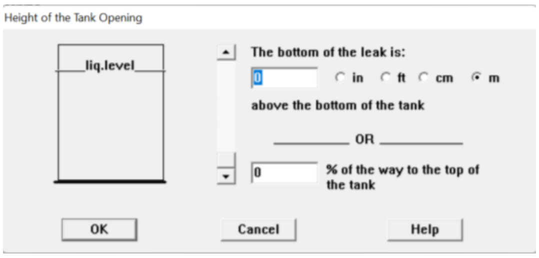


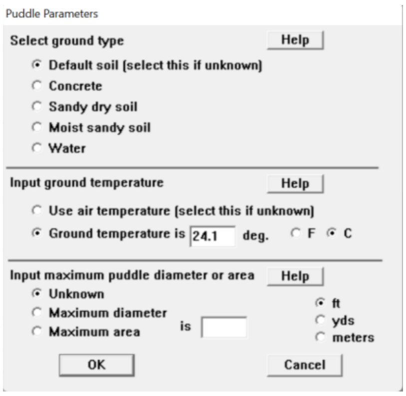
After the first scenario requirements, type of tank failure was selected as 'leaking tank, chemical is not burning and forms an evaporating puddle'.



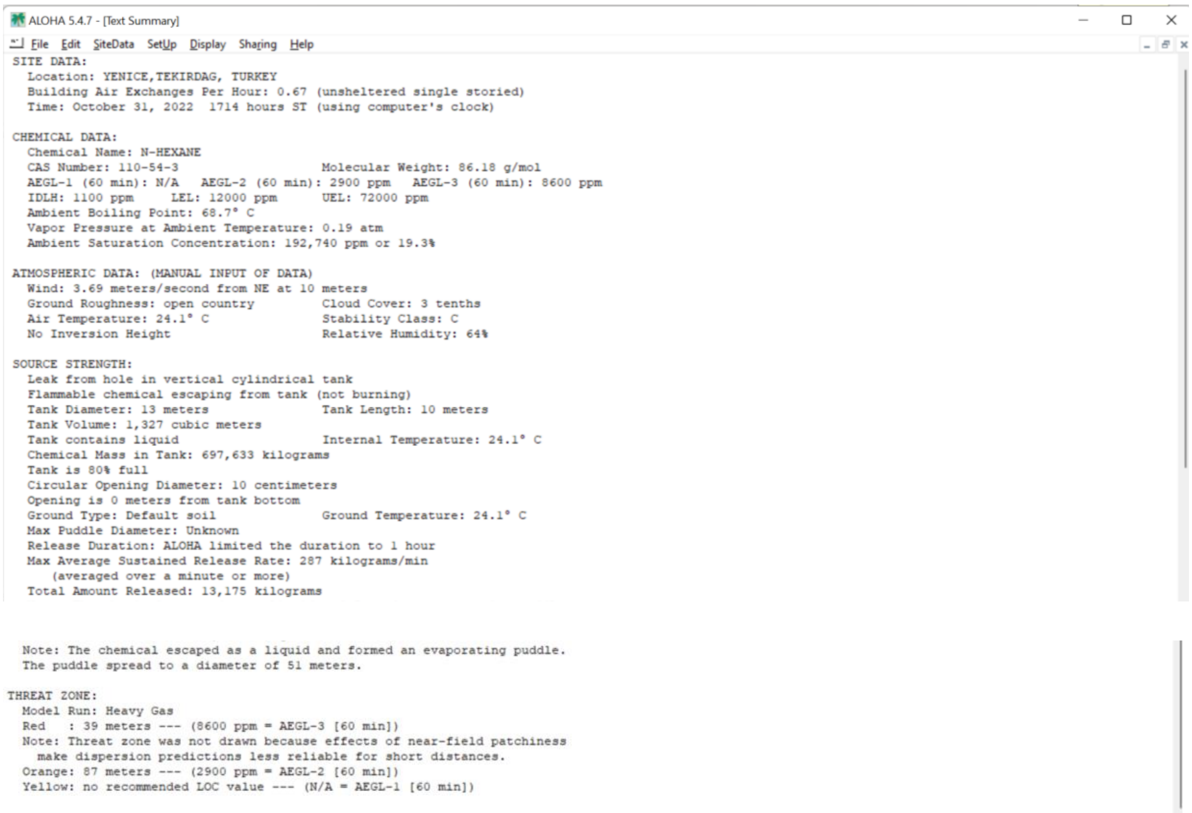
Based on scenario 1 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it's the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.



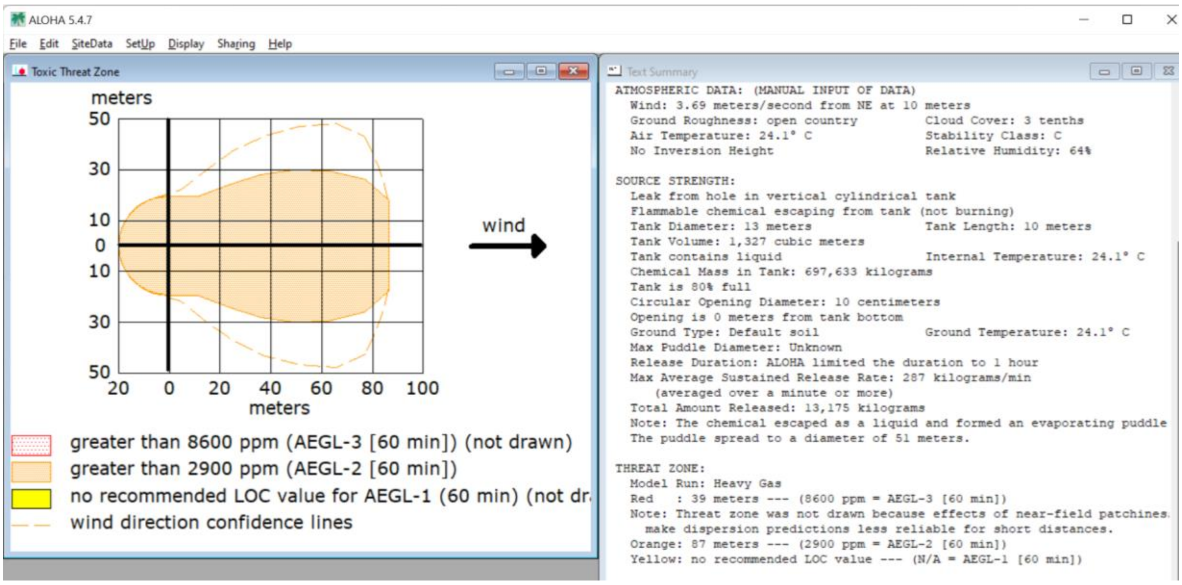


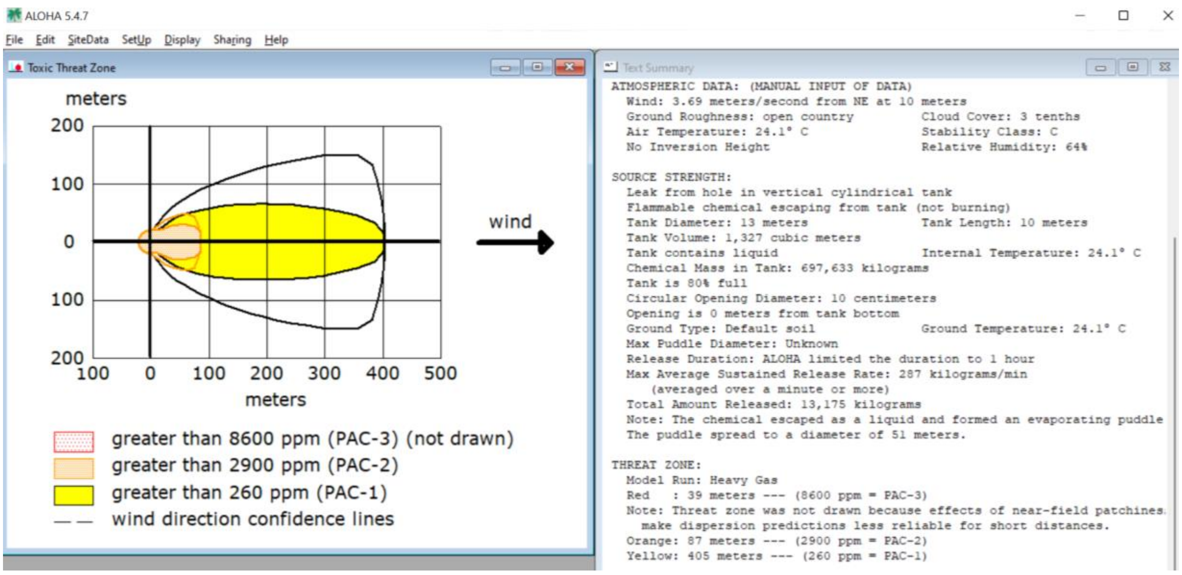


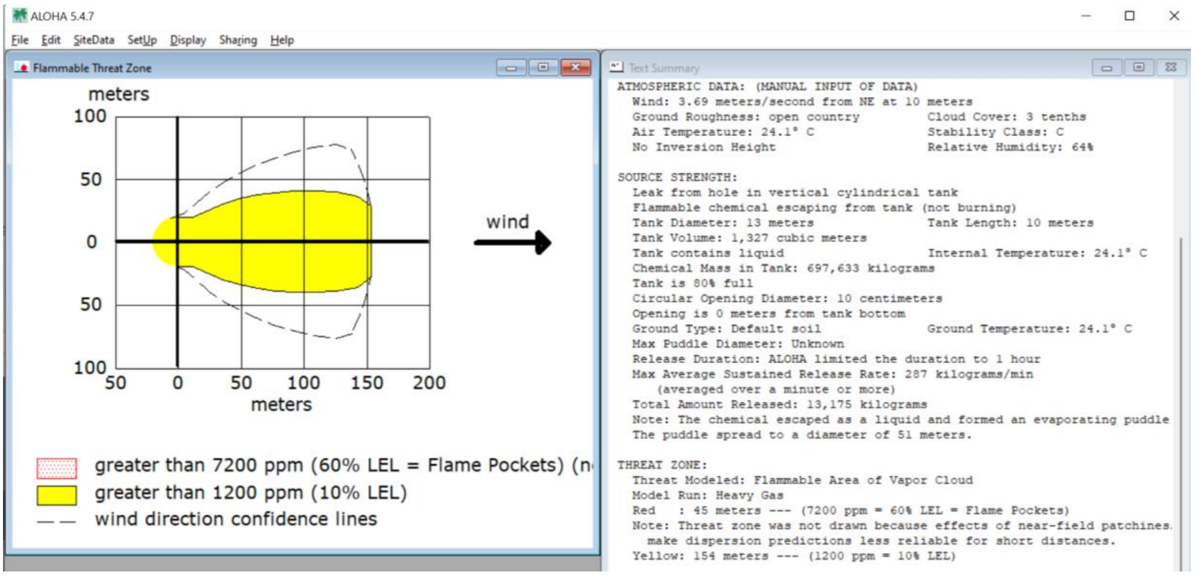
Threat zones such as toxic area of vapor cloud, flammable area of vapor cloud and blast area of vapor cloud explosion were obtained in the display part, and their toxic levels were highlighted according to thereat zones such as red, orange, and yellow.

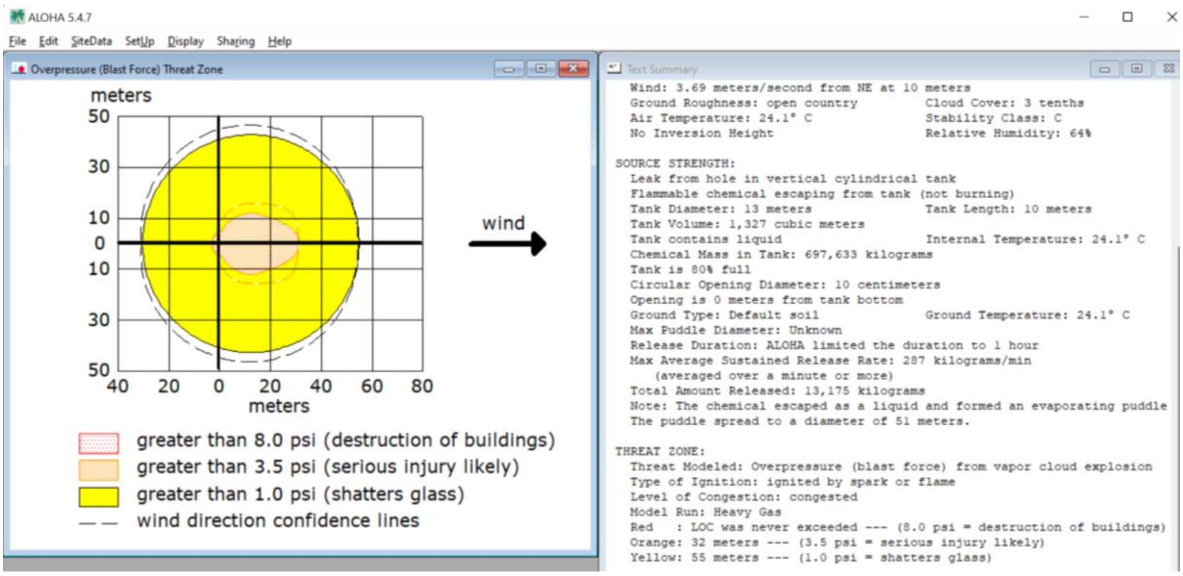



```
SITE DATA:
  Location: YENICE,TEKIRDAG, TURKEY
  Building Air Exchanges Per Hour: 0.67 (unsheltered single storied)
  Time: October 31, 2022  1714 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: N-HEXANE
  CAS Number: 110-54-3                  Molecular Weight: 86.18 g/mol
  AEGL-1 (60 min): N/A   AEGL-2 (60 min): 2900 ppm   AEGL-3 (60 min): 8600 ppm
  IDLH: 1100 ppm     LEL: 12000 ppm      UEL: 72000 ppm
  Ambient Boiling Point: 68.7° C
  Vapor Pressure at Ambient Temperature: 0.19 atm
  Ambient Saturation Concentration: 192,740 ppm or 19.3%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 3.69 meters/second from NE at 10 meters
  Ground Roughness: open country        Cloud Cover: 3 tenths
  Air Temperature: 24.1° C              Stability Class: C
  No Inversion Height                   Relative Humidity: 64%

SOURCE STRENGTH:
  Leak from hole in vertical cylindrical tank
  Flammable chemical escaping from tank (not burning)
  Tank Diameter: 13 meters              Tank Length: 10 meters
  Tank Volume: 1,327 cubic meters
  Tank contains liquid                  Internal Temperature: 24.1° C
  Chemical Mass in Tank: 697,633 kilograms
  Tank is 80% full
  Circular Opening Diameter: 10 centimeters
  Opening is 0 meters from tank bottom
  Ground Type: Default soil             Ground Temperature: 24.1° C
  Max Puddle Diameter: Unknown
  Release Duration: ALOHA limited the duration to 1 hour
  Max Average Sustained Release Rate: 287 kilograms/min
     (averaged over a minute or more)
  Total Amount Released: 13,175 kilograms

  Note: The chemical escaped as a liquid and formed an evaporating puddle.
  The puddle spread to a diameter of 51 meters.

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 39 meters --- (8600 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because effects of near-field patchiness
    make dispersion predictions less reliable for short distances.
  Orange: 87 meters --- (2900 ppm = AEGL-2 [60 min])
  Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])
```


ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Toxic Threat Zone
meters
50
30
10
0
10
30
50
20 0 20 40 60 80 100
meters
wind
greater than 8600 ppm (AEGL-3 [60 min]) (not drawn)
greater than 2900 ppm (AEGL-2 [60 min])
no recommended LOC value for AEGL-1 (60 min) (not dr
wind direction confidence lines
Text Summary
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.69 meters/second from NE at 10 meters
Ground Roughness: open country Cloud Cover: 3 tenths
Air Temperature: 24.1° C Stability Class: C
No Inversion Height Relative Humidity: 64%
SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 24.1° C
Chemical Mass in Tank: 697,633 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil Ground Temperature: 24.1° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 287 kilograms/min
(averaged over a minute or more)
Total Amount Released: 13,175 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 51 meters.
THREAT ZONE:
Model Run: Heavy Gas
Red : 39 meters --- (8600 ppm = AEGL-3 [60 min])
Note: Threat zone was not drawn because effects of near-field patchines
make dispersion predictions less reliable for short distances.
Orange: 87 meters --- (2900 ppm = AEGL-2 [60 min])
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

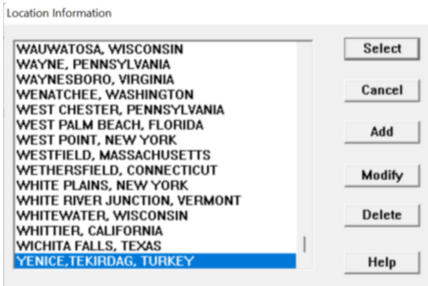

ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Toxic Threat Zone
meters
200
100
0
100
200
100 0 100 200 300 400 500
meters
wind
greater than 8600 ppm (PAC-3) (not drawn)
greater than 2900 ppm (PAC-2)
greater than 260 ppm (PAC-1)
wind direction confidence lines
Text Summary
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.69 meters/second from NE at 10 meters
Ground Roughness: open country Cloud Cover: 3 tenths
Air Temperature: 24.1° C Stability Class: C
No Inversion Height Relative Humidity: 64%
SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 24.1° C
Chemical Mass in Tank: 697,633 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil Ground Temperature: 24.1° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 287 kilograms/min
(averaged over a minute or more)
Total Amount Released: 13,175 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 51 meters.
THREAT ZONE:
Model Run: Heavy Gas
Red : 39 meters --- (8600 ppm = PAC-3)
Note: Threat zone was not drawn because effects of near-field patchines
make dispersion predictions less reliable for short distances.
Orange: 87 meters --- (2900 ppm = PAC-2)
Yellow: 405 meters --- (260 ppm = PAC-1)


ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Flammable Threat Zone
meters
wind
meters
greater than 7200 ppm (60% LEL = Flame Pockets) (n
greater than 1200 ppm (10% LEL)
wind direction confidence lines
Text Summary
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.69 meters/second from NE at 10 meters
Ground Roughness: open country Cloud Cover: 3 tenths
Air Temperature: 24.1° C Stability Class: C
No Inversion Height Relative Humidity: 64%
SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 24.1° C
Chemical Mass in Tank: 697,633 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil Ground Temperature: 24.1° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 287 kilograms/min
(averaged over a minute or more)
Total Amount Released: 13,175 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 51 meters.
THREAT ZONE:
Threat Modeled: Flammable Area of Vapor Cloud
Model Run: Heavy Gas
Red : 45 meters --- (7200 ppm = 60% LEL = Flame Pockets)
Note: Threat zone was not drawn because effects of near-field patchiness
make dispersion predictions less reliable for short distances.
Yellow: 154 meters --- (1200 ppm = 10% LEL)

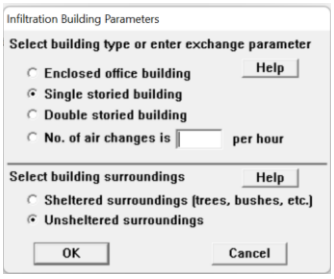

ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Overpressure (Blast Force) Threat Zone
meters
wind
meters
greater than 8.0 psi (destruction of buildings)
greater than 3.5 psi (serious injury likely)
greater than 1.0 psi (shatters glass)
wind direction confidence lines
Text Summary
Wind: 3.69 meters/second from NE at 10 meters
Ground Roughness: open country Cloud Cover: 3 tenths
Air Temperature: 24.1° C Stability Class: C
No Inversion Height Relative Humidity: 64%
SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 24.1° C
Chemical Mass in Tank: 697,633 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil Ground Temperature: 24.1° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 287 kilograms/min
(averaged over a minute or more)
Total Amount Released: 13,175 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 51 meters.
THREAT ZONE:
Threat Modeled: Overpressure (blast force) from vapor cloud explosion
Type of Ignition: ignited by spark or flame
Level of Congestion: congested
Model Run: Heavy Gas
Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)
Orange: 32 meters --- (3.5 psi = serious injury likely)
Yellow: 55 meters --- (1.0 psi = shatters glass)

C. ALOHA Inputs for Scenario I for Autumn Season

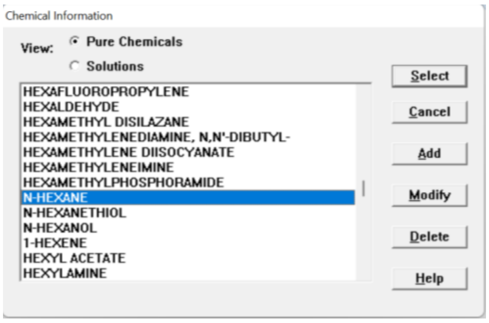
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



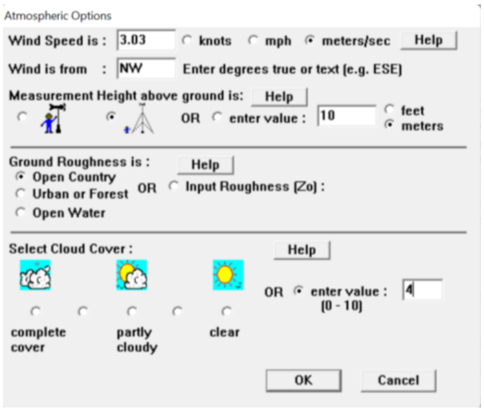
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

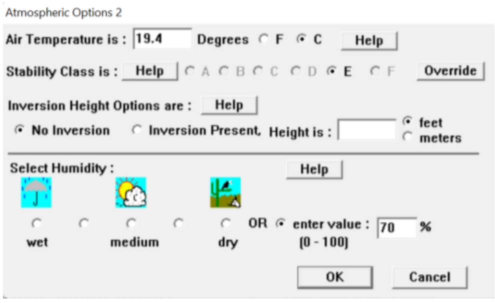


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

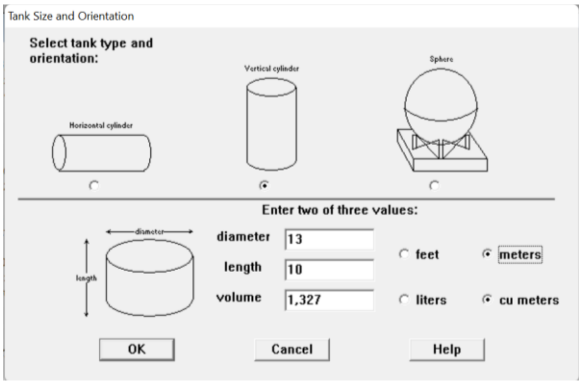


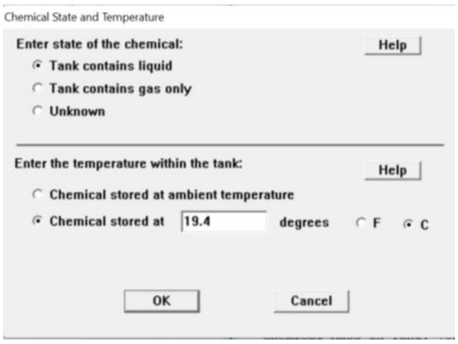
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the autumn season. For the autumn season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 4, the air temperature was obtained at 19.4 ° C. After all, the stability of the class was selected as E automatically. When no inversion for height was selected and humidity was entered as 70 %, inputs of atmospheric parameters were finished.

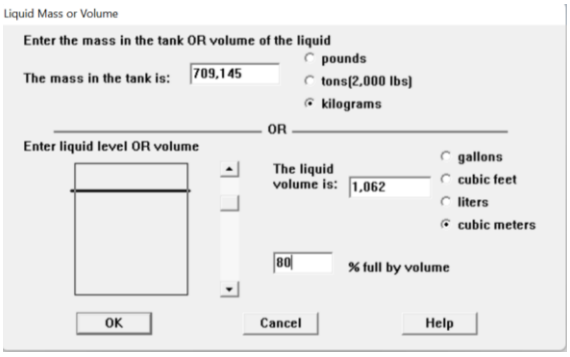




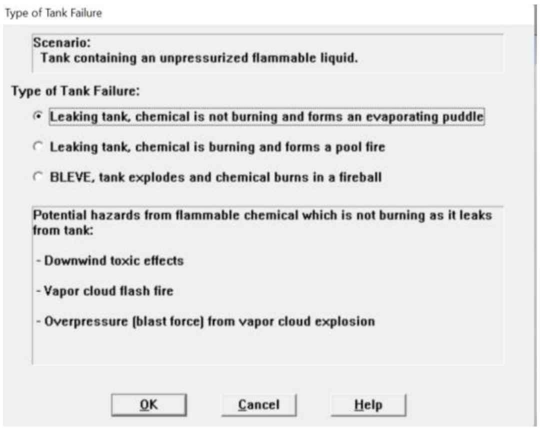
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



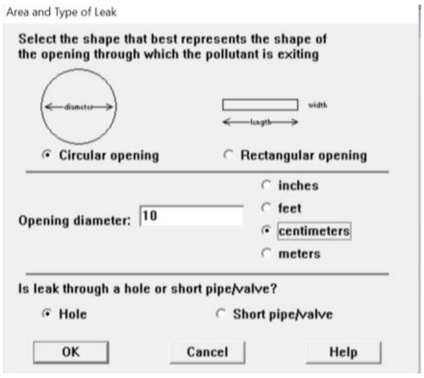


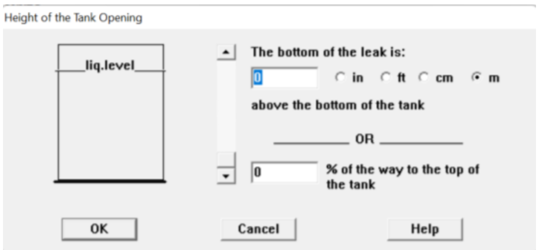


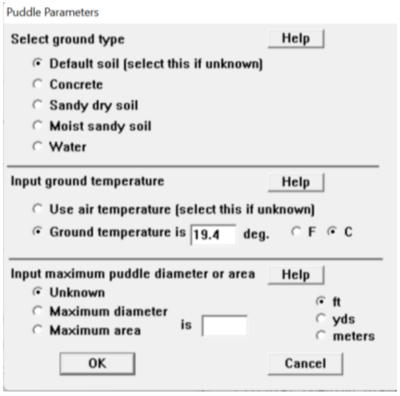
After the first scenario requirements, type of tank failure was selected as ‘leaking tank, chemical is not burning and forms an evaporating puddle’.



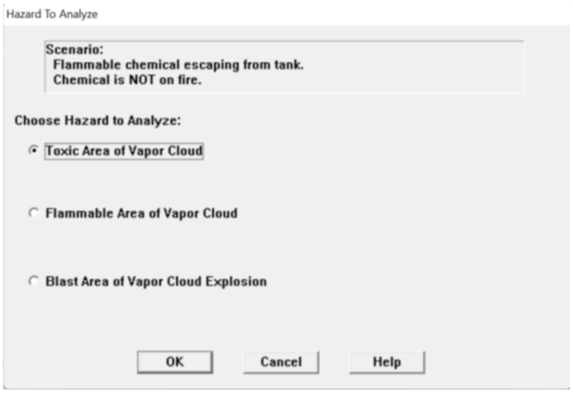
Based on scenario 1 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it’s the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.

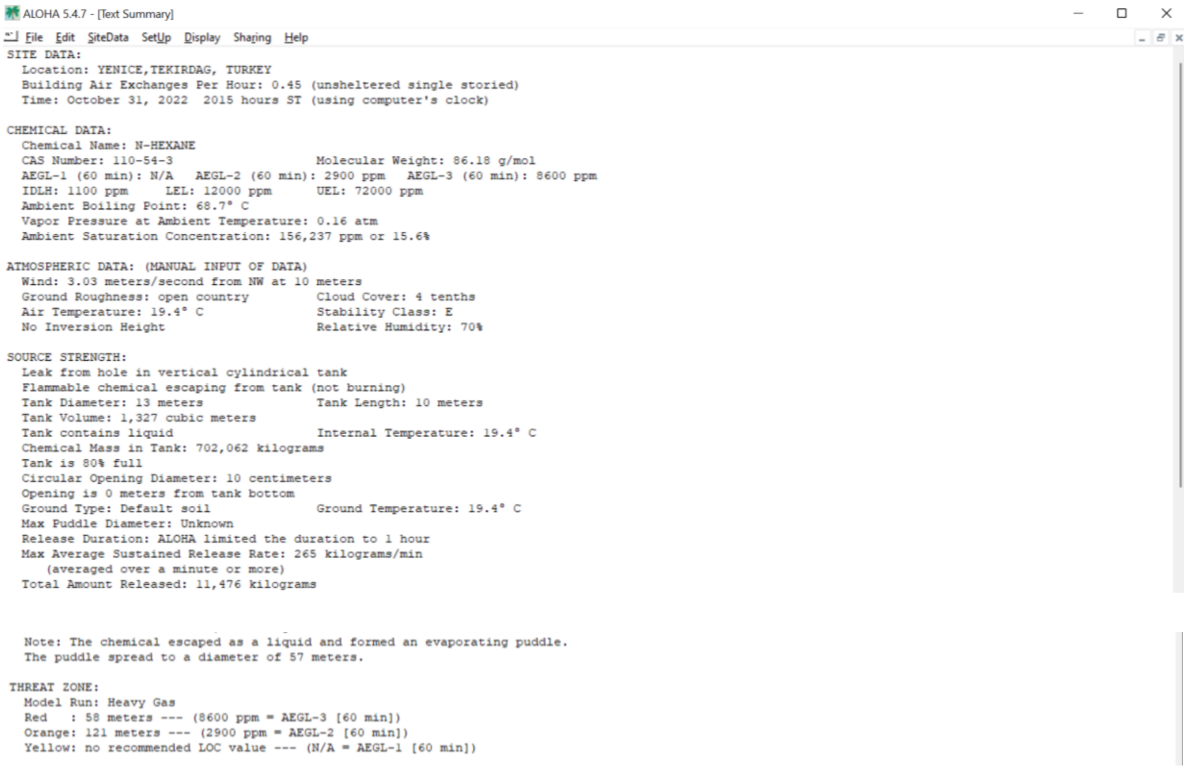






Threat zones as toxic area of vapor cloud, flammable area of vapor cloud and blast area of vapor cloud explosion were obtained in display part, and their toxic levels were highlighted according to thereat zones such as red, orange and yellow.





ALOHA 5.4.7 - [Text Summary]

File Edit SiteData SetUp Display Sharing Help

SITE DATA:
Location: YENICE,TEKIRDAG, TURKEY
Building Air Exchanges Per Hour: 0.45 (unsheltered single storied)
Time: October 31, 2022 2015 hours ST (using computer's clock)

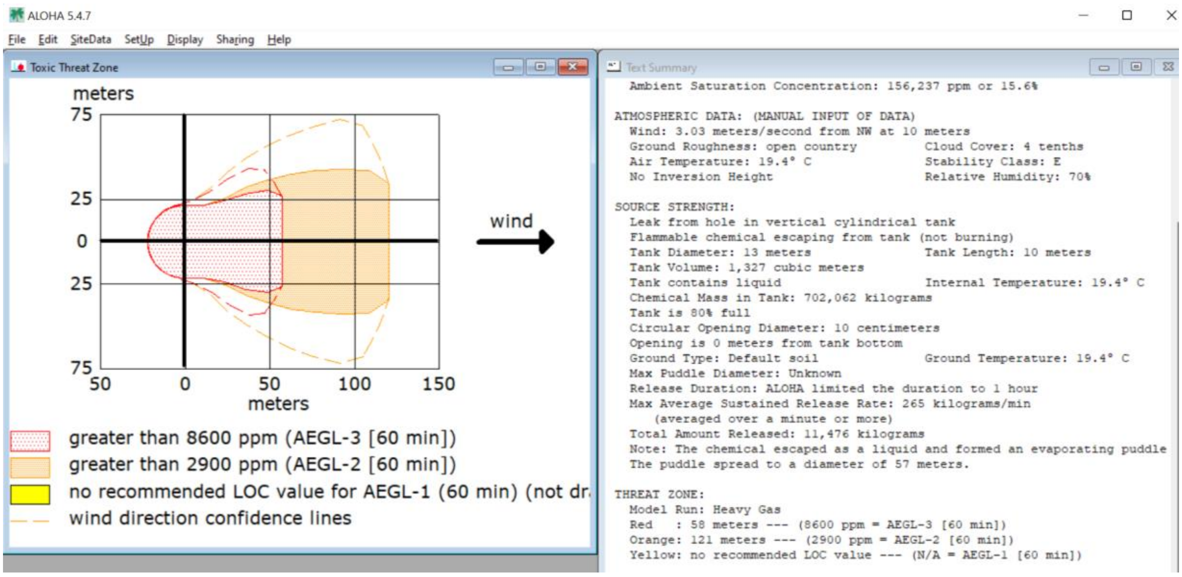
CHEMICAL DATA:
Chemical Name: N-HEXANE
CAS Number: 110-54-3 Molecular Weight: 86.18 g/mol
AEGL-1 (60 min): N/A AEGL-2 (60 min): 2900 ppm AEGL-3 (60 min): 8600 ppm
IDLH: 1100 ppm LEL: 12000 ppm UEL: 72000 ppm
Ambient Boiling Point: 68.7° C
Vapor Pressure at Ambient Temperature: 0.16 atm
Ambient Saturation Concentration: 156,237 ppm or 15.6%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.03 meters/second from NW at 10 meters
Ground Roughness: open country Cloud Cover: 4 tenths
Air Temperature: 19.4° C Stability Class: E
No Inversion Height Relative Humidity: 70%

SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 19.4° C
Chemical Mass in Tank: 702,062 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil Ground Temperature: 19.4° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 265 kilograms/min
(averaged over a minute or more)
Total Amount Released: 11,476 kilograms

Note: The chemical escaped as a liquid and formed an evaporating puddle.
The puddle spread to a diameter of 57 meters.

THREAT ZONE:
Model Run: Heavy Gas
Red : 58 meters --- (8600 ppm = AEGL-3 [60 min])
Orange: 121 meters --- (2900 ppm = AEGL-2 [60 min])
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

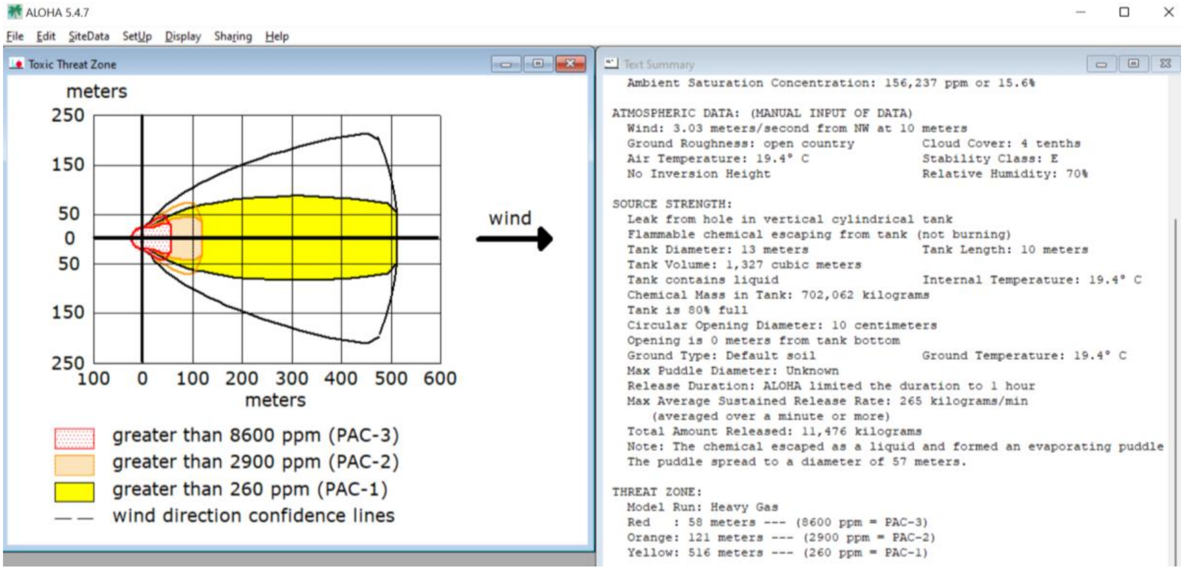


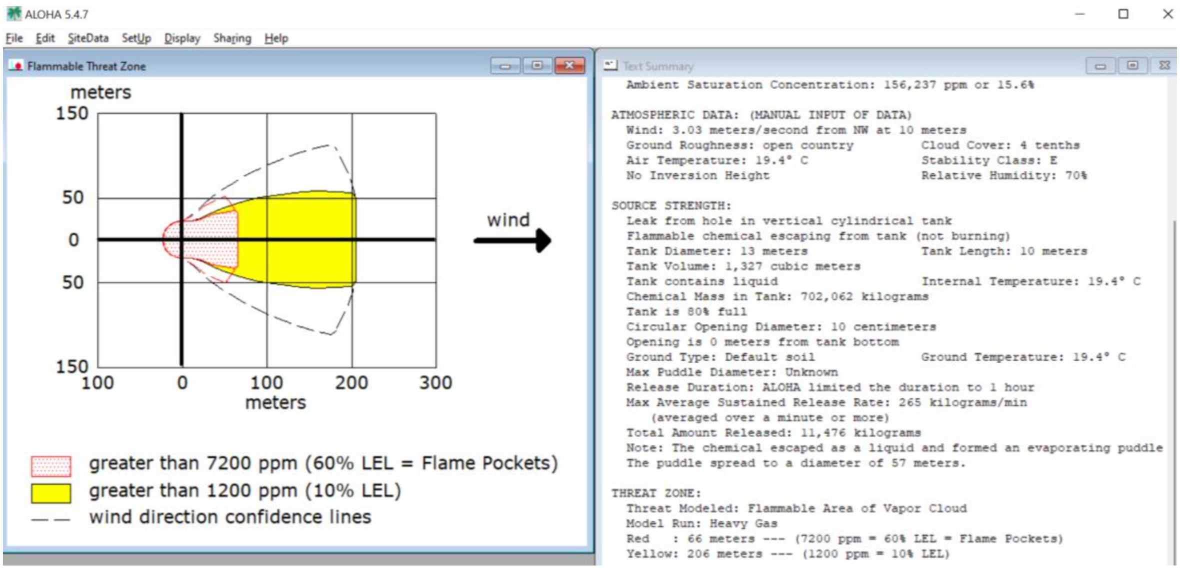
Ambient Saturation Concentration: 156,237 ppm or 15.6%

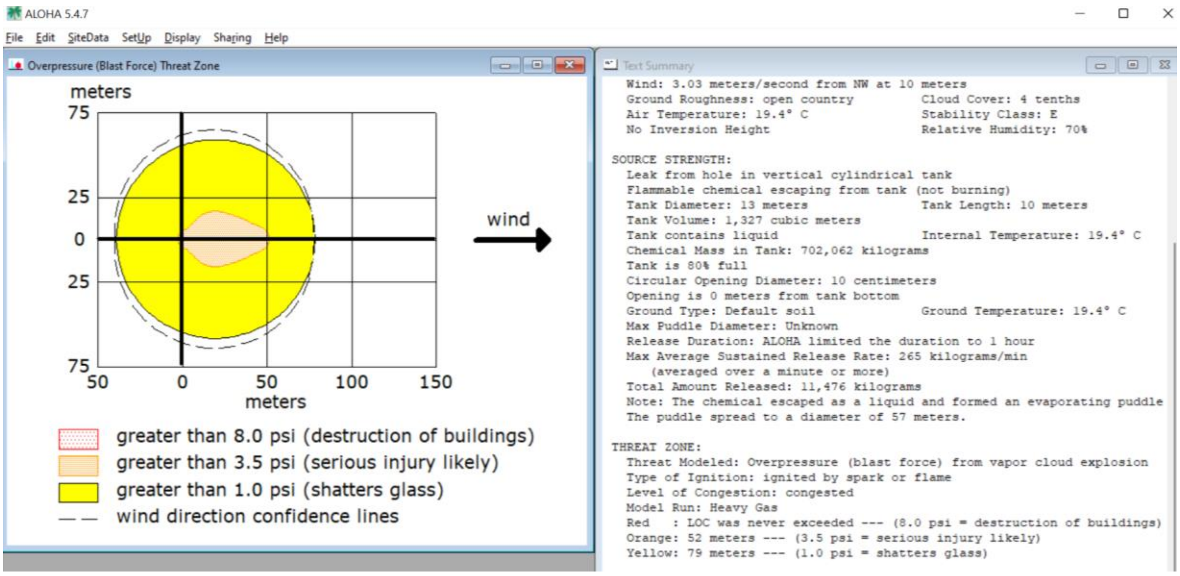
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.03 meters/second from NW at 10 meters
Ground Roughness: open country Cloud Cover: 4 tenths
Air Temperature: 19.4° C Stability Class: E
No Inversion Height Relative Humidity: 70%

SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid Internal Temperature: 19.4° C
Chemical Mass in Tank: 702,062 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil Ground Temperature: 19.4° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 265 kilograms/min
(averaged over a minute or more)
Total Amount Released: 11,476 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 57 meters.

THREAT ZONE:
Model Run: Heavy Gas
Red : 58 meters --- (8600 ppm = AEGL-3 [60 min])
Orange: 121 meters --- (2900 ppm = AEGL-2 [60 min])
Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])

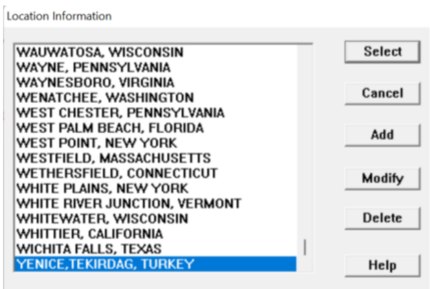

ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Toxic Threat Zone
meters
250
150
50
0
50
150
250
100 0 100 200 300 400 500 600
meters
wind
greater than 8600 ppm (PAC-3)
greater than 2900 ppm (PAC-2)
greater than 260 ppm (PAC-1)
wind direction confidence lines
Text Summary
Ambient Saturation Concentration: 156,237 ppm or 15.6%
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.03 meters/second from NW at 10 meters
Ground Roughness: open country
Cloud Cover: 4 tenths
Air Temperature: 19.4° C
Stability Class: E
No Inversion Height
Relative Humidity: 70%
SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters
Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid
Internal Temperature: 19.4° C
Chemical Mass in Tank: 702,062 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil
Ground Temperature: 19.4° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 265 kilograms/min
(averaged over a minute or more)
Total Amount Released: 11,476 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 57 meters.
THREAT ZONE:
Model Run: Heavy Gas
Red : 58 meters --- (8600 ppm = PAC-3)
Orange: 121 meters --- (2900 ppm = PAC-2)
Yellow: 516 meters --- (260 ppm = PAC-1)


ALOHA 5.4.7
File Edit SiteData SetUp Display Sharing Help
Flammable Threat Zone
meters
150
50
0
50
150
100 0 100 200 300
meters
wind
greater than 7200 ppm (60% LEL = Flame Pockets)
greater than 1200 ppm (10% LEL)
wind direction confidence lines
Text Summary
Ambient Saturation Concentration: 156,237 ppm or 15.6%
ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3.03 meters/second from NW at 10 meters
Ground Roughness: open country
Cloud Cover: 4 tenths
Air Temperature: 19.4° C
Stability Class: E
No Inversion Height
Relative Humidity: 70%
SOURCE STRENGTH:
Leak from hole in vertical cylindrical tank
Flammable chemical escaping from tank (not burning)
Tank Diameter: 13 meters
Tank Length: 10 meters
Tank Volume: 1,327 cubic meters
Tank contains liquid
Internal Temperature: 19.4° C
Chemical Mass in Tank: 702,062 kilograms
Tank is 80% full
Circular Opening Diameter: 10 centimeters
Opening is 0 meters from tank bottom
Ground Type: Default soil
Ground Temperature: 19.4° C
Max Puddle Diameter: Unknown
Release Duration: ALOHA limited the duration to 1 hour
Max Average Sustained Release Rate: 265 kilograms/min
(averaged over a minute or more)
Total Amount Released: 11,476 kilograms
Note: The chemical escaped as a liquid and formed an evaporating puddle
The puddle spread to a diameter of 57 meters.
THREAT ZONE:
Threat Modeled: Flammable Area of Vapor Cloud
Model Run: Heavy Gas
Red : 66 meters --- (7200 ppm = 60% LEL = Flame Pockets)
Yellow: 206 meters --- (1200 ppm = 10% LEL)

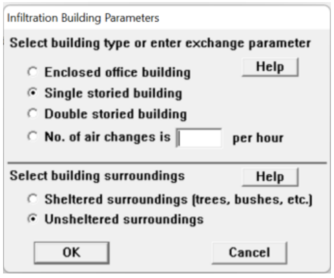


D. ALOHA Inputs for Scenario I for Winter Season

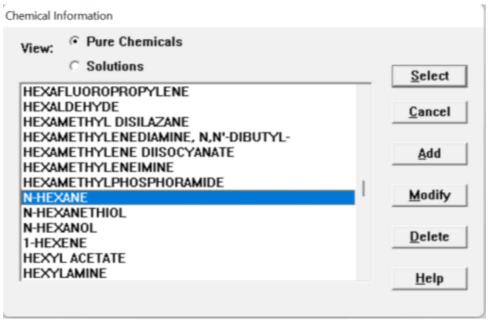
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



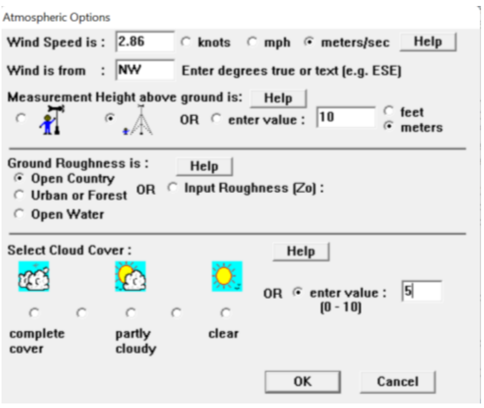
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

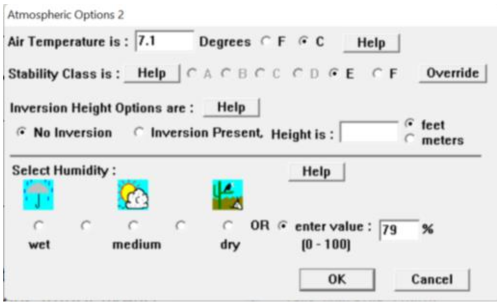


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

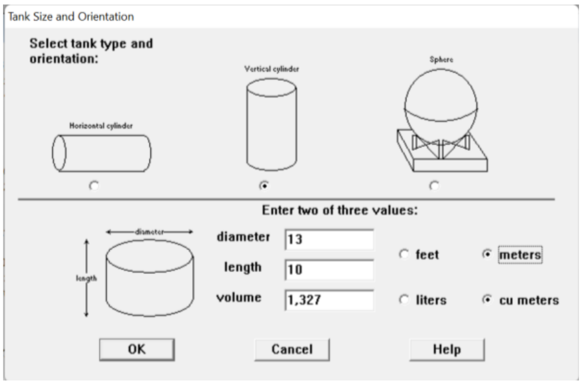


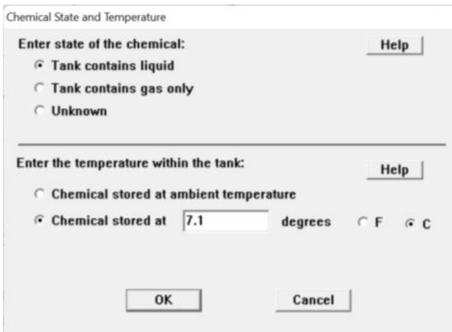
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the winter season. For the winter season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 5, the air temperature was obtained at 7.1 º C. After all, the stability of the class was selected as E automatically. When no inversion for height was selected and humidity was entered as 79 %, inputs of atmospheric parameters were finished.

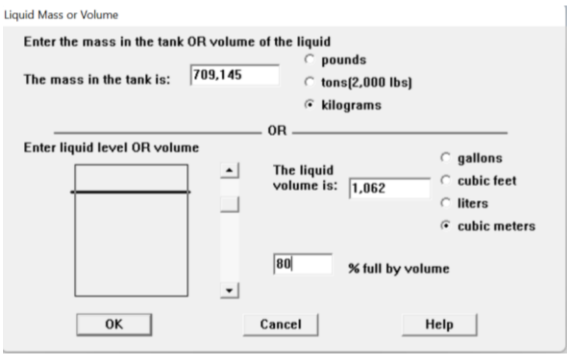




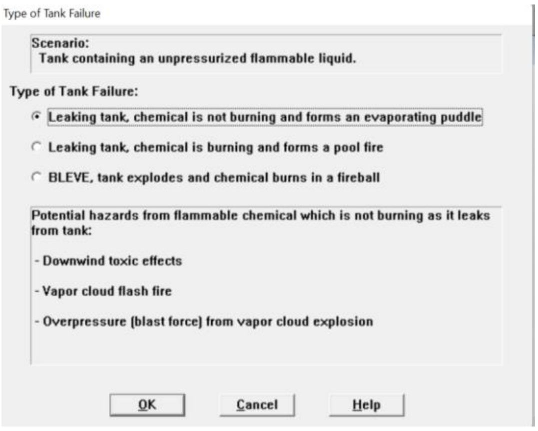
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



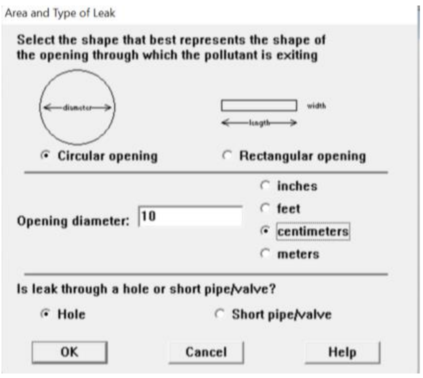


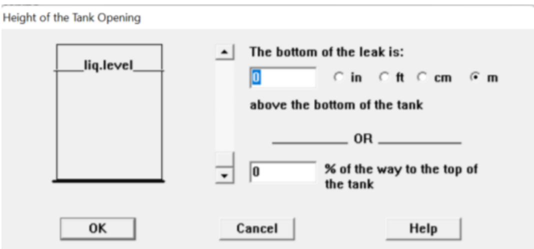


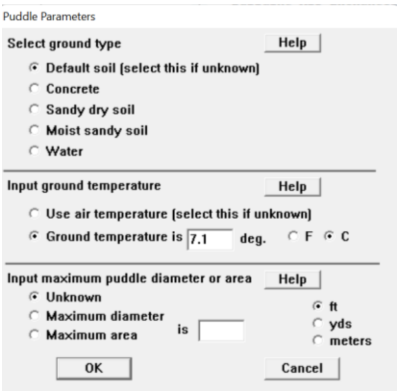
After the first scenario requirements, type of tank failure was selected as 'leaking tank, chemical is not burning and forms an evaporating puddle'.



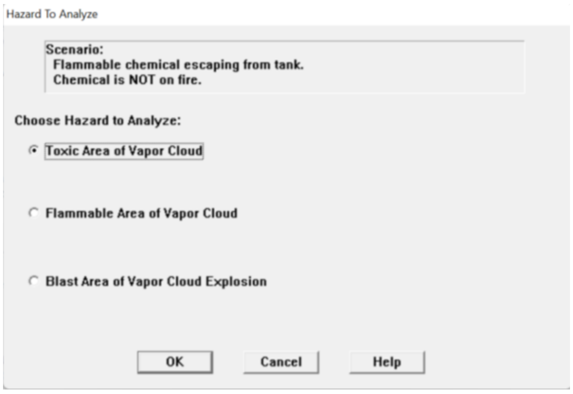
Based on scenario 1 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it's the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.





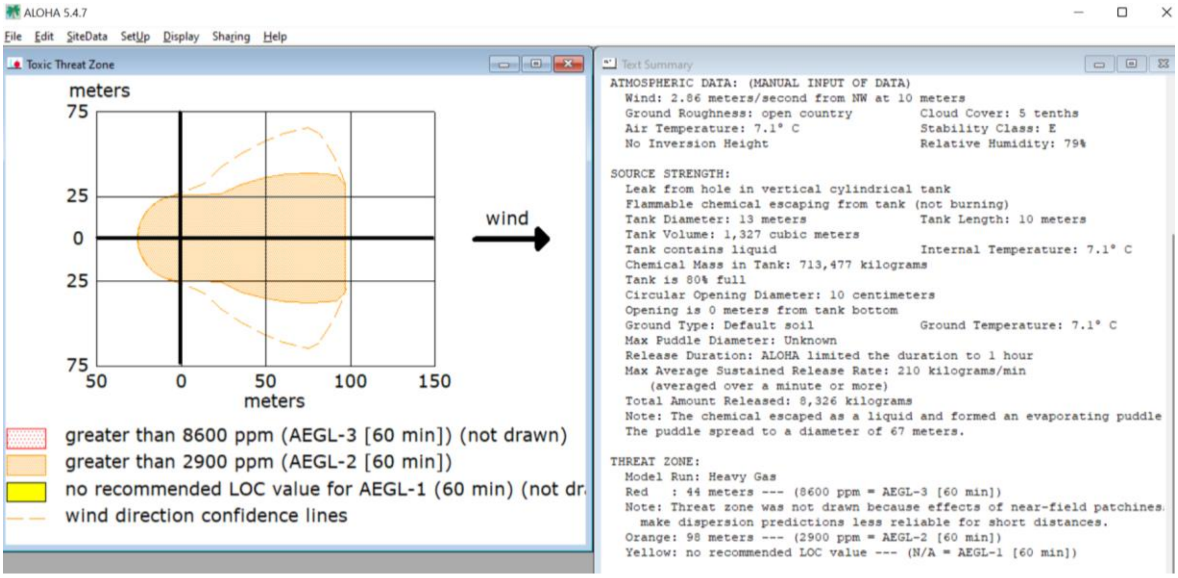


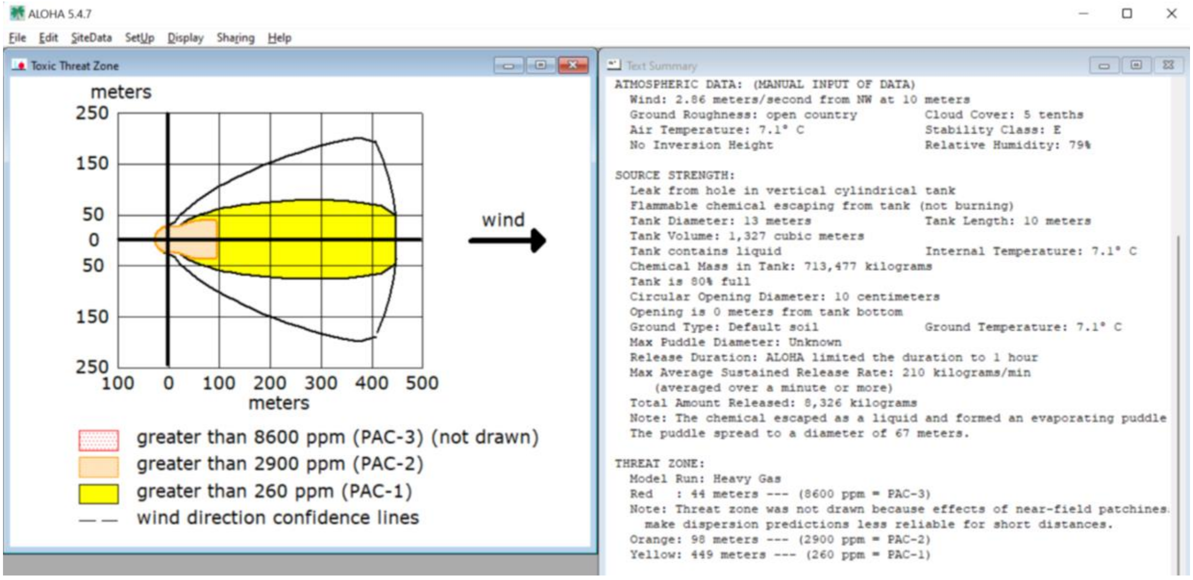
Threat zones as toxic area of vapor cloud, flammable area of vapor cloud and blast area of vapor cloud explosion were obtained in display part, and their toxic levels were highlighted according to thereat zones such as red, orange and yellow.

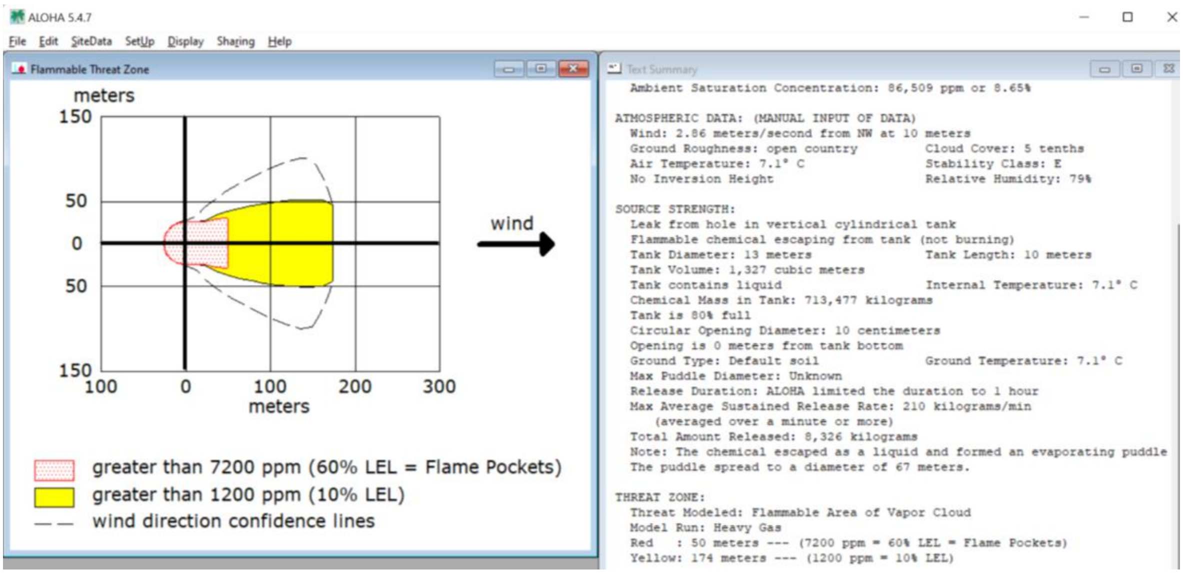


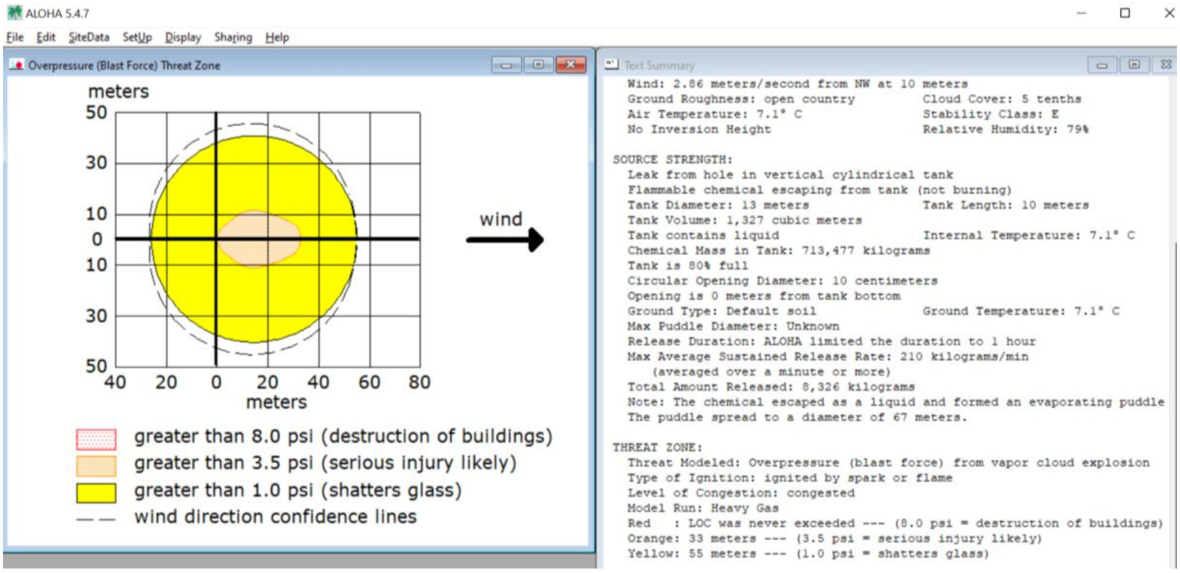

```
SITE DATA:
  Location: YENICE,TEKIRDAG, TURKEY
  Building Air Exchanges Per Hour: 0.56 (unsheltered single storied)
  Time: October 31, 2022  2045 hours ST (using computer's clock)

CHEMICAL DATA:
  Chemical Name: N-HEXANE
  CAS Number: 110-54-3                  Molecular Weight: 86.18 g/mol
  AEGL-1 (60 min): N/A   AEGL-2 (60 min): 2900 ppm   AEGL-3 (60 min): 8600 ppm
  IDLH: 1100 ppm     LEL: 12000 ppm      UEL: 72000 ppm
  Ambient Boiling Point: 68.7° C
  Vapor Pressure at Ambient Temperature: 0.086 atm
  Ambient Saturation Concentration: 86,509 ppm or 8.65%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 2.86 meters/second from NW at 10 meters
  Ground Roughness: open country         Cloud Cover: 5 tenths
  Air Temperature: 7.1° C                Stability Class: E
  No Inversion Height                    Relative Humidity: 79%

SOURCE STRENGTH:
  Leak from hole in vertical cylindrical tank
  Flammable chemical escaping from tank (not burning)
  Tank Diameter: 13 meters               Tank Length: 10 meters
  Tank Volume: 1,327 cubic meters
  Tank contains liquid                   Internal Temperature: 7.1° C
  Chemical Mass in Tank: 713,477 kilograms
  Tank is 80% full
  Circular Opening Diameter: 10 centimeters
  Opening is 0 meters from tank bottom
  Ground Type: Default soil              Ground Temperature: 7.1° C
  Max Puddle Diameter: Unknown
  Release Duration: ALOHA limited the duration to 1 hour
  Max Average Sustained Release Rate: 210 kilograms/min
     (averaged over a minute or more)
  Total Amount Released: 8,326 kilograms
```

```
  Note: The chemical escaped as a liquid and formed an evaporating puddle.
  The puddle spread to a diameter of 67 meters.

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 44 meters --- (8600 ppm = AEGL-3 [60 min])
  Note: Threat zone was not drawn because effects of near-field patchiness
    make dispersion predictions less reliable for short distances.
  Orange: 98 meters --- (2900 ppm = AEGL-2 [60 min])
  Yellow: no recommended LOC value --- (N/A = AEGL-1 [60 min])
```



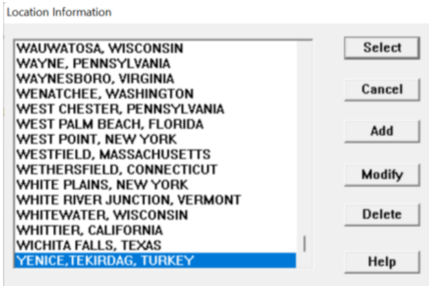




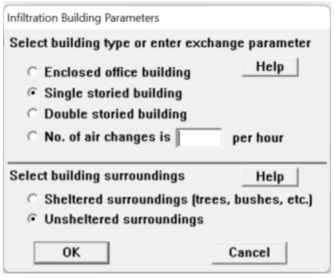


E. ALOHA Inputs for Scenario II for Spring Season

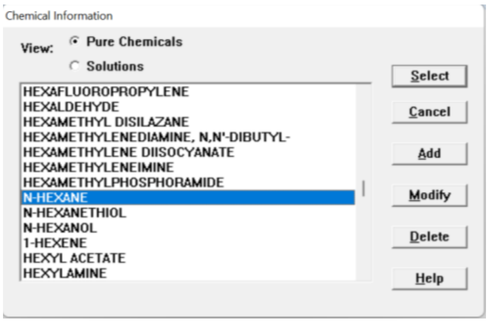
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



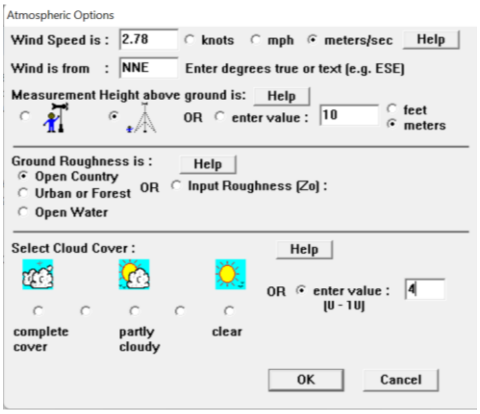
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

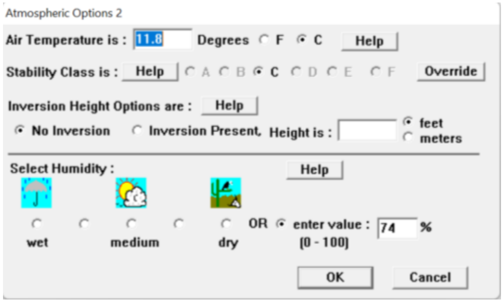


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

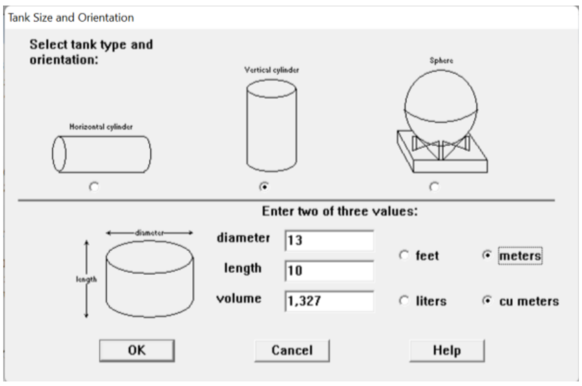


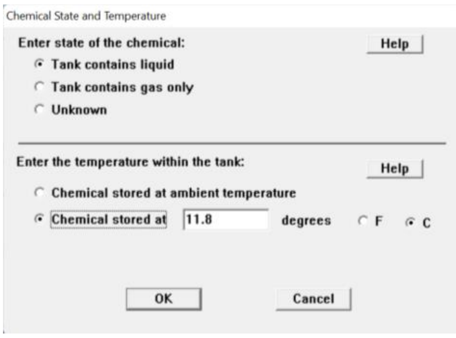
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the spring season. For the spring season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surroundings of the storage tank. Then, while the value of cloud cover was entered, the air temperature was obtained at 11.8 ° C. After all, the stability of the class was selected as C automatically. When no inversion for height was selected and humidity was entered as 74 %, inputs of atmospheric parameters were finished.

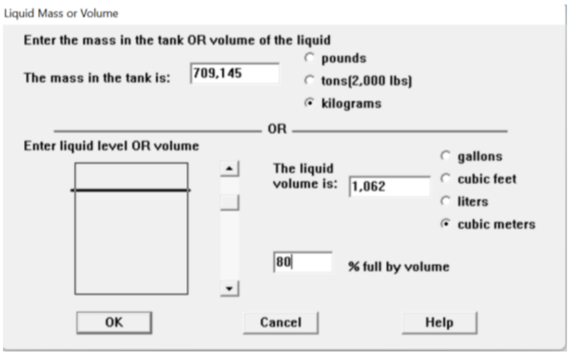




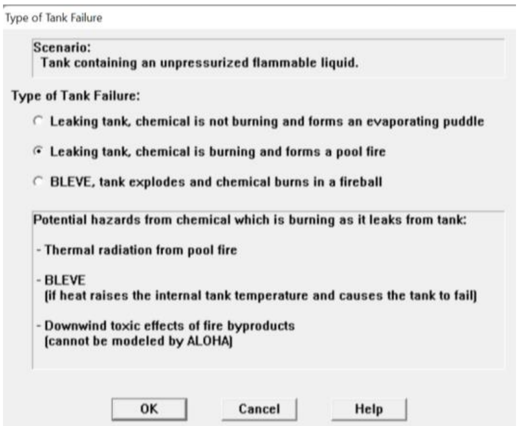
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



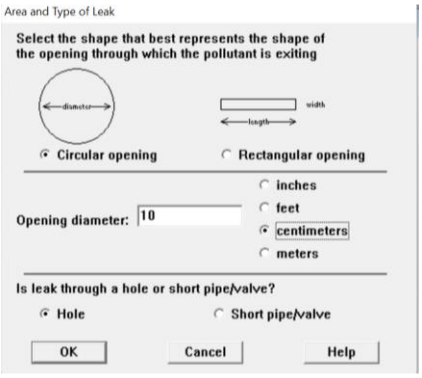


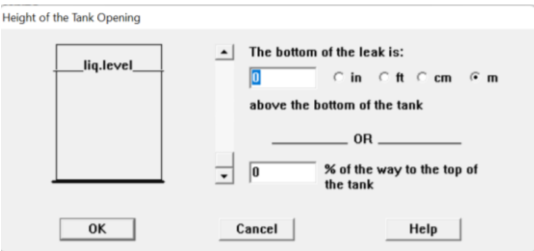


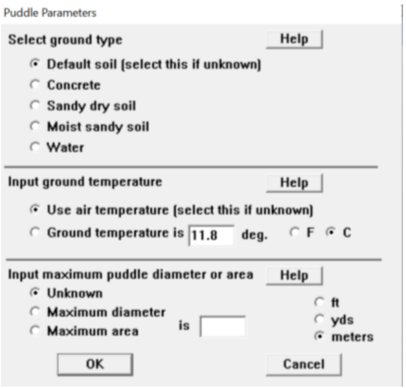
After the second scenario requirements, type of tank failure was selected as 'leaking tank, chemical is not burning and forms a pool fire'.



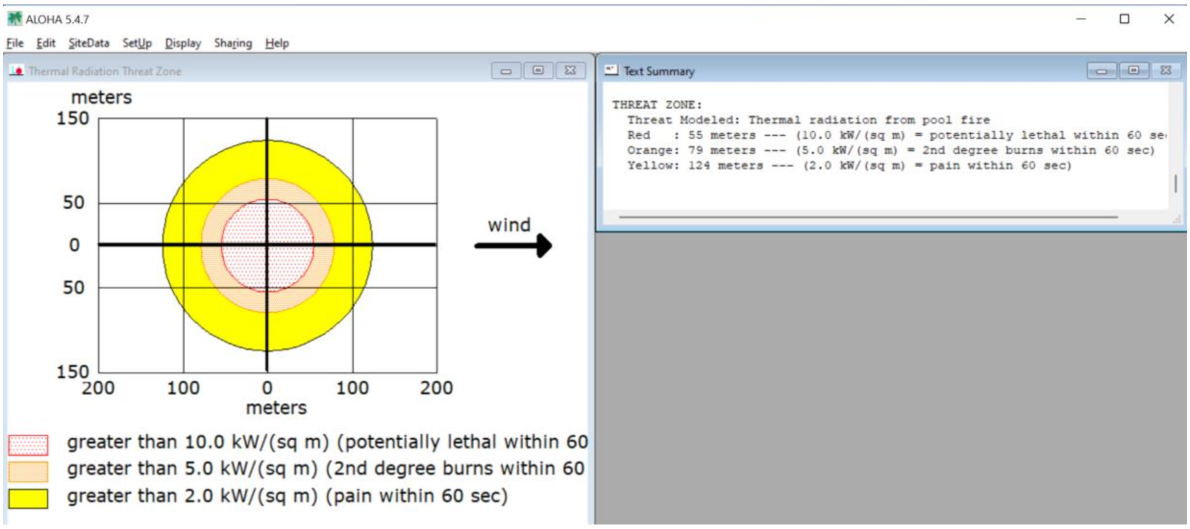
Based on scenario 2 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it's the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.





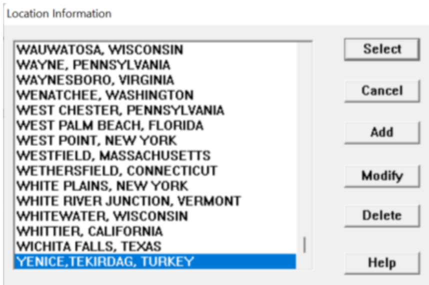


After selection of threat zone in display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange and yellow.

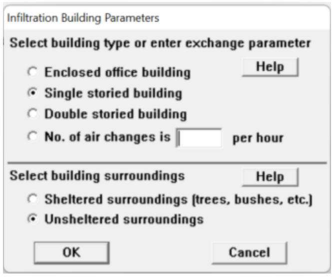


F. ALOHA Inputs for Scenario II for Summer Season

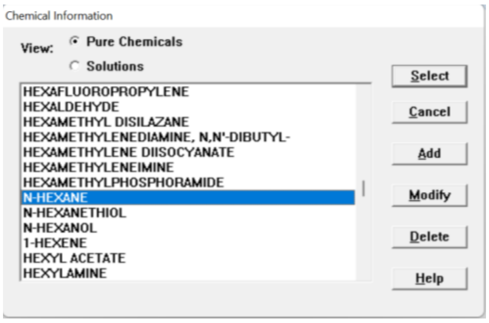
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



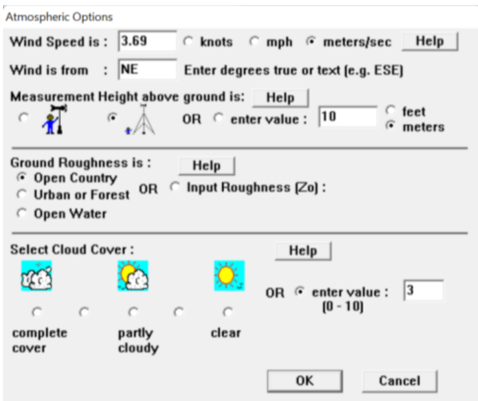
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

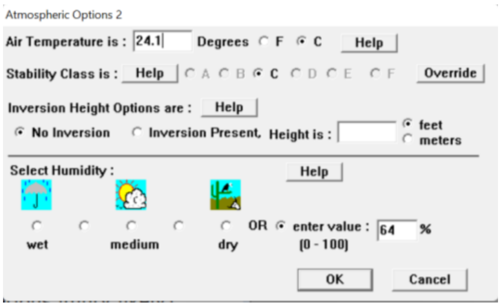


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

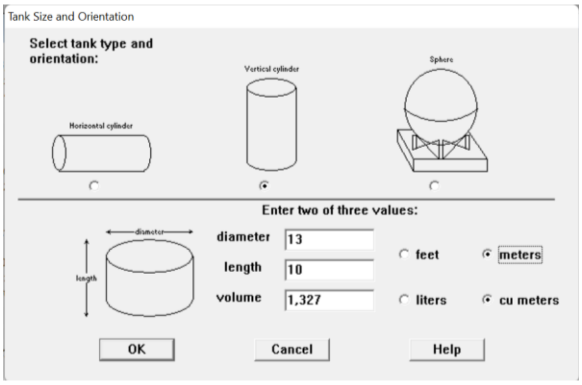


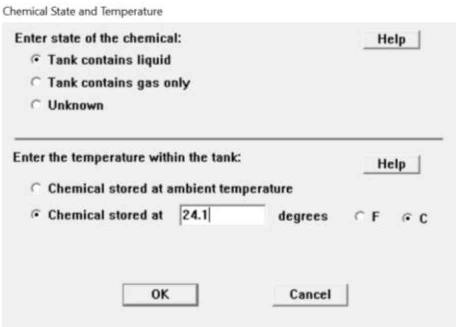
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the summer season. For the summer season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 3, the air temperature was obtained at 24.1 º C. After all, the stability of the class was selected as C automatically. When no inversion for height was selected and humidity was entered as 64 %, inputs of atmospheric parameters were finished.

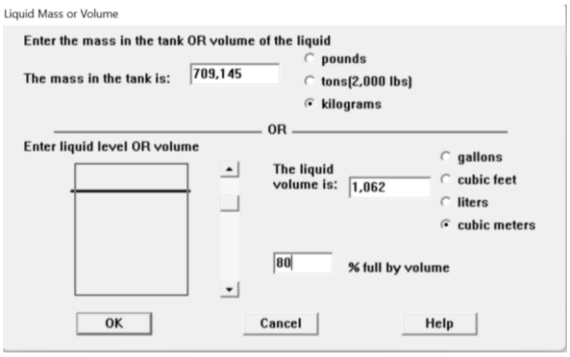




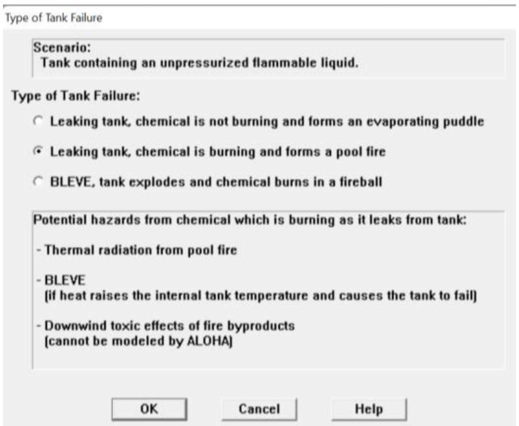
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



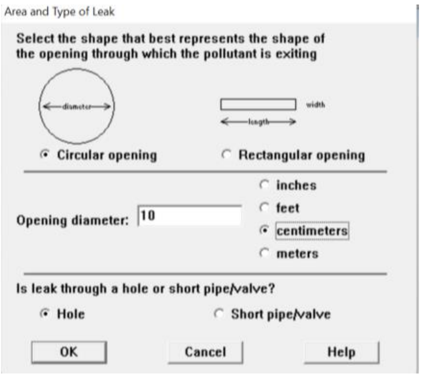


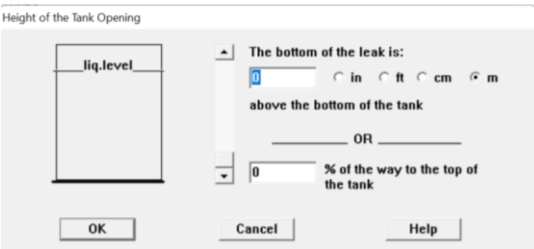


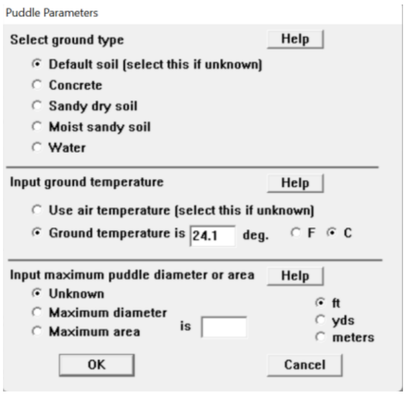
After the second scenario requirements, type of tank failure was selected as ‘leaking tank, chemical is not burning and forms a pool fire’.



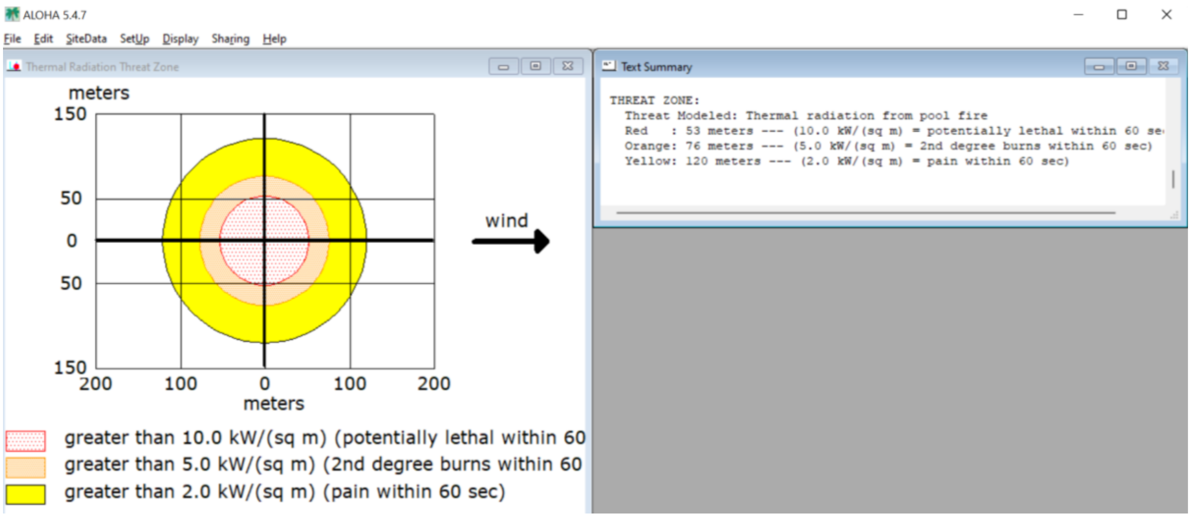
Based on scenario 2 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it’s the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.





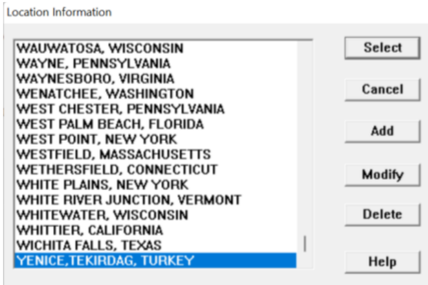


After selection of threat zone in display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange and yellow.

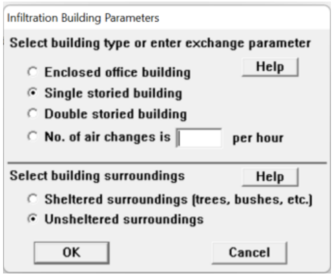


G. ALOHA Inputs for Scenario II for Autumn Season

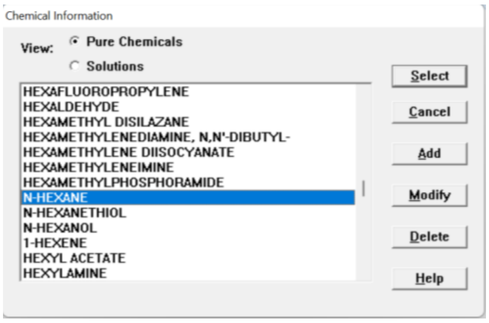
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



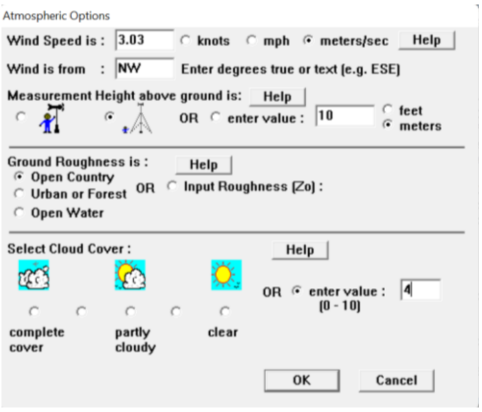
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

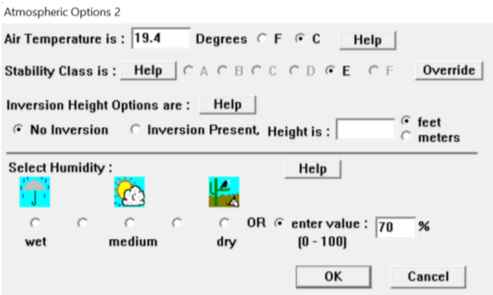


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

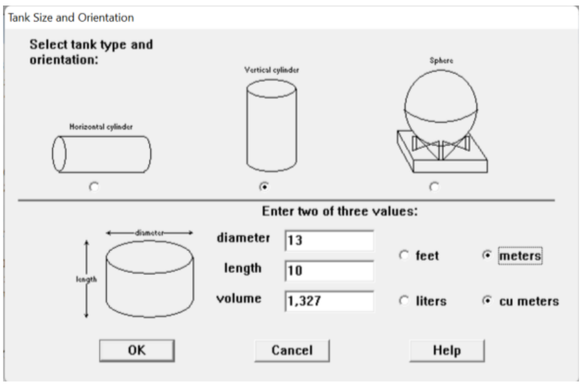


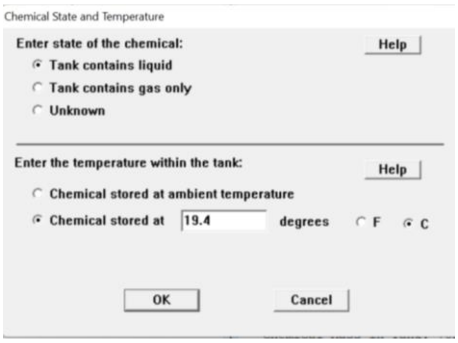
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the autumn season. For the autumn season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 4, the air temperature was obtained at 19.4 ° C. After all, the stability of the class was selected as E automatically. When no inversion for height was selected and humidity was entered as 70 %, inputs of atmospheric parameters were finished.

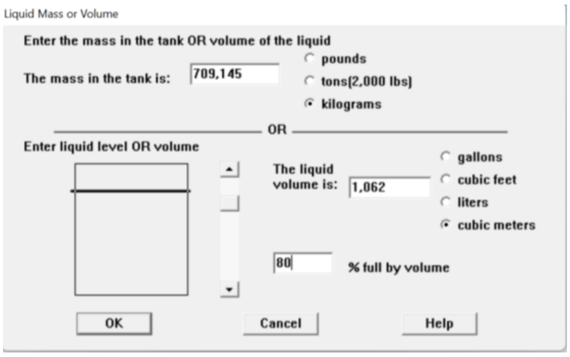




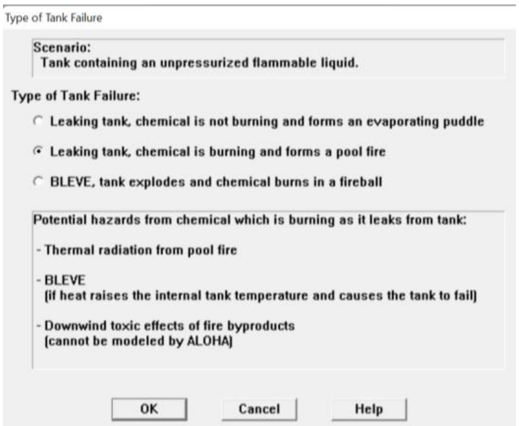
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



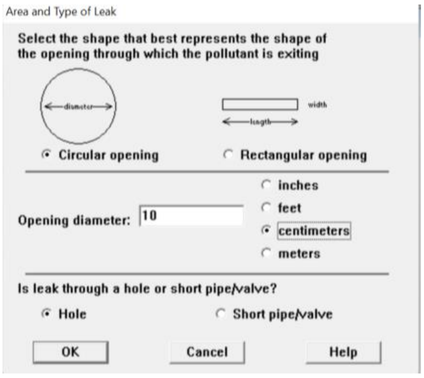


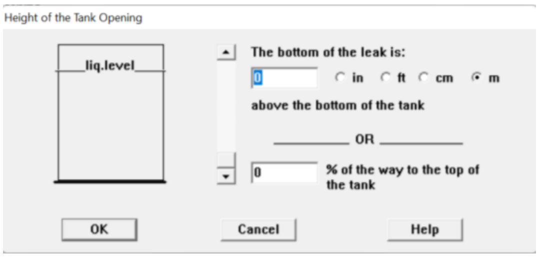


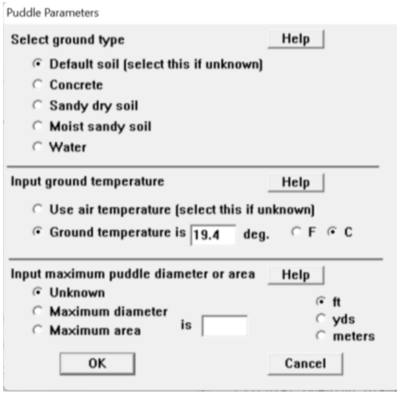
After the second scenario requirements, type of tank failure was selected as ‘leaking tank, chemical is not burning and forms an a pool fire’.



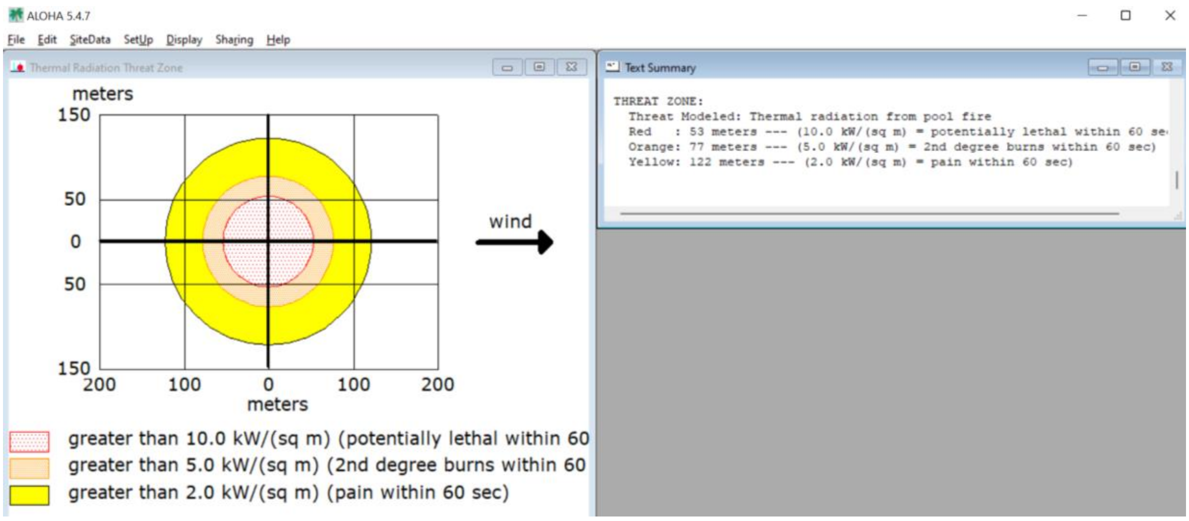
Based on scenario 2 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it’s the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.





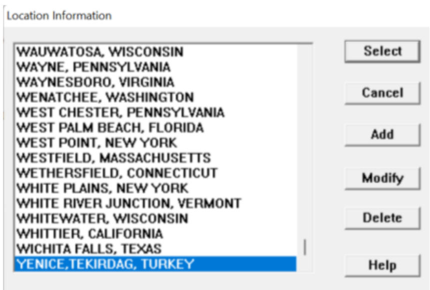


After selection of threat zone in display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange and yellow.

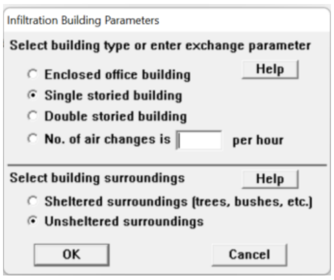


H. ALOHA Inputs for Scenario II for Winter Season

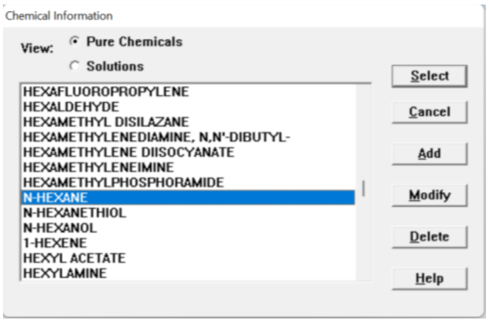
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



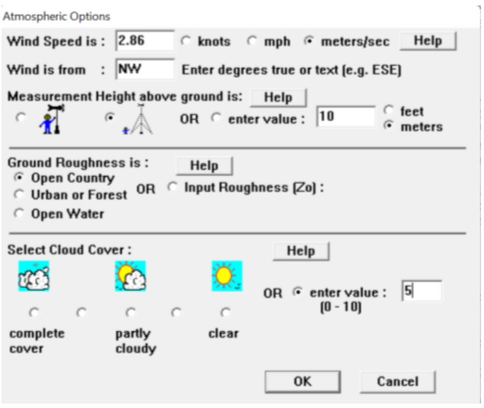
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

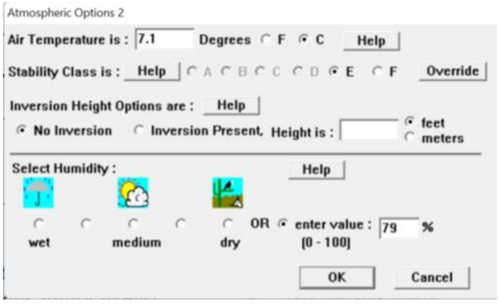


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

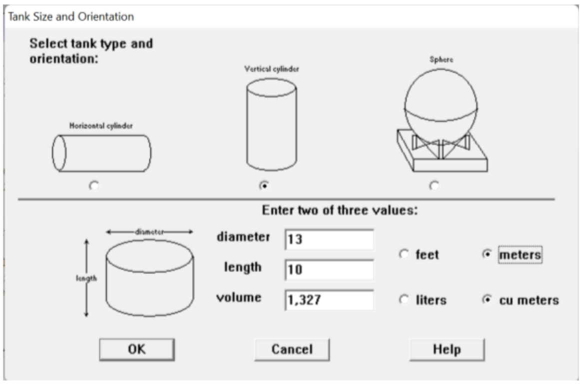


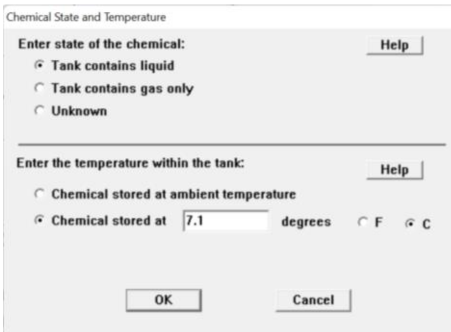
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the winter season. For the winter season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 5, the air temperature was obtained at 7.1 º C. After all, the stability of the class was selected as E automatically. When no inversion for height was selected and humidity was entered as 79 %, inputs of atmospheric parameters were finished.

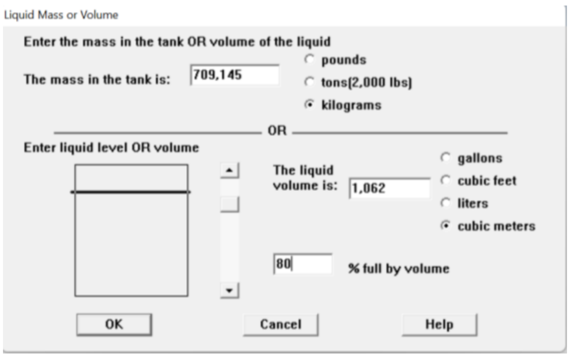




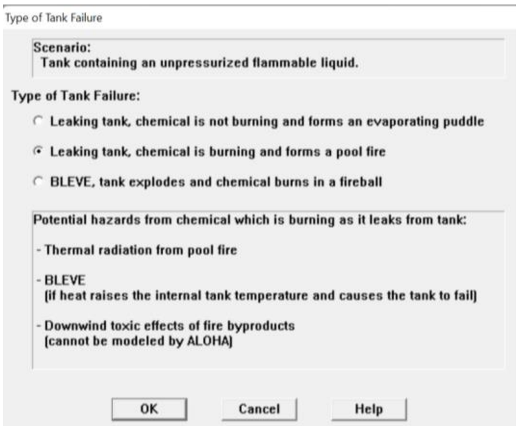
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



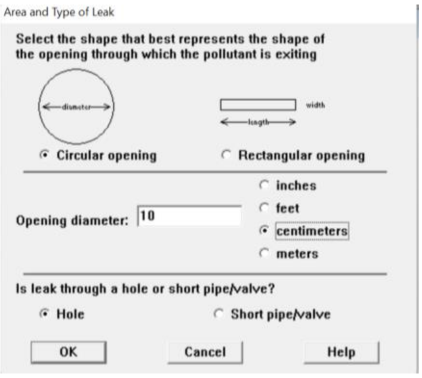


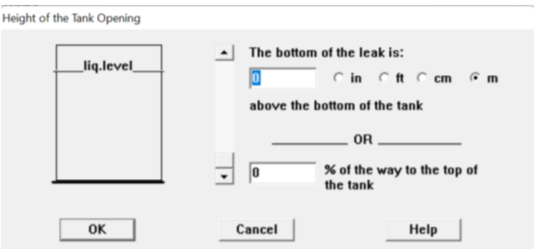


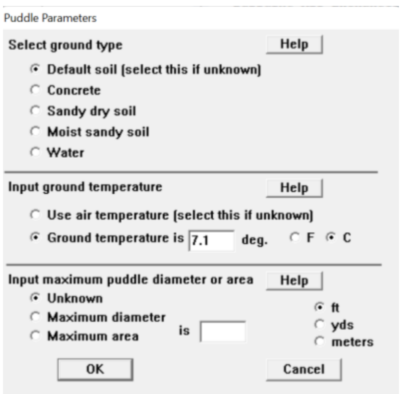
After the second scenario requirements, type of tank failure was selected as ‘leaking tank, chemical is not burning and forms an a pool fire’.

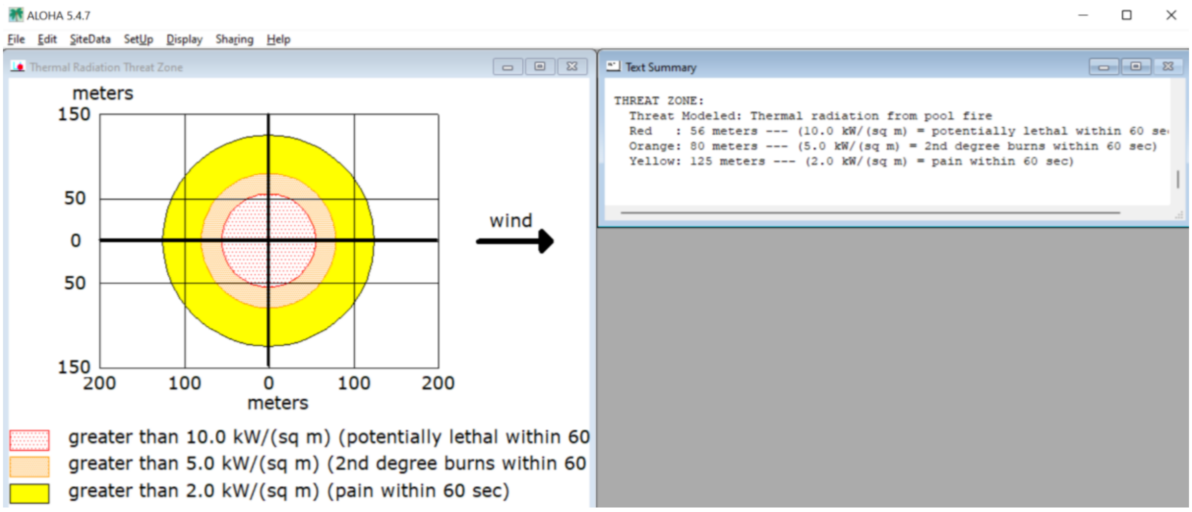


Based on scenario 2 and its failure type, opening was selected as circular, and its diameter was 10 cm through a hole. Also, it’s the bottom of leak was entered as 0 m above bottom of the tank. Then, puddle parameters were identified.



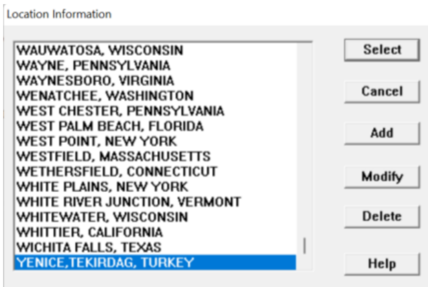




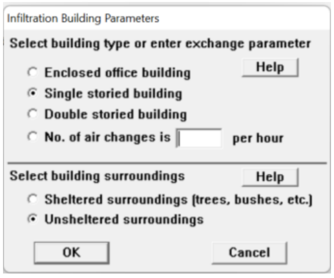


İ. ALOHA Inputs for Scenario III for Spring Season

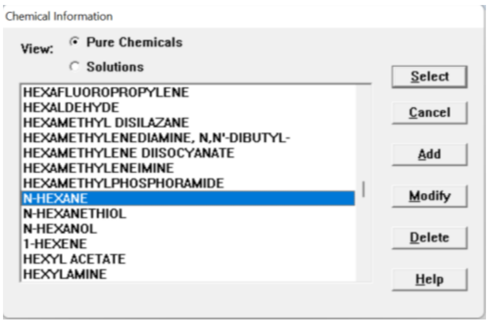
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



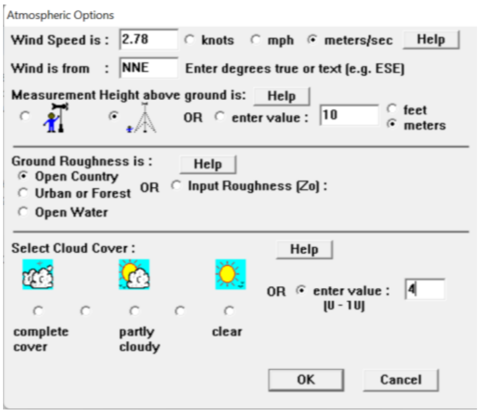
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

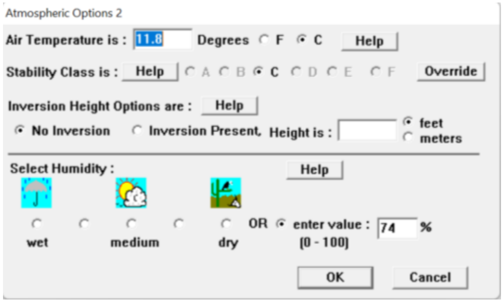


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

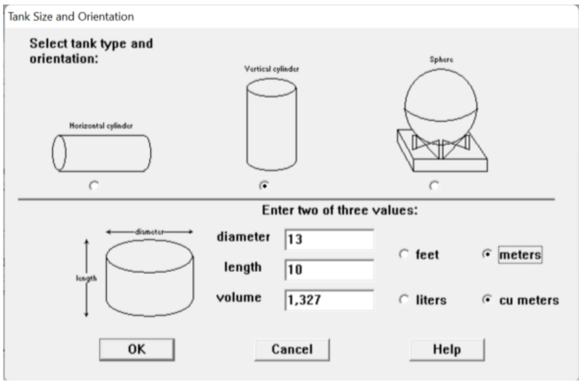


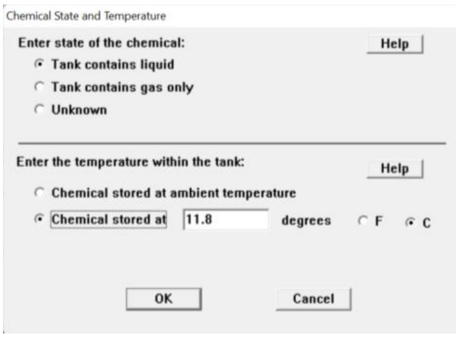
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the spring season. For the spring season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surroundings of the storage tank. Then, while the value of cloud cover was entered, the air temperature was obtained at 11.8 ° C. After all, the stability of the class was selected as C automatically. When no inversion for height was selected and humidity was entered as 74 %, inputs of atmospheric parameters were finished.

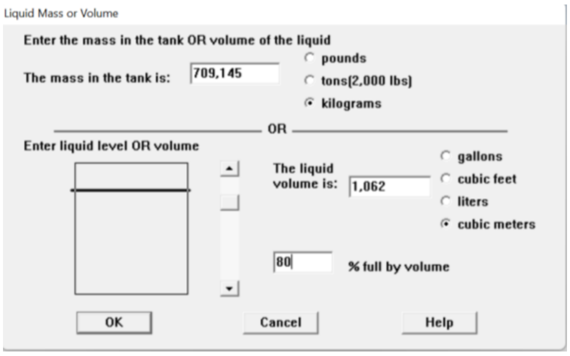




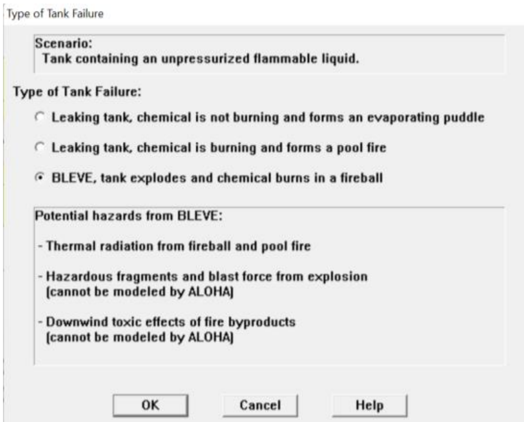
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



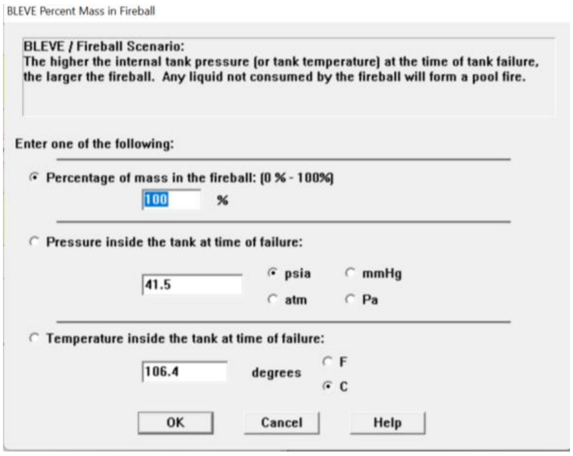




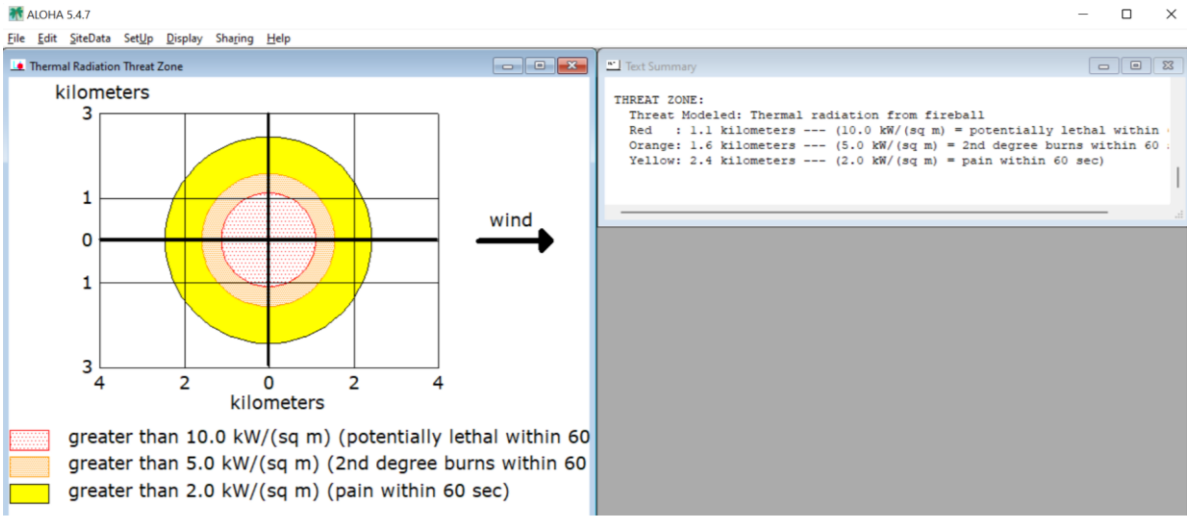
After the third scenario requirements, type of tank failure was selected as 'BLEVE, tank explodes and chemical burns in a fireball'.



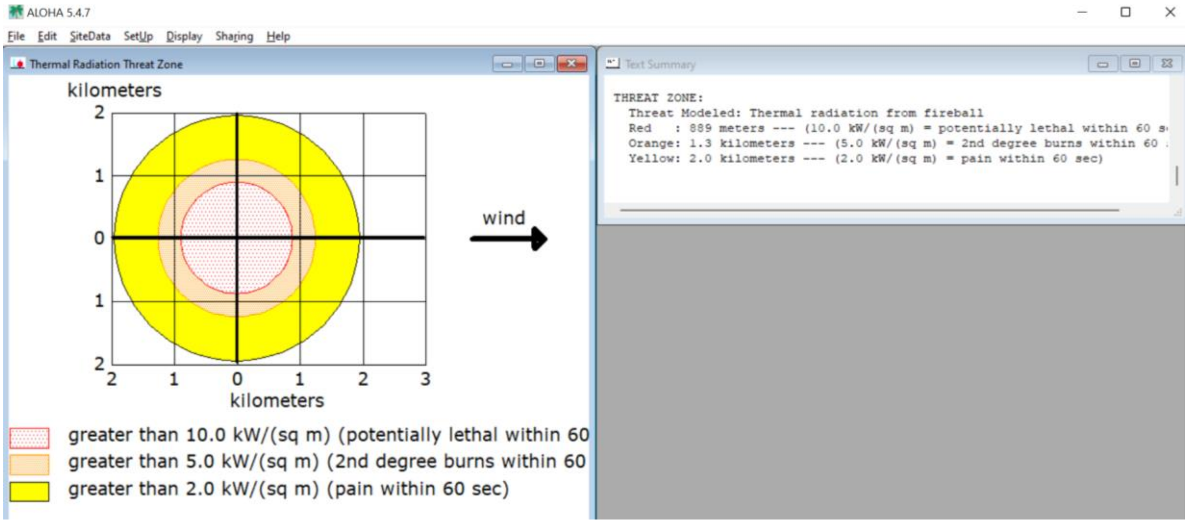
Based on scenario 3 and its failure type as BLEVE/ fireball scenario, the percentage of mass in the fireball was selected with its maximum value as 100 %.



After the selection of the threat zone in the display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange, and yellow.

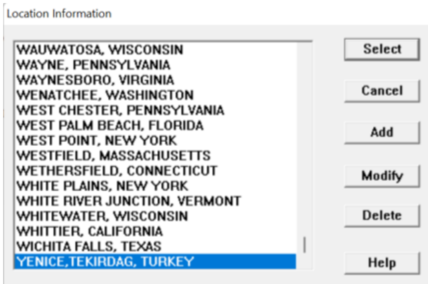


Also, the same procedure was repeated for the percentage of mass in the fireball was selected with a value of 50 % to compare it with the maximum level.

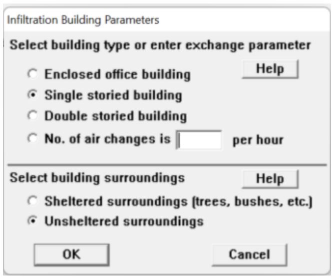


J. ALOHA Inputs for Scenario III for Summer Season

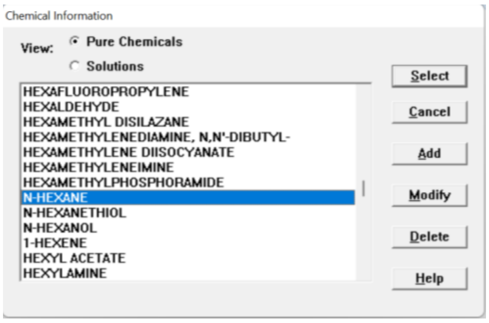
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



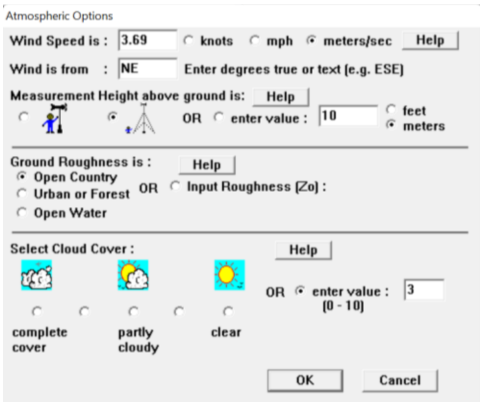
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

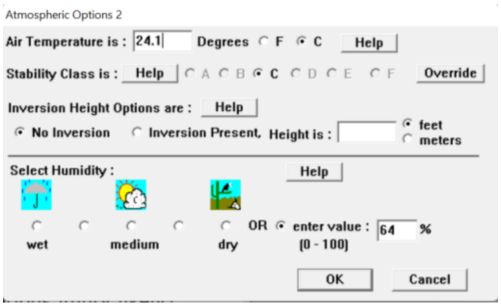


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

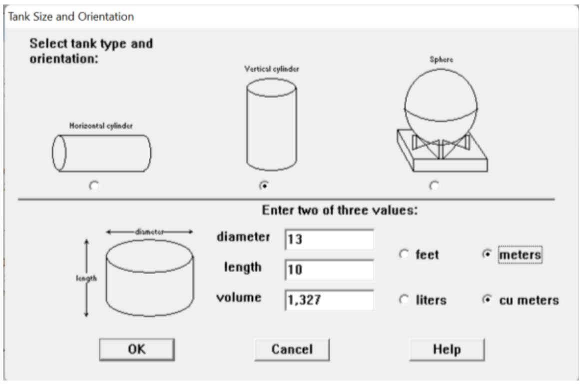


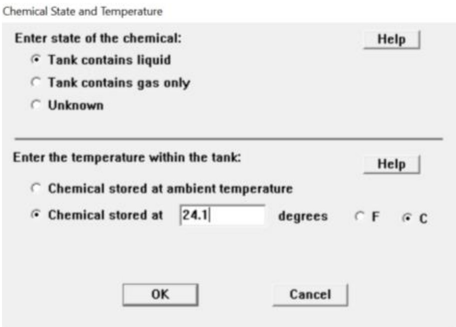
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the summer season. For the summer season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 3, the air temperature was obtained at 24.1 º C. After all, the stability of the class was selected as C automatically. When no inversion for height was selected and humidity was entered as 64 %, inputs of atmospheric parameters were finished.

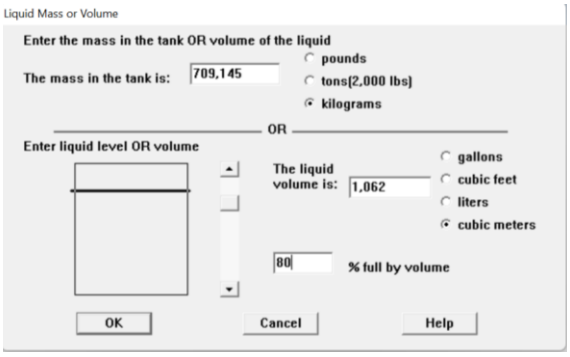




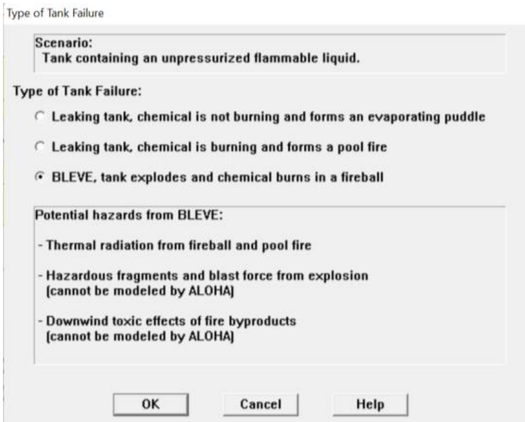
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



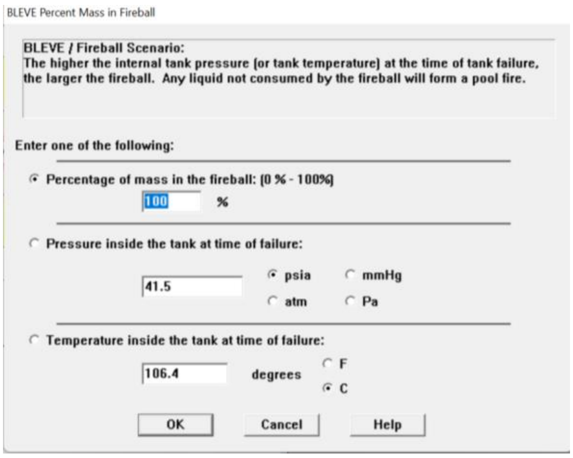




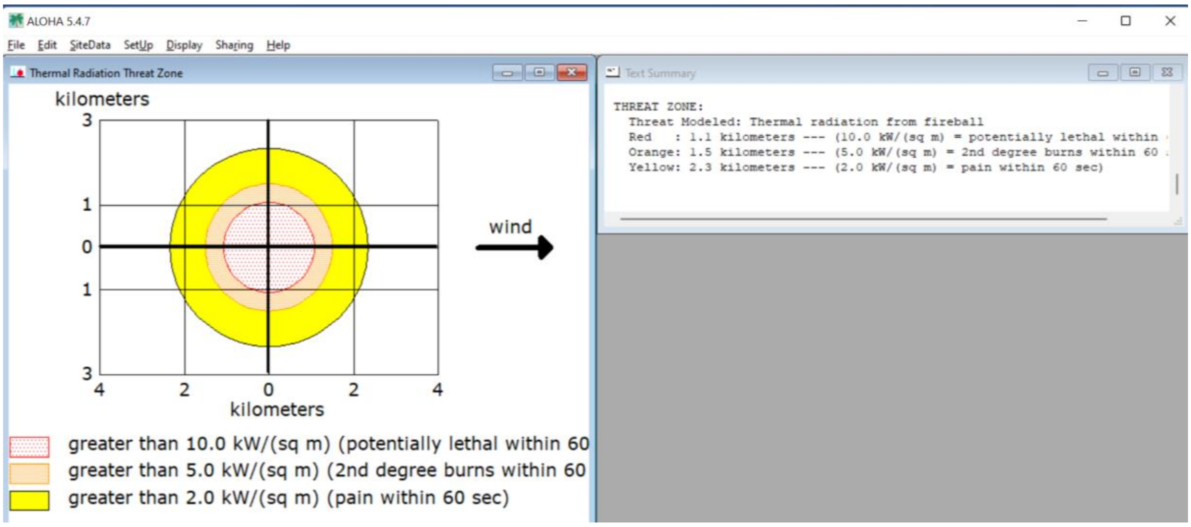
After the third scenario requirements, type of tank failure was selected as 'BLEVE, tank explodes and chemical burns in a fireball'.



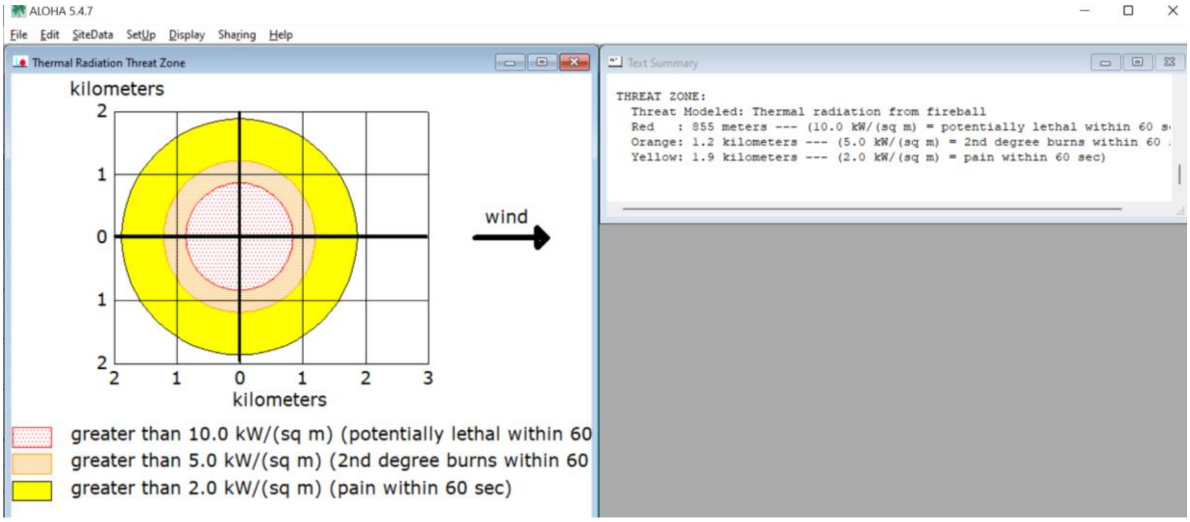
Based on scenario 3 and its failure type as BLEVE/ fireball scenario, the percentage of mass in the fireball was selected with its maximum value as 100 %.



After the selection of the threat zone in the display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange, and yellow.

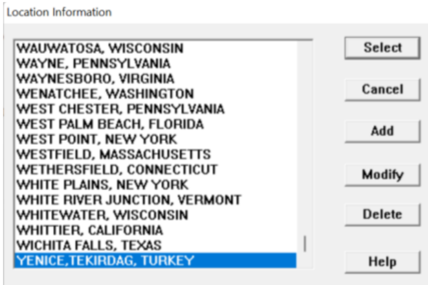


Also, the same procedure was repeated for the percentage of mass in the fireball was selected with a value of 50 % to compare it with the maximum level.

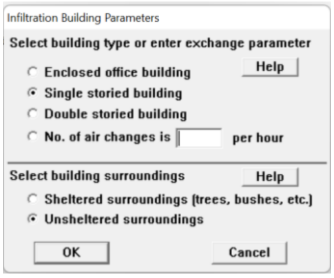


K. ALOHA Inputs for Scenario III for Autumn Season

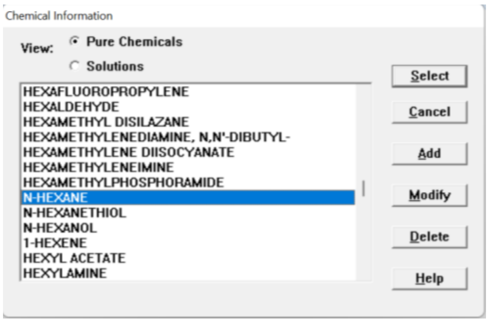
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



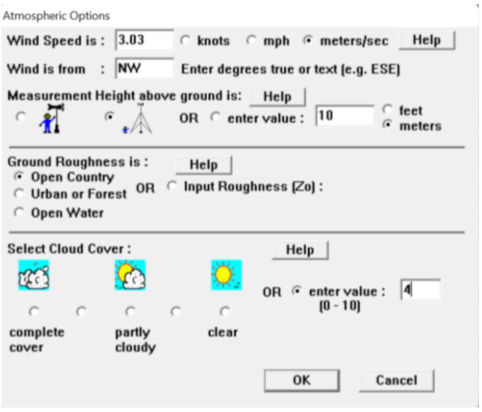
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

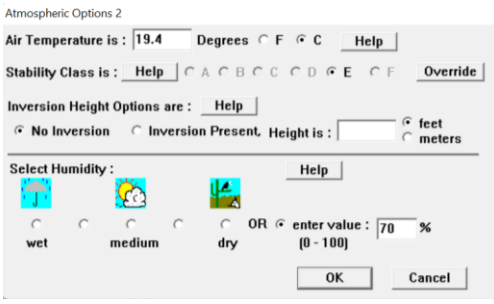


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

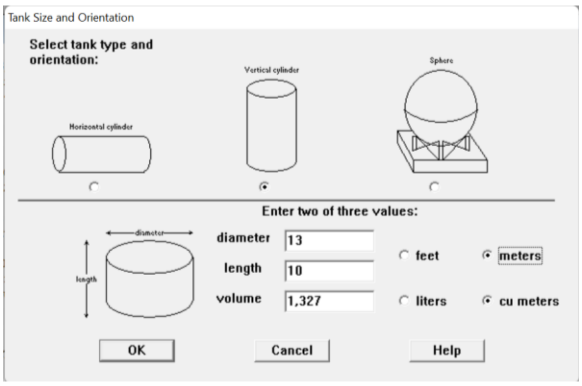


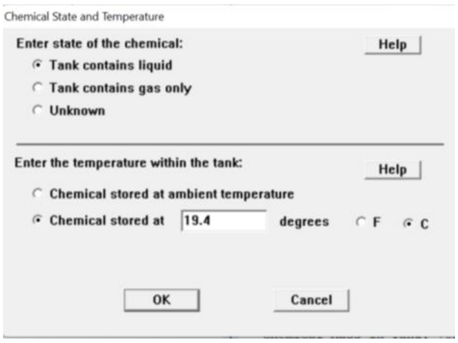
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the autumn season. For the autumn season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 4, the air temperature was obtained at 19.4 ° C. After all, the stability of the class was selected as E automatically. When no inversion for height was selected and humidity was entered as 70 %, inputs of atmospheric parameters were finished.

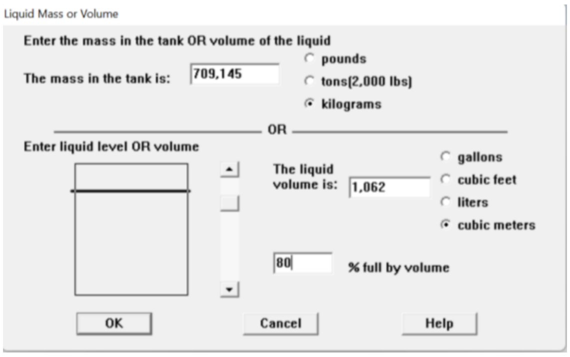




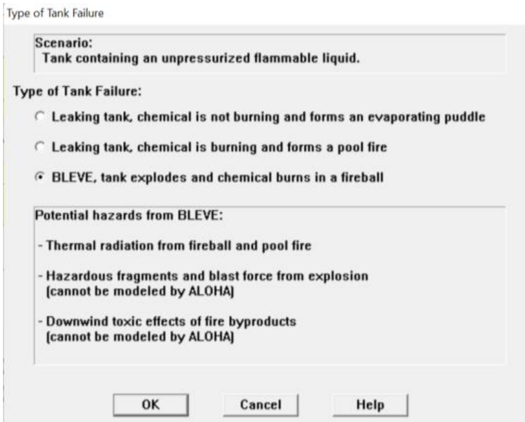
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



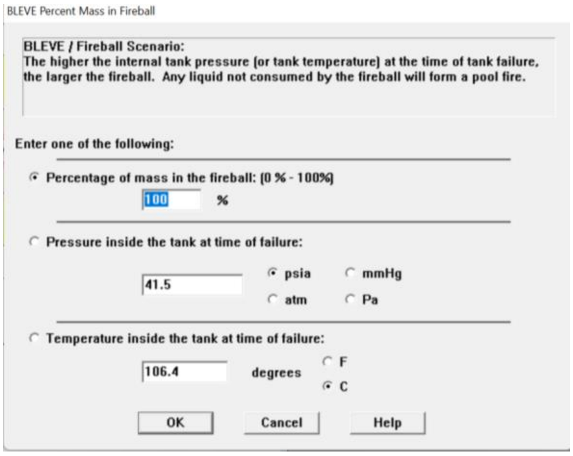




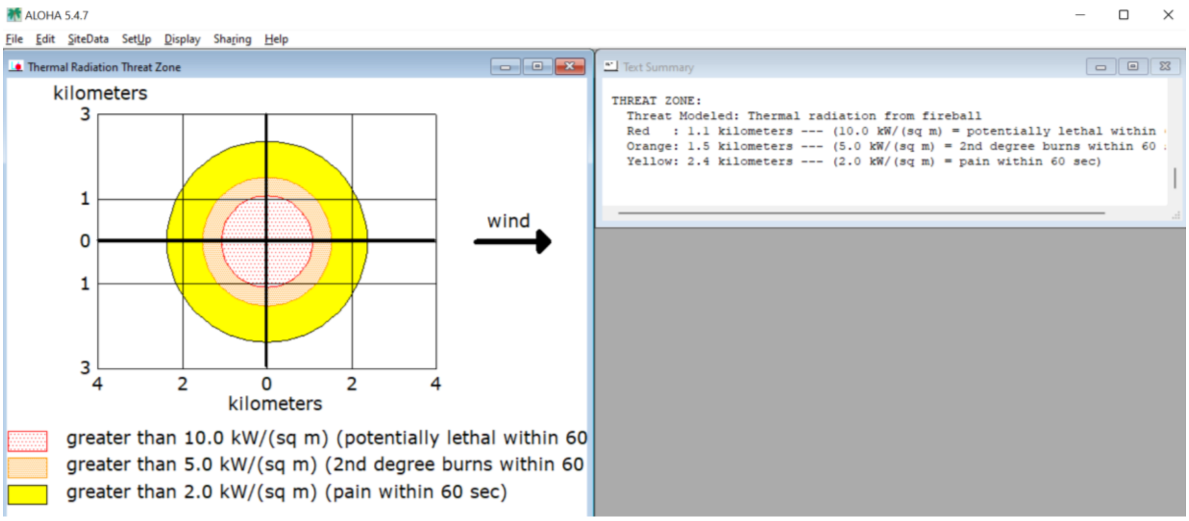
After the third scenario requirements, type of tank failure was selected as ‘BLEVE, tank explodes and chemical burns in a fireball’.



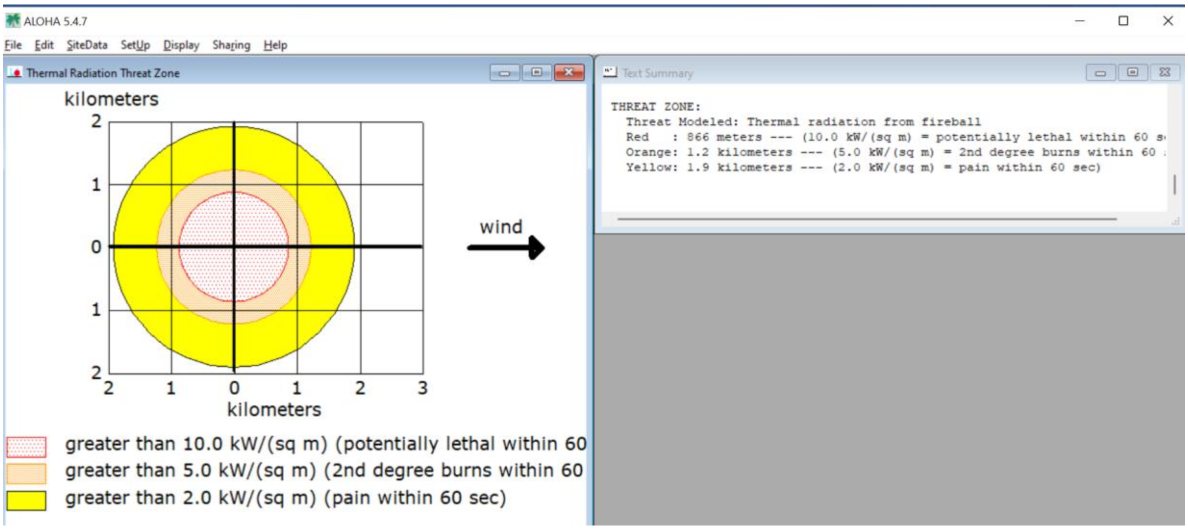
Based on scenario 3 and its failure type as BLEVE/ fireball scenario, the percentage of mass in the fireball was selected with its maximum value as 100 %.



After the selection of the threat zone in the display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange, and yellow.

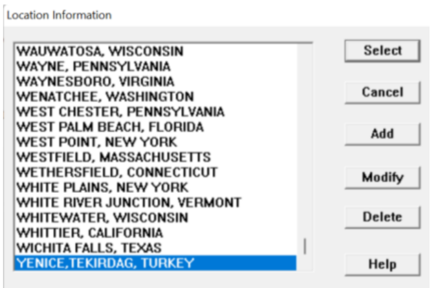


Also, the same procedure was repeated for the percentage of mass in the fireball was selected with a value of 50 % to compare it with the maximum level.

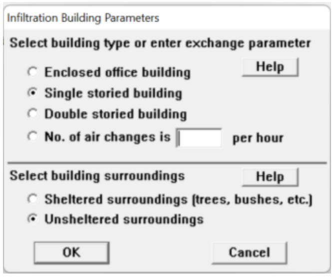


L. ALOHA Inputs for Scenario III for Winter Season

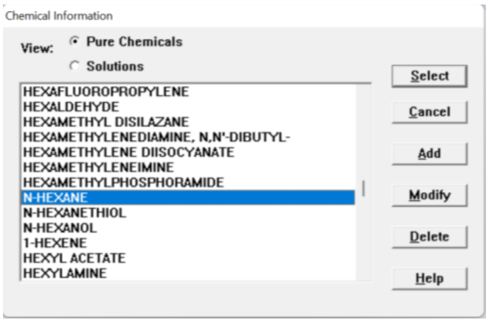
First, the location information of located o storage tank was added to the location list of ALOHA software. Then, it was selected for location information.



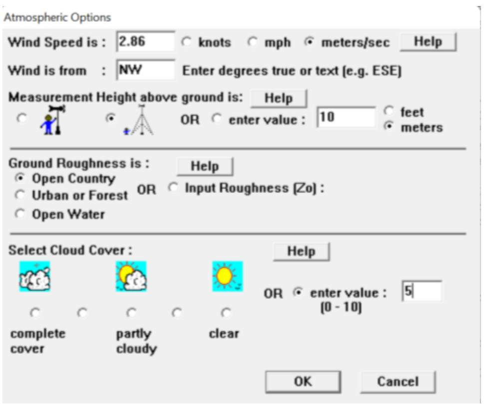
In the second step, the building type of located storage tank was specified. The storage tank was selected as single storied building and unsheltered surroundings were chosen for its surrounding.

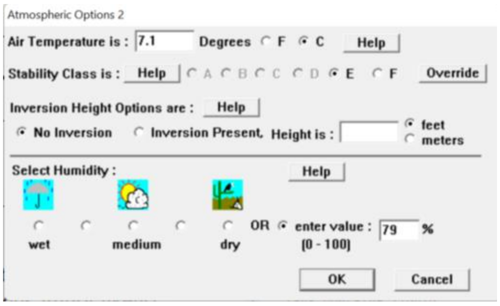


In the setup part, chemical information was highlighted as pure chemicals and n-hexane-type chemicals.

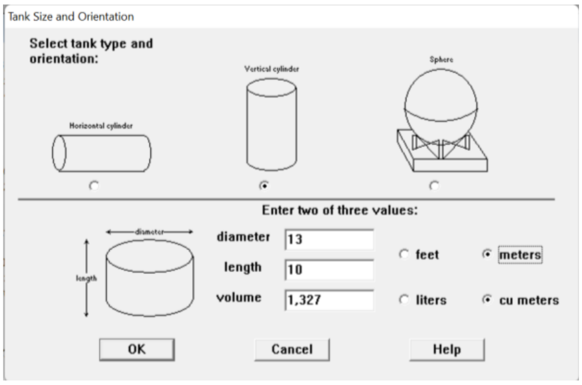


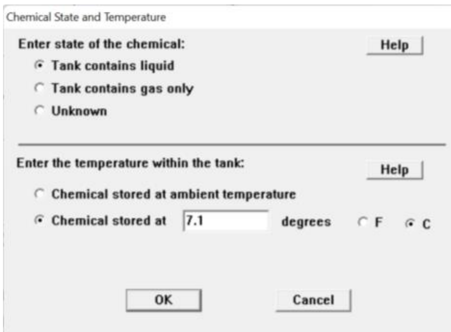
Also, in the same sections as the setup part, atmospheric conditions as user input were identified for the winter season. For the winter season, needed parameters were entered on atmospheric options. Additionally, after parameters related to wind were entered, ground roughness was selected as an open country by considering the surrounding of the storage tank. Then, while the value of cloud cover was entered as 5, the air temperature was obtained at 7.1 º C. After all, the stability of the class was selected as E automatically. When no inversion for height was selected and humidity was entered as 79 %, inputs of atmospheric parameters were finished.

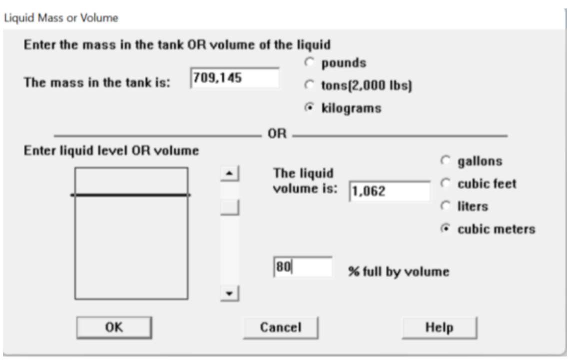




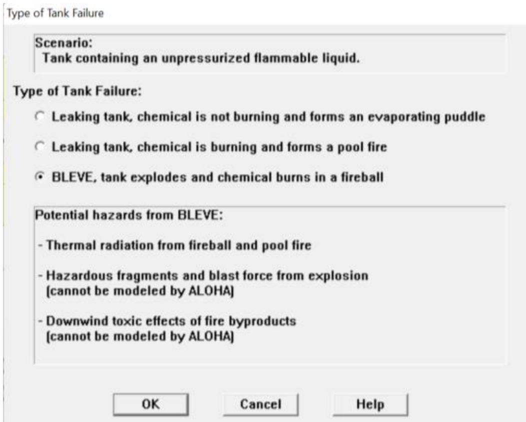
Then, in the source region from setup part, tank size and its orientation were selected by considering real parameters. Then, chemical stages and temperature of storage material were entered. Also, liquid mass and its volume in the tank were identified.



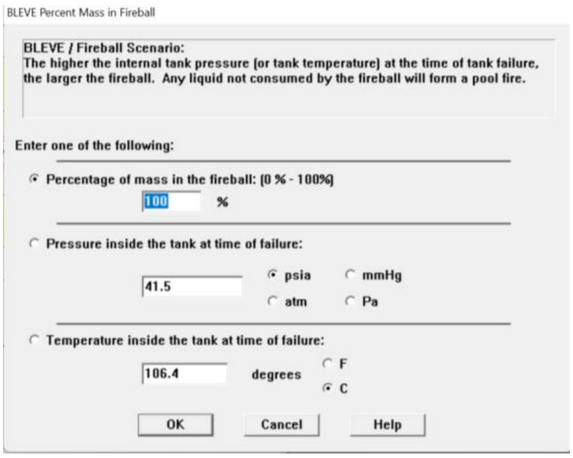




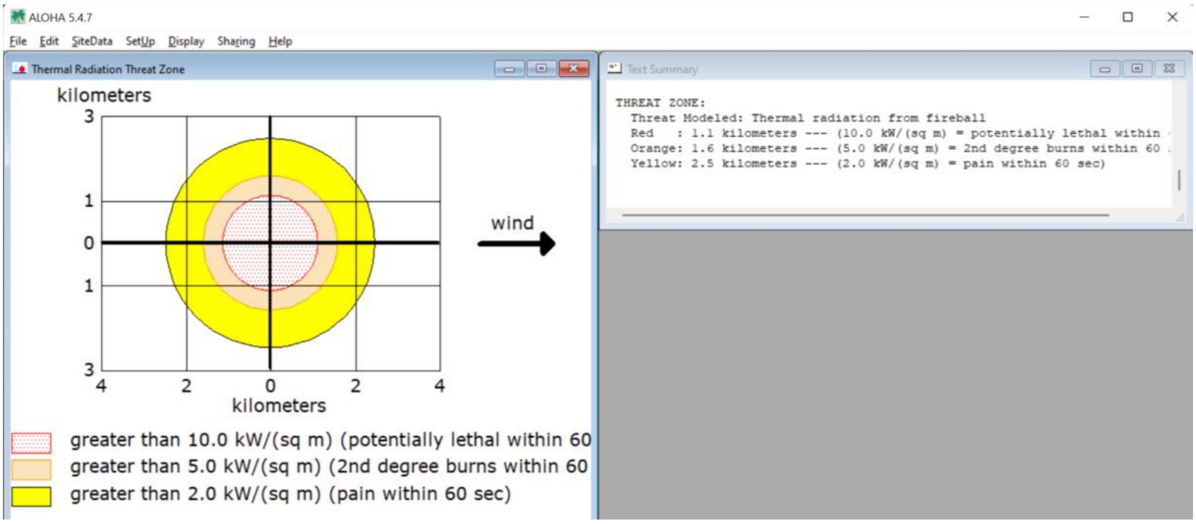
After the third scenario requirements, type of tank failure was selected as ‘BLEVE, tank explodes and chemical burns in a fireball’.



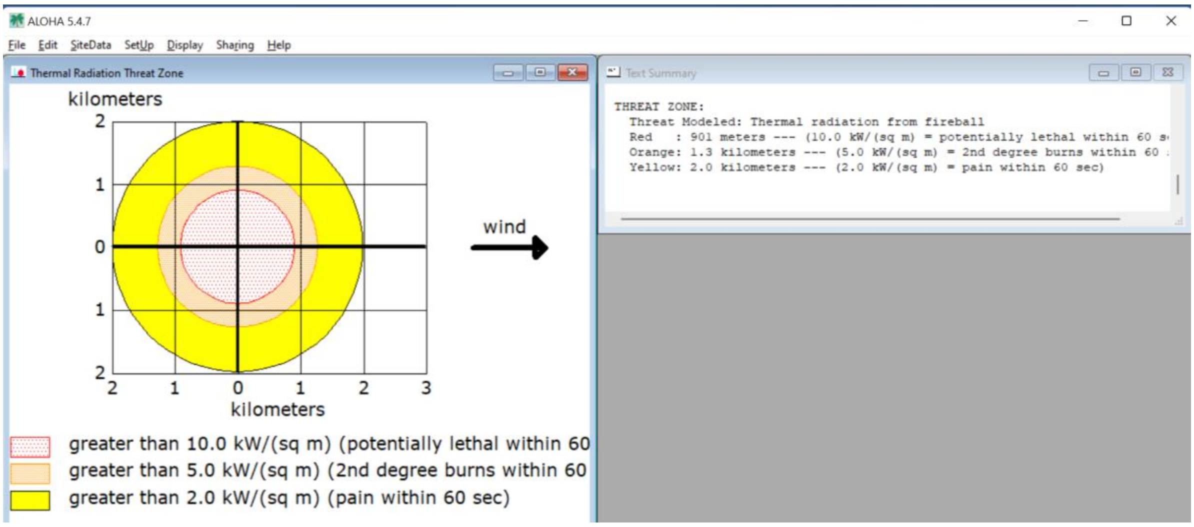
Based on scenario 3 and its failure type as BLEVE/ fireball scenario, the percentage of mass in the fireball was selected with its maximum value as 100 %.



After the selection of the threat zone in the display part, threat zones as thermal radiation was obtained, and their lethality levels were highlighted according to thereat zones such as red, orange, and yellow.



Also, the same procedure was repeated for the percentage of mass in the fireball was selected with a value of 50 % to compare it with the maximum level.



M. Monthly Aboveground Storage Tank Inspection Checklist

QUESTION	YES	NO	COMMENTS/ACTIONS /DATE CORRECTED
VISUAL CHECK			
Are the internal and external plates in good state?			
Is the bottom side in good state?			
Is its upper side as roof in good condition?			
Is its piping system in good condition?			
Are its foundations and supports in good condition?			
Is there any sign as leaks or spills around the tank?			
SAFETY PRECAUTIONS			
Are the safety materials in proper place?			
Are the safety equipment work operationally?			
Are the safety measurement instructions posted?			
Is there any prevention and measurements in the case of vandalism and unauthorized access?			

ANCILLARY EQUIPMENT			
Are the valves work operationally?			
Is the overfill prevention system work operationally?			
Is the monitoring equipment operating properly?			

N. Annual Aboveground Storage Tank Inspection Checklist

QUESTION	YES	NO	COMMENTS/ACTIONS /DATE CORRECTED
FENCING & ACCESS			
Is the area fenced safely?			
Is there any prevention and measurements in the case of vandalism and unauthorized access?			
Is the ladder fixed in base?			
Is the ladder locked to illegal entry?			
ROOF VENTING			
Is the roof venting operating properly?			
Are air gap present and operating properly?			