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Modeling the Consequences of Benzene Leakage from Tank using ALOHA in Tar Refining Industrial of Kerman, Iran

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ABSTRACT: The emission and dispersion of pollutants from the tanks of coking and tar refining industries in the environment is always probable. This study aimed to evaluate the hazard radius of benzene release from the tank of one of the coking and tar refining industries. Areal Location of Hazardouse Atmosphere (ALOHA) model Version 5.4.7 was used to predict the hazard radius of leakage and dispersion of benzene from a tank in different seasons. The maps of the toxic and flammable vapor cloud of benzene, evaporation rate from puddle and the concentration of toxic and flammable vapor cloud inside and outside of the office building were prepared. The results indicated that the maximum average benzene released from the tank was 282 Kg/min and the total amount of benzene leakage was 11997 kg in 60 min in summer. The maximum diameter of the created evaporating puddle was 71 m in autumn. The maximum toxic and flammable concentrations of benzene inside an office building were 772 and 936 ppm, respectively whilethey were 3720 and 3540 ppm outside a building in autumn. Based on the Acute Exposure Guideline Levels (AEGL) and Lower Explosive Limit (LEL) criterias, the maximum hazard radius was 1200 and 200 m in autumn. The toxic vapor cloud of benzene covered some parts of the adjacent coking plant. However, the boundaries of the flammable vapor cloud failed to reach the adjacent industries. The scenario of this study is safe for the adjacent residents and unsafe for the personnel. Thus, presenting a strategy to deal with this process incident is essential.

Keywords: AEGL and LEL criterias, evaporation puddle, process accidents, threat zone, toxic and flammable vapor cloud.

INTRODUCTION

The toxicity and flammability of some chemicals pose significant risks to human health and surrounding environments and become a bottleneck for the development of the chemical industry (Yu et al., 2020). Benzene is known as a chemical harmful to human health and the environment. The International Agency for Research on

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Cancer (IARC) has classified benzene as a human carcinogen. Exposure to benzene has been associated with adverse health effects, including haematopoietic disorders such as bone marrow deficiency as manifested in the reduction of the number of circulating blood cells, anemia, thrombocytopenia, leucopenia, aplastic anemia, and acute myelogenous leukemia in both rodents and humans (Kasemy et al., 2019). The range of human exposure to benzene occurs from standing at a gas station to a process accident (Hobza et al., 1994; Soleimani and Amini, 2017). A process accident caused by a benzene leak has great danger for people working in the chemical facilities and residents living close to these facilities (Onelcin et al., 2013). During a major accident, toxic vapor clouds, overpressure waves, and heat radiation effects fail to delay a claim for their toll (Hosseinnia et al., 2018). Despite efficient risk management, catastrophic events cannot often be avoided over the lifetimes of industries (Calixto and Larouvere, 2010). The use of toxic chemical substances such as benzen calls for careful handling could result in the dispersion of toxins into the atmosphere andto severe environmental pollution and casualties because the leak of benzen is caused by improper handling or accidents (Tseng et al., 2012). Therefore, emergency planning as mitigation measure plays a key role in reducing the consequences of accidents by avoiding fatalities and injuries, protecting the environment, and accelerating the resumption of normal operations (Hosseinnia et al., 2018). However, less attention has been paid to multi-plant emergency response planning in chemical industrial areas. In these industrial areas, other plants and nearby communities may be affected in addition to the company where the major accident takes place (Wu et al., 2015). The consequence assessment of risks such as the release of hazardous chemicals in the environment is one of the most urgent steps to increase the level of safety in the design phase or activity of industrial units (Zhao et al., 2020). Predicting the fluid behavior after release and its emissions into the environment is highly important for estimating the consequences and possible injuries, as well as the awareness of the maximum safe radius of fire, explosion and emission of toxic substances. In addition, it can play a crucial role in dealing with accidents in emergency situations (Yu et al., 2020).

Todays, multiple software models such as Hazard Prediction and Assessment Capability (HPAC), Dense Gas Dispersion Model (DEGADIS), Process Hazard Analysis Software Tool (PHAST) and Areal Location of Hazardouse Atmosphere (ALOHA), has been developed to predict the spread of toxic and dangerous materials,each one having particular characteristics consistent with its application (Beheshti et al., 2018; Shahpari et al., 2019). Modeling the material emissions by reliable software can define the affected area from theleakage of hazardous materials; Moreover, emergency response program can be planned using the modeling results. No pre-formulated plan is available in Iran for emergency response. Ramil et al. (2018),used ALOHA software (Version 5.4.7)the consequence due to sulfuric acid dispersion from two petrochemical plant in East Coast Region of Peninsular Malaysia (The first chemical plant located in Gebeng Industrial Estate, Pahang State and the second petrochemical plant located in at Teluk Kalong Industrial Estate, Trengganu). The results indicated that the dispersion radius of sulfuric acid affects the adjacent facilities and other chemical plants in proximity. The threat zones with the radius of 1.15 km (red), 4.2 km (orange) and 9.7 km (yellow) were determined for the first petrochemical plant, respectively. In addition, they reported that for the second petrochemical plant, the threat zones were greater than

9.65 km for all zones. Fatemi et al. (2017) usedALOHA software to estimate the maximum and minimum simulated threat zones (AGEL-1) by chlorine release from a chlorine warehouse in Shourabad, Ray, Iran during summer and winter at 8.8 and 6.4 km, respectively. Jani et al. (2016) modeled the 2005 Graniteville, South Carolina, 54,915 kg railcar chlorine release using both the ALOHA and HPAC plume modeling systems. The results revealed that the HPAC model estimated 60-min average concentrations ranged from 11,642 ppm at 0.1 km downwind to 0 ppm at 25.0 km downwind. Furthermore, upwind dispersion up to 0.7 km due to gravitational slumping and maximum width to specific concentrations (2,000, 400, and 20 ppm) were reported for the HPAC model. However, The ALOHA predicted 60-min average concentrations ranged from 156000 ppm at a receptor 0.1 km downwind (x) to 10 ppm at a receptor 10 km downwind. Further, they reported that unlike HPAC, the ALOHA system failed to report values past 10 km downwind. The results of Kalatpoor et al. (2011), with the aim of health, safety, and environmental risk assessment of a gas transfer pipeline in an oily area of Gachsaran using the Kent's pipeline risk assessment method and ALOHA software, indicated that health, safety and environmental risks of section 2 (the next 13 kilometers of outgoing pipeline from gas station after the first 3 kilometers) was greater. Considering the massive production of benzene with high flammability and toxicity in the coking and tar refining industry in the present study, the potential of explosion and damages increased. On the other hand, the lack of enough study on process risks and the necessity of applying the emergency response planning in this area ignored the consequences related to benzene leak from tank. With this explanation, this study aimed to to evaluate the possible scenarios of leakage benzene from the tanks and determination of the threat zone (Toxic and flammable vapor cloud) using ALOHA software.

MATERIALS AND METHODS

The studied area: This study conducted a scenario based in Zarand, Kerman province, Iran in 2019. The studied coking and tar refining complex is located the geographical location of 30˚ 45΄ 33" North Latitude and 56˚ 39΄ 34" of East Longitude (Figure 1). For this purpose , the studied area was examined due to its chemical manufacturing plants and warehouses due to the kind of the involved chemicals . Then, the distance of the tanks containing various chemicals of this industry to urban areas and agricultural lands (1 km) was evaluated. By examining aerial photos in Google Earth software and interview to HSE and engineering experts, this study realized that the arrangement of the tanks so that damaging a tank would lead to a domino effect (A domino effect or chain reaction is the cumulative effect produced when one event sets off a chain of similar events). Therefore, the tanks of the studied industry, especially the benzene tank, posed a risk to people including workers and the neighboring industries. The production data of the studied industry indicated that the annual nominal capacity of this factory was 400000 ton metallurgical coke, 19000 ton tar refining products from the coking process and 5000 ton raw benzene and 1100 ton sulfur from the produced gas. This refinery, with an annual production capacity of 30000 ton, is the second biggest tar refinery in the country. Since there is no management program for taking actions in emergencies, the hazards of chemical leakage from the tanks of this industrial plant should be identified to enable the development of such a management plan.

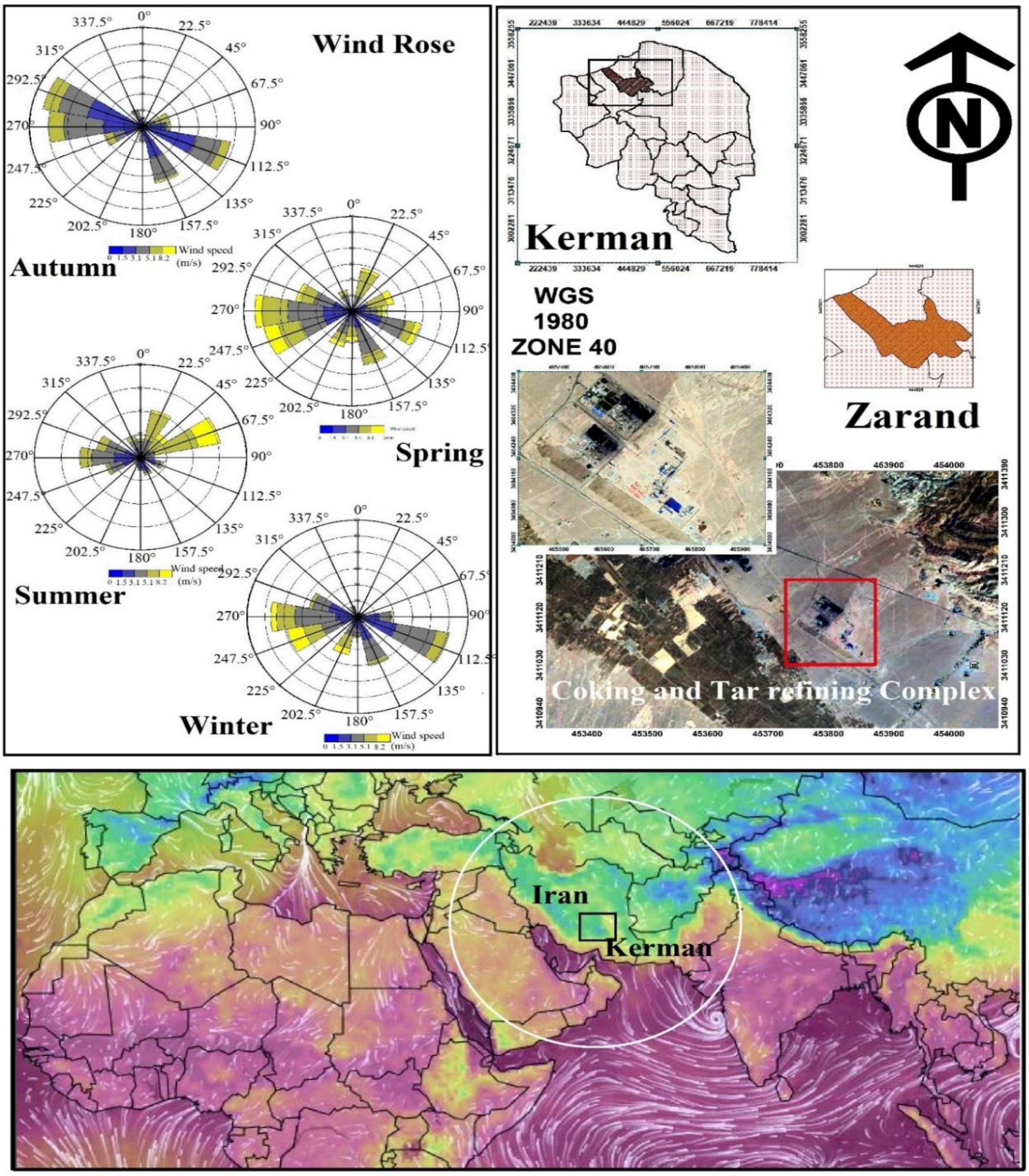

Fig. 1. The location of coking and tar refining complex in Zarand, Kerman province, Iran

ALOHA model: ALOHA, is an air-dispersion model for evaluating hazardous chemical scenarios and determining the likely footprint of such leak. The latest version of ALOHA model is version 5.4.1 which was published in February 2007. The simulation model was jointly developed by organizations including the 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) (Tseng et al. 2012). ALOHA helps planners make comparisons, develop optional leak scenarios, and help them visualize what may happen (Jani et al. 2016). Many clouds of chemical vapor are colorless, and ALOHA is especially helpful in the scenarios involving these chemicals. This software is helpful to model a leak that travels less than six miles (Ilic et al. 2018). Responders can use ALOHA as a response tool to quantify what chemical dangers can be present. This software links chemistry, toxicology, and meteorological data. ALOHA can help firefighters make an educated guess about what levels of the leaked chemical would likely present a fire hazard, or a health hazard (Cherradi et al. 2018). ALOHA can help responders estimate if the level of the flammable or toxic gas in the building rises to the point of causing a fire or explosion (Beheshti et al., 2018). After entering the requisite data into ALOHA, then ALOHA will give the likely threat zone of a leak. ALOHA uses two separate dispersion models including Gaussian plume model (GPM) and heavy gases model (HGM). The GPM describes movement and spread of a neutrally buoyant gas, which is approximately the same density as air (Shamsuddin et al. 2017). The heavy gas dispersion calculations were derived from the DEGADIS model, being developed in part by the U.S. EPA. The HGM is used when the density of gas contaminant is higher than air (Li et al. 2015). The result is some vapors to move in the opposite direction of the wind from the release point (Cherradi et al. 2018). After determining the model for estimating gas dispersion, ALOHA plots the points a concentration higher than Level of Concern (LOC). LOCs are used to assess the flammable and toxicity threat of a chemical release (Ilic et al. 2018). ALOHA has some limitations. ALOHA fails to incorporate the effects of particulates, fires or chemical reactions, or chemical solutions or mixtures. The use of ALOHA should be avoided in these instances except in certain situations. ALOHA cannot help with indoor releases, during rain or snow, for distances over six miles from the release point, for releases lasting over an hour, with hilly terrain, or with the "canyon" effect of urban areas with high-rise buildings (U.S. EPA and NOAA. 2007).

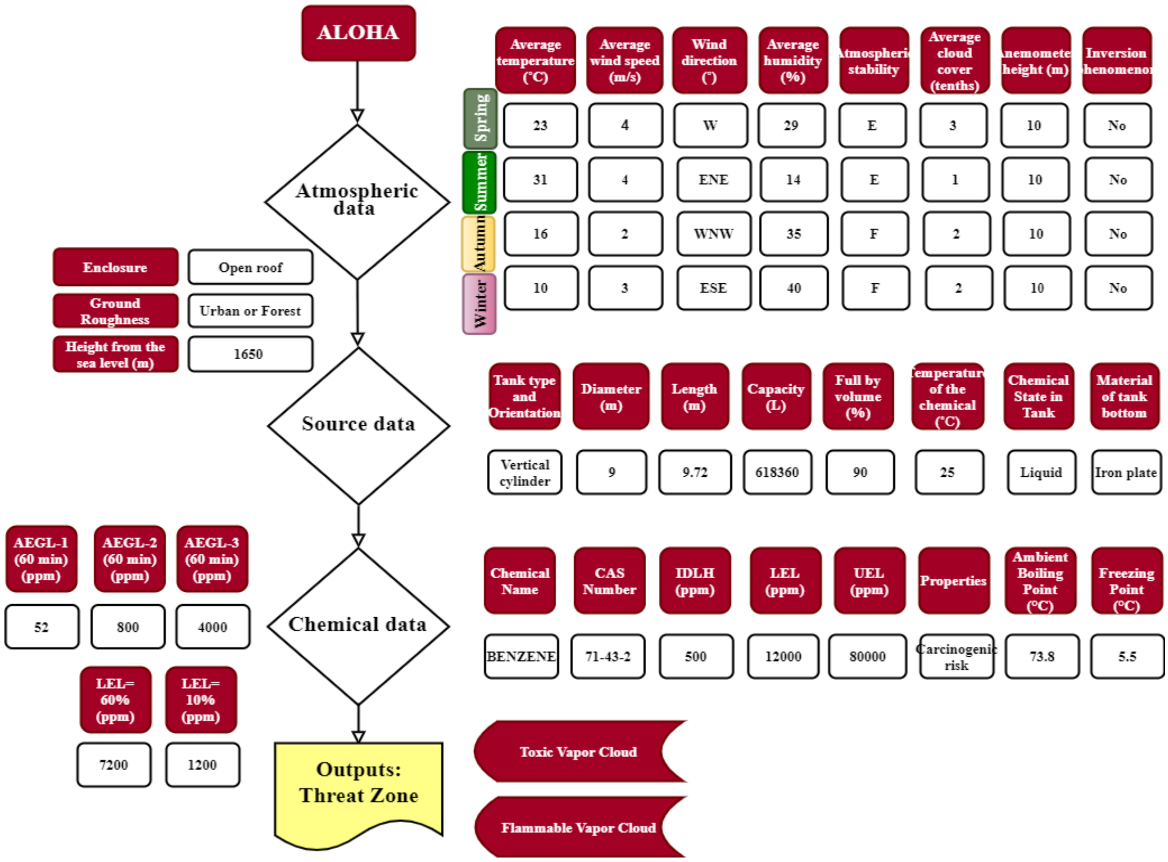

Fig. 2. The atmospheric, source and chemical input data for the implementation of the ALOHA model

Data collection and modeling: This study was performed to model and evaluate the environmental consequences of benzene leakage from the tank. For estimating the radius of benzene dispersion towards the adjacent area next to the plant, the consequence modelling using ALOHA Version 5.4.7 was developed. The required parameters for ALOHA software to model a benzen leakage from tanks included the site data (source place and geometric information of tanks), atmospheric data (temperature, humidity, direction and speed of wind, terrain and other atmospheric parameters) and chemical data (Figure 2).

- **Atmospheric data:** Weather condition is one of the random parameters affecting the dispersion behavior of a leak event. Leak events should be simulated in different weather conditions to consider variable meteorological conditions occurring over time. In this study, weather data were received from the site https://data.irimo.ir.
- **Chemical data:** In order to run the model, the hazardous material which is released and its physical and chemical properties were specified. The characteristics of the chemicals released ultimately determined the shape, magnitude and severity of the plume. This study used the HazMat site (https://www.hazmattool.com) as chemical data provider, allowing the retrieval of hazardous material description stored in the HazMat database. The HazMat information concerns the product identification, the nature of danger, the physical and chemical properties, security instructions, transportation conditions, etc.
- **Source data:** The exact source characteristics such as geometric properties, storage capacity, etc. were described for this type of data. In this study, this type of data was obtained through field visits and interviews with HSE and engineering experts.

Consequences are calculated by using a simplified procedure based on empirical equations for a predefined hole size which reflects the range of possible outcomes. Results are expressed in quantitative terms, as impact areas, which are determined by combining consequence areas derived from the modelling and probabilities associated with the various scenarios (Vianelloa et al. 2014). The scenario in this study is benzene leakage due to the creation of a hole with a diameter of 100 mm on the iron wall of the vertical cylindrical tank with a capacity of 618360, of which 90% of liquid benzene is stored. The position of the fracture created on the tank is 7 m above the ground. The storage temperature of benzene in the tank equals the ambient temperature (25°C). This scenario is divided into two parts as follows:

- Modeling the domain offormation of the benzene toxic vapor cloud
- Modeling the domain of formation of the benzene flammable vapor cloud

In this study, in addition to preparing maps for the two defined scenarios, the concentration of benzene toxic and flammable vapor cloud in the indoor and outdoor of the office building was estimated.

In order to determine the domain of flammable and toxic vapor cloud, of LOCs such as Lower Explosive Limit (LEL) and Acute Exposure Guideline Levels (AEGLs) used as follows:

Based on the AEGLs, the acute exposure levels used in this study are classified into levels (Beheshti et al., 2018):

Level 1: At this concentration, it is predicted that the general population, including susceptible individuals can experience irritation, annoyance and some non-sensory and asymptomatic effects. However, the effects are not disabling and are transient and reversible (AEGL-1 (60 min): 52 ppm).

Level 2: At this concentration, susceptible individuals may experience adverse and severe effects or irreversible effects. In this case, people may lose their ability to escape (AEGL-2 (60 min): 800 ppm).

Level 3: At this concentration, people may lose their lives or in other words, expose at this level of concentration maybe life threatening (AEGL-3 (60 min): 4000 ppm).

LEL is the minimum concentration (%) of a gas or vapor in the air which can cause fire at the presence of an ignition source (spark, hear, etc.) and is expressed as the volume percentage of flammable gas in the air (Gas, 2013). In this study, based on this criterion, the LOC level for two levels of benzene is defined as:

Level 1: A concentration of 7200 ppm benzene equals to LEL= 60%, in this case, extreme safety considerations against explosion should be considered.

Level 2: A concentration of 1200 ppm benzene equals to LEL= 10%, in this case, safety considerations against explosion should be considered.

After entering the required data to ALOHA software, the outputs included the dispersion maps of benzene toxic and flammable vapor cloud based on the selected ALOHA model, determination of Max Average Sustained Release Rate in averaged over a minute or more, the total amount released, and diameter of the evaporating puddle.

RESULTS AND DISCUSSION

The results related to the domain of formation of the banzen toxic vapor cloud (threat zone) at different distances from the tank in spring, summer, autumn and winter are shown in Fig. 3. The simulation computed the range of toxic vapor, assuming the release in one hour of the contents from the damaged tank. Based on the results, the threat zone for benzene toxic vapor cloud in spring, summer, autumn and winter was divided into three layers ofred, orange, and yellow. Red zone represents AEGL-3 which expose concentration of 4000 ppm and was dispersed to 53, 62, 99 and 61 m from the tank in spring, summer, autumn and winter, respectively. Orange zone represents AEGL-2 which exposes concentration of 800 ppm and was dispersed to 167, 187, 251 and 188 m from the tank in spring, summer, autumn and winter, respectively. However, yellow zone represents AEGL-1 which expose concentration of 52 ppm and was dispersed to 1000, 1100, 1200 and 1100 m from the tank in spring, summer, autumn and winter, respectively. The predicted threat zone distance from the tank in autumn compared to spring and summer and winter, had the radius increase by 200, 100 and 100 m, respectively. The radius of wind confidence line of the threat zone was 1000, 1100, 1200 and 1100 m in spring, summer, autumn and winter, respectively. Meteorology greatly influences dispersion. Air movements can move, disperse, or trap a pollutant cloud. Wind speed and atmospheric stability are the primary factors which influence dispersion (Zhang et al., 2015). Atmospheric stability is a measure of the mixing or turbulence in the atmosphere, whhighly depending on the amount of solar radiation heating the air near the ground (Mao et al., 2020). The results of the present study indicated that the maximum and minimum dispersion distance of benzene toxic vapor cloud occurs in autumn and spring, respectively. Atmospheric stability in autumn and spring is in F and E classes, respectively. The results of the study showed that the rate of spread of heavy gases is much higher than in an unstable atmosphere in a more stable atmosphere because the movement of air flow in the axis perpendicular to the ground is low and the pollutants spreads more in the horizontal axis (Pourbabaki et al., 2018).

Therefore, stability in autumn increases the dispersion distance of benzene toxic vapor cloud. For a release under low wind speed, the cloud meander a lot and we will be unsure about the snakelike path that the cloud will take. Consequently, a greater area should be assumed where the cloud be. For high wind speeds, the dashed lines will be close to the footprint because of smaller expected cloud meander. In the present study, this condition occurred in spring and summer. However, for the low winds which are more subject to cloud meander, the area of the dashed lines may actually be a complete circle with the radius being the footprint length, indicating that the wind could shift and blow the cloud in any direction (U.S. EPA and NOAA. 2007). In the present study, this condition occurred in autumn. Another consideration in predicting where the cloud goes is its "meander." As we know, wind direction can change many times.

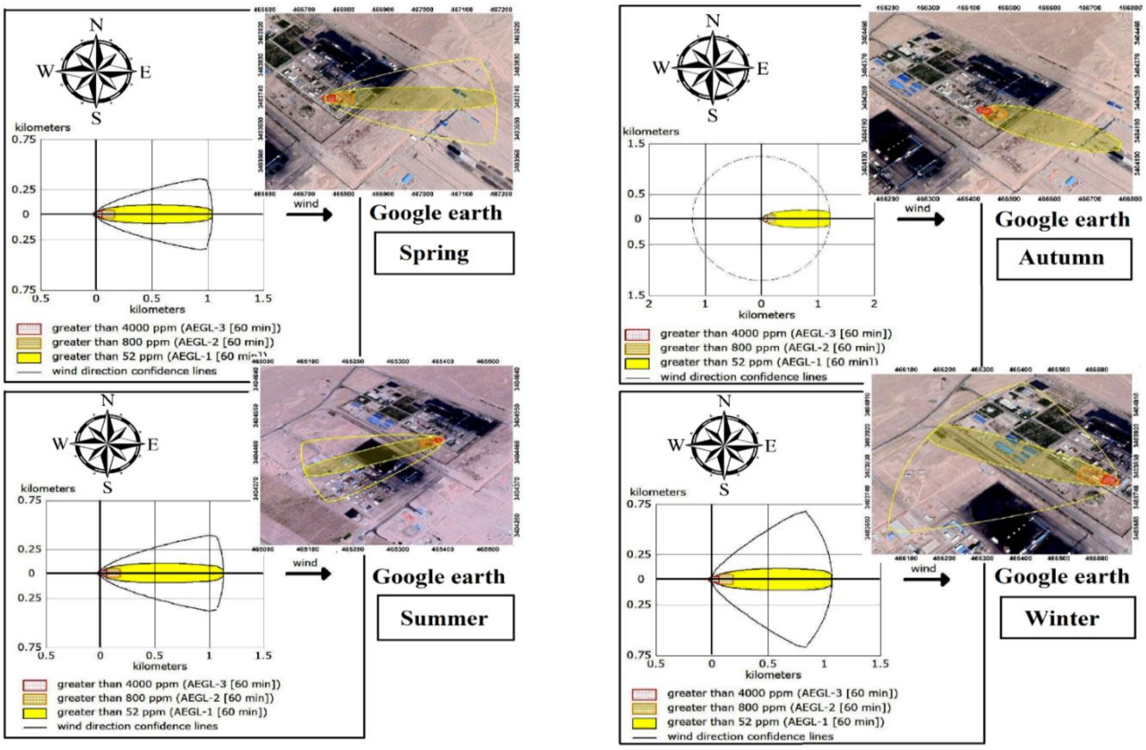

Fig. 3. Graphical modeling of domain of formation of the benzene toxic vapor cloud at different distances from the tank in spring, summer, autumn and winter

Generally, the prevailing wind direction in the region play a decisive role in the movement of the benzene toxic vapor cloud (Hassoon et al., 2019). In the current study, the prevailing wind direction of the region in spring, summer, autumn and winter was W, ENE, WNW and ESE, respectively. For this reason, the approximate direction of banzen toxic vapor cloud in spring, summer, autumn and winter was E, WSW, ESE and WNW, respectively. Other results of the present study showed that the villages around the studied industry were not affected by the banzen toxic vapor cloud, based on the scenario selected. Nevertheless, neighboring industries were exception. In general, there are two ideal classes of sources. One is an instantaneous source, where the pollutant is released into the atmosphere all at once. The other type of release is a continuous source, where the material is released at an approximately steady rate for a longer period of time. ALOHA considers continuous releases lasting up to 60 minutes. In other words, ALOHA can model instantaneous, intermediate, and continuous types of releases (U.S. EPA and NOAA. 2007;

Macdonald, 2003). A gas will enter the atmosphere immediately; a liquid will form a puddle and will then enter the atmosphere by evaporation. In this study, the tank capacity and the volume of stored material were 618360 and 556524 Lit, respectively. The results of thisstudy indicated that benzene max average sustained release rate (averaged over a minute or more) from the damaged tank in spring, summer, autumn and winter were 249, 282, 151 and 155 kg/min, respectively. The total amount of benzene released from the tank in the mentioned seasons was 10096, 11997, 5618 and 5672 kg, respectively. The banzen evaporation rate from puddle depended on the Vapor Pressure of the liquid at ambient temperature, the wind flow across the puddle surface, and the ambient saturation concentration. As the liquid vapor pressure increases, the rate of evaporation increases. Liquid vapor pressure is affected by temperature and the evaporation rate from the puddle surface will increase with increasing temperature. When banzen evaporates, its air surrounding gets saturated by it. Wind speed increases the rate of evaporation by quickly removing the saturated air thereby allowing more evaporation to occur (Oribi and Abdulkareem 2020). In the present study, the evaporation rate of benzene from the puddle formed in summer (Wind speed 4 m/s, temperature 31°C, Vapor Pressure of the liquid at ambient temperature 0.16 atm, Ambient Saturation Concentration 199608 ppm equal to 20%) was the highest. The lowest evaporation rate was in winter (Wind speed 3 m/s and temperature 10°C, Vapor Pressure of the liquid at Ambient Temperature 0.060 atm, Ambient Saturation Concentration 72834 ppm equal to 7.28%). These results are consistent with the results of Jafarnia et al. (2018). The results showed that the evaporation rate of benzene liquid from the puddle up to 60 minutes in spring, summer, autumn and winter was equal to 280, 300, 170 and 150 kg, respectively. Such results revealed that the release of benzene from the tank and evaporation from the puddle for up to 60 minutes had an increasing trend and the direction of the curve and was upward in different seasons of the year, (Fig. 4).

Table 1. Liquid vapor pressure and Ambient Saturation Concentration of benzene in different seasons

Season	Unit	Spring	Summer	Autumn	Winter
Liquid vapor pressure	**(atm)**	0.11	0.16	0.081	0.060
Ambient Saturation Concentration	**ppm**	138723	199608	98907	72834
	%	13.9	20	9.89	7.28

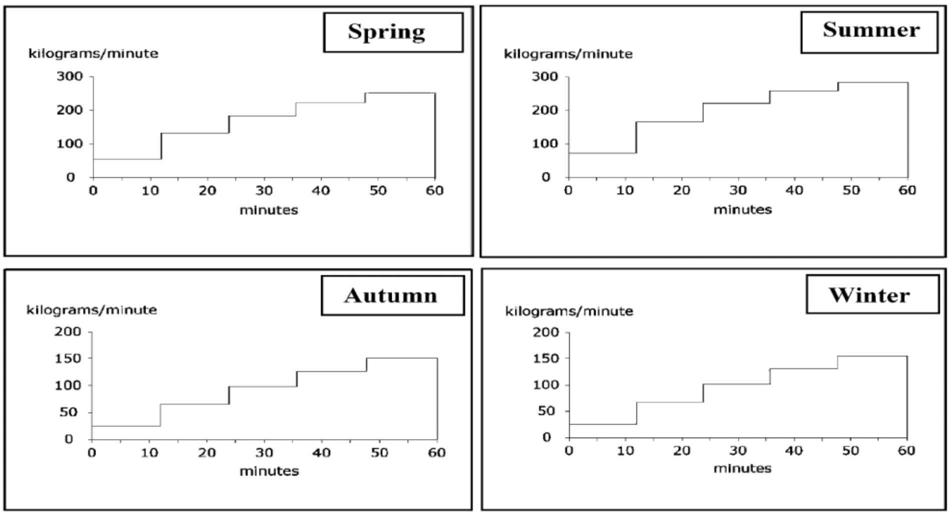

Fig. 4. Evaporation rate of benzene from the puddle formed in spring, summer, autumn and winter

Other results relaetd to the modeling of banzen vapor cloud showed that banzen flammable vapor cloud threat zone was smaller than the toxic vapor cloud. Based on the results, the threat zone for benzene flammable vapor cloud in autumn was divided into two layer of red and yellow. The red zone for spring, summer and winter was not shown in ALOHA graphical outputs. However, based on the text output, red zone represented 60% LEL which exposed concentration of 7200 ppm and was dispersed to 32, 41, 67 and 38 m from the tank in spring, summer, autumn and winter, respectively. Yellow zone represented 10% LEL which exposed concentration of 1200 ppm and was dispersed to 126, 143, 200 and 145 m from the tank in spring, summer, autumn and winter, respectively. With the modeling results for the benzene toxic vapor cloud threat zone, the most dispersion of flammable benzene vapor occured in autumn. Based on ALOHA graphic outputs, the radius of dispersion in the flammable vapor cloud was in the plant privacy and no threat zone was predicted in the urban area and adjacent industries. In addition, thedispersion of benzene flammable vapor cloud in the coke depot areas was not. Therefore, the risk of fire in these areas was low whilethere was a risk of fire in the office buildings adjacent to the tank in different seasons (Fig. 5).

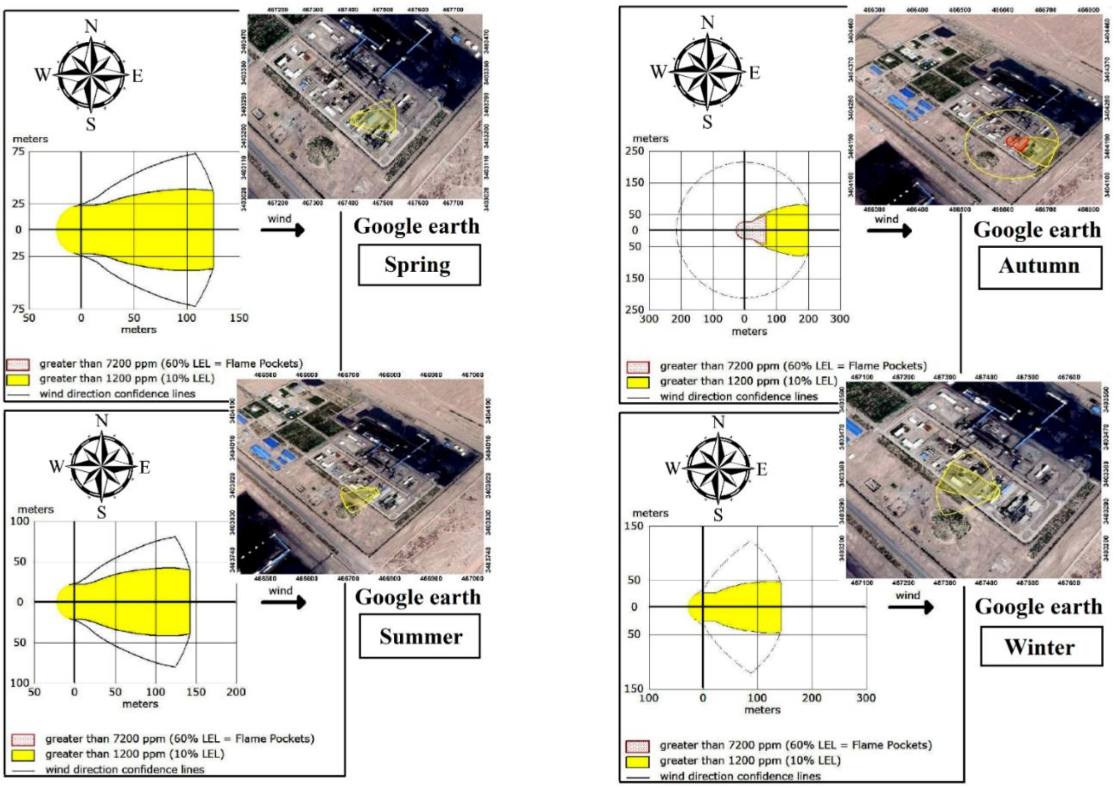

Fig. 5. Graphical modeling of domain of formation of the benzene flammable vapor cloud at different distances from the tank in spring, summer, autumn and winter

The values of exposure to benzene toxic and flammable vapor cloud as a function of time in office building are shown in Fig. 6. According to this figure, the results of exposure to toxic and flammable vapor cloud have been reported only for summer and winter seasons. The exposure values are not predicted for spring and autumn. The location of the office building as the most important building where employees spend most of their time is the southeast of the tank. The diagrams (a) and (b) indicate the concentration of benzene toxic vapor cloud. The stepped and dashed line curves in these diagrams show the concentration of benzene indoor and outdoor the office building, respectively. The results showed that the concentration of benzene toxic vapor cloud in the office building in summer and winter is higher than the AEGL-1 standard after 25 minutes from the start of the accident. Furthermore, the concentration of benzene toxic vapor cloud in the office building exceeded from the AEGL-2 standard only in summer after 55 minutes from the accident. Other results showed that the concentration of benzene toxic vapor cloud exceeded AEGL-1 and AEGL-2 standards in both seasons after approximately 12 minutes from the time of the accident. The concentration of benzene toxic vapor cloud indoor and outdoor the office building did not exceed the AEGL-3 standard in summer and winter. The results of concentration of benzene flammable vapor cloud indoor and outdoor the office building in summer and winter are shown in diagrams (c) and (d). The concentration of benzene flammable vapor cloud in office buildings did not exceed the standard 10 ٪ LEL in summer and winter. However, the concentration of benzene flammable vapor cloud in outside the office building 12 minutes after the start of the accident exceeded the 10% LEL standard.

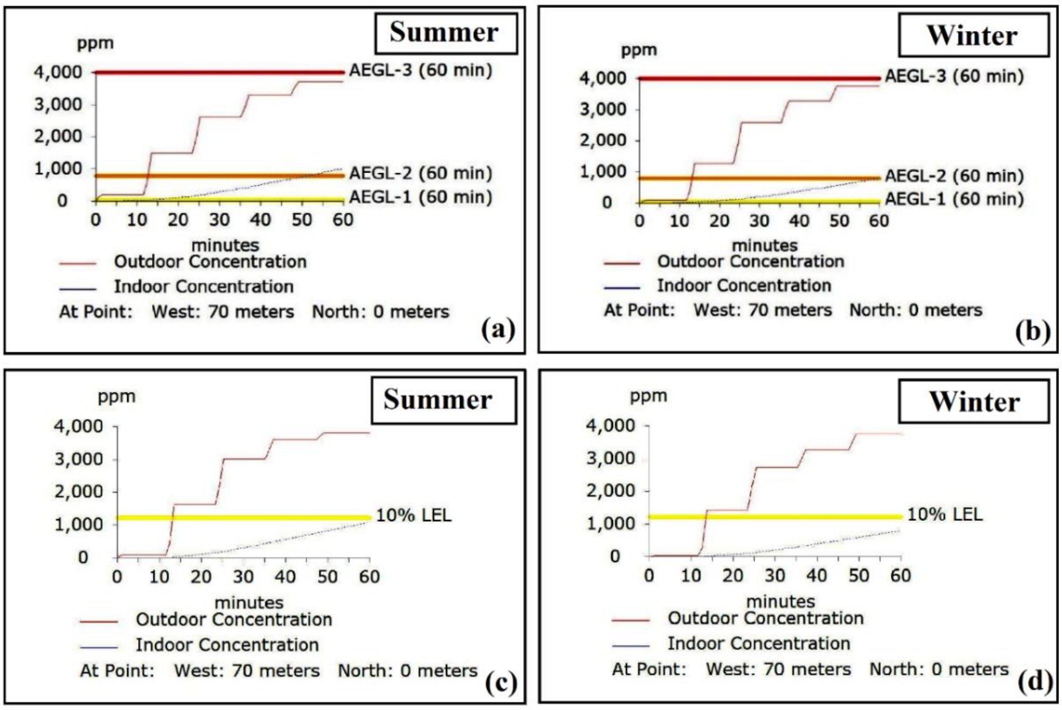

Fig. 6. The values of exposure to benzene toxic (a, b) and flammable (c, d) vapor cloud as a function of time in office building for the summer and winter

Managing the consequences of benzene leak from tanks: Considering the threat zone of the toxic vapor cloud, presenting some control strategies for the prevention of human casualties and equipment damage is essential. For this purpose, the first suggested approach in the management of incidents is using smart tanks in the studied industry. In a smart tank, changes in liquid level contained in the tank is continuously monitored and data are transferred to the processor. Another solution is forming support groups like firefighting teams in the threat zone in different seasons. Furthermore, the correct locating of equipment and installations based on the Wind Rose of the region can be beneficial. Investigatingthe Wind Rose of different seasons, the frequency of winds is in the directions between 315˚ to 67˚ is very low; thus, it is the best place for relocating office buildings or constructing underground shelters to reduce the occurrence of incidents in North-West to North-East regions of the plant. Another approach for reducing the damages of an incident is to inform the residents, increase the awareness of the staff and the relief force, and install suitable scrubbers at the site to reduce the exposure of people. Considering the benzene discharge rate, the quick action of the relief force in reaching the incident location is not possible and therefore necessary equipment should be provided for the personnel and guards at site location, so that they can activate alarms and have a quick and proper response to the incidents. Installing alarm systems in threat zones and teaching the personnel how to deal with such situations, providing emergency telephone lines and communication devices for better coordination with the adjacent industries, and peparing a response plan for emergencies can reduce the harmful impacts of toxic and dangerous substance release.

CONCLUSION

The results of this study showed that autumn has more risks in the occurrence of the defined scenario than other seasons due to the dispersion distance of benzene toxic and flammable vapor cloud. Other results indicated that the concentration of benzene toxic vapor cloud in the office building failed to exceed the AEGL-3 standard in summer and winter. Therefore, the risk of employees death due to benzene inhalation is low up to 60 minutes after the accident. However, the levels of benzene toxic vapor cloud exceeded the AEGL-2 standard 55 minutes after the accident in summer. Thus, susceptible employees may experience adverse and severe effects or irreversible effects at this concentration. Furthermore, the findings of this study indicated that the threat region of the benzene flammable vapor cloud is limited to the studied plant and fails to reach the adjacent plants. Considering the defined scenario in ALOHA model, the hazard radius of benzene leak from the tank in the studied plant can be predicted to be at a safe level for the near villages. However, it the predicted threat zone is hazardous for the employees and the reduction of casualties of the incident is possible by applying the previously mentioned strategies. Implementing the quantitative risk assessment (QRA), evaluating the role and effectiveness of barriers against benzen leaks, as well as the obstacles to the ultimate consequences caused by a benzen leak, and calculating the probability of failure of the obstacles can help acheive more realistic results. The results of the researchers' studies with the results of this study may provide a more accurate decision-making ability to manage safety risks.

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The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been thoroughly observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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