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Risk Assessment of Gasoline Storage Unit of National Iranian Oil Product Distribution Company using PHAST Software

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ABSTRACT

The present study evaluates the risk of the gasoline tank of the National Iranian Oil Product Distribution Company (NIOPDC) in Sari region using process hazard analysis software tool (PHAST) and according to the environmental and process data of the unit. The consequences of different scenarios such as small and medium leakage, constant release rate and complete rupture were modeled and then the range of each one was obtained according to the intensity of radiation or pressure wave and the safe distances of each was determined. Due to the consequences of the explosion, the worst results were related to the weather conditions of 2/3 F for 4700, 2400, and 2300 meters, respectively. Also, based on eruptive and sudden fire data, the intensity of radiation which corresponds to the immediate death or destruction of equipment was seen in climatic conditions of (2/3 F and 4/1 D), at intervals of 180 and 160 meters distances, respectively. In these two weather conditions flammability intervals were 10520 and 450 meters. Then, by combining the severity of these accidents with the distribution of the population and the probability of their occurrence, the level of risk for these storages was determined.

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1. INTRODUCTION

Since the desire for safety and security is an integral part of the nature of human beings, having a life free of danger has always been the desire and objective of all people. The development of various industries enhanced the well-being of human beings, but they created new potential dangers as well. Furthermore, the process facilities and equipment that are used for productivity, profitability and wealth creation in various industries, have a great potential for causing harm to people, property and the environment. Risk analysis and assessment is one of the most important tools to maintain and improve the level of safety in the society and especially in industry [1-3]. For this purpose, in existing or under design industrial units, risk assessment is performed for the hazards that may occur due to human error or equipment failure. Storage tanks in refineries and petrochemical units contain high amounts of hazardous and sometimes flammable substances [4, 5]. These tanks are fragile and easily damaged by a slight increase in pressure or vacuum, therefore, they are more prone to accidents than other equipment. As a result, a small accident can cause millions of dollars in property damage and stop the production process, and it also may result in loss of life. Given the events that have taken place in the case of storage tanks in recent years, the importance of assessing and evaluating the risk of storage tanks in refinery units is completely clear. Based on the available resources, 242 accidents have occurred in the chemical tanks of industrial facilities in worldwide, during the last 40 years. Of the 242 accidents, 114 cases were occurred in North America, 72 cases in Asia and 38 cases in the Europe. The highest number of accidents, 116 cases (47.8%), were occurred in the oil refineries, 64 cases (26.4%) in oil terminals and loading platforms and about 25.7% in petrochemical units. The results of this study show that 74% of the mentioned accidents in the oil industry are related to the oil storage and loading terminals. The highest number of causes of accidents are

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fire and explosion in these tanks that were 85% of all the cases. About 33% of accidents were related to lightning and 30% of them were due to human error, including operational and repair errors. Other causes of accidents include equipment failure, vandalism, rupture, leakage and rupture of lines, static electricity and open fire around tanks. Gasoline storage tanks, as one of the most important industrial facilities, are always exposed to the risk of fire and explosion, therefore, risk assessment of these tanks is an effective step to prevent accidents or reduce their severity [4, 6]. Unfortunately, in our country it is normally ignored. Perhaps among the important reasons is the lack of sufficient familiarity with the basic principles of quantitative and qualitative risk assessment. One of the most important and common accidents in industrial units, public buildings and crowded places that endanger human lives and damage equipment and tools, is the phenomenon of fire and explosion [7]. Some of the incidents include the gasoline fire in Cubatao, Brazil, which killed more than 500 people; the Bhopal disaster in India, which killed at least 2,500 people; the reservoir explosion in Mexico, which injured 4,200 persons and killed 452 individuals. The explosion of flammable material in Mexico's sewage network, which was estimated to cost more than $ 7 billion. As a result, these accidents have caused human, equipment and environmental catastrophes, and sometimes these damages are heavy and irreparable. Such an events are causing more concern and people are thinking about the consequences and effects of process accidents in industrial activitie [7]. A study conducted in the field of energy in recent years [8-11] indicated that accidents caused by explosions and fires in the oil industry accounted for 25% of the total economic losses. It is in the second place, after nuclear energy. The high human, economic and environmental damage reported from accidents can be a very good reason to show the need to observe safety principles, not only in chemical units but in all fields [12]. In the present study the generalities of risk assessment and its application, including the steps of identifying hazards in a process, modeling potential hazards such as fire, explosion or consequences related to toxicity of materials, risk assessment and its extent will be described. The risk assessment will be done specifically for the gasoline storage unit of NIOPDC in the Sari region. PHAST specialized software is used to model the consequences of accidents in this unit. Finally, after performing the calculations of probable risk of accidents in this unit and comparing it with valid criteria, appropriate suggestions will be provided to reduce the risk of relevant accidents.

2. MATERIALS AND METHODS

This study uses PHAST software. PHAST software is one of the most popular and useful accident modeling software related to the release of toxic substances, fire and explosion [13-16]. This software is provided by DNV Company and is well known for its industrial and public safety hazards. This model is one of the best models presented for the distribution of materials in the environment. This model covers a wide range of pure materials lighter or heavier than air and it is able to model a mixture of materials. It also includes sudden, permanent release and evaporation from the surface of the ponds. Release height and average ground surface roughness are considered in this model. In this article, the risk assessment of the gas tank of the NIOPDC in Sari region is examined. These tanks are made of carbon steel, and they are in the cylinders form with a height and diameter of 12.84 and 34.178 meters, respectively, and the total volume of each of them is 10,000 cubic meters. There are 8 similar tanks next to each other in the studied unit.

2. 1. Modeling the Consequences of Scenarios

Scenario definition is one of the first steps in risk assessment that predicts possible events. In the present study, the scenarios are defined as follows: Due to wear and defects that may occur in the system, there is a possibility of kerosene leakage from various parts of the source, such as leaks from flanges, washers, and connecting pipes, sudden puncture and bursting of the tank. Depending on the kerosene conditions, the consequences of the blast wave and the intensity of the current radiation from the reservoir events are investigated. The environmental consequences of the release of kerosene from storage tanks into the environment and the destruction of the environment are among the chronic hazards that affect human life and other organisms in the long run.

The different scenarios that are examined in this study are:

- Leakage with small diameters (10 mm)
- Complete rupture of the tank and its sudden discharge
- Release of the entire materials in the tank at a constant release rate in 10 minutes

Considering that one of the stages of modeling the release of materials in the environment is the climatic characteristics of the environment, Table 1 indicates the seasonal average conditions (hot-cold) climate for the Sari region and the environmental conditions of the region. Therefore, for modeling, the outcome of each of these conditions is considered as modeling conditions. The results of the outcome modeling were obtained according to the studied unit conditions and environmental characteristics and according to the equations expressed in the third chapter.

3. RESULTS AND DISCUSSION

3. 1. The First Scenario - Small Leak

The modeling results in climatic conditions (2.3 F and 4.1 D)

TABLE 1. Climatic and Environmental Conditions of the Region

	Hot	Cold
Average Temperature ℃	13	25
Wind Speed (m/s)	2.3	4.1
Sustainability Class	F	D
Humidity	0.9	0.75
Radiation (kW/m^2)	0.4	0.7
Surface Roughness (mm)	183	183

for the leakage scenario indicate a sudden fire, eruptive fire, and explosion. Figure 1 (a and b) show the amplitude of the cloud concentration created on the land surface from the top view in terms of distance from the source and the width of the cloud created in 2.3 F and 1.4 D weather conditions. Flammability concentrations of 9026 and 4513 ppm for climates 2.3 F and 1.4 D are advanced to a distance of 19.5 - 27 m and 13- 24 m from the reservoir, respectively. The cloud width created for the lower limit of flammability in two weather conditions of 2.3 F and 1.4 D is 18 and 5 meters, respectively. According to the results, in 2.3 F weather conditions, due to the lower wind speed and more stable atmospheric conditions, the cloud is created to spread at a greater distance. Figure 2 (a and b) indicate the enclosed area to the concentration of fire. The half of this concentration is for sudden fire in weather conditions of 2.3 F and 4.1 D. In these figures the horizontal axis is the distance from the release source in the wind direction; the vertical axis is the distance from the release source in the direction perpendicular to the wind and parallel to the earth's surface. These diagrams are to determine the geographical location of the range of radiation caused by a sudden fire. According to the results, in weather conditions 2.3 F a zone with a radius of 27 meters, which is marked with a line, has a concentration of more than half of the lower flammability limit. On the other hand, a zone with a radius of 20 meters has a concentration more than the flammability limit. While these distances are 4.1, the radius is 24 m and 14 m for weather conditions of 4.1 D. In other words, as the wind speed increases, the scattered cloud concentration dilutes faster, reducing the ignition concentration parameter limit.

Figure 3 (a and b) show the radiation from the eruptive fire based on the distance in the wind direction for a leak with a diameter of 10 mm. In these figures, the different levels of thermal radiation specified by the model for eruptive fire are shown as limits in terms of distance. In these diagrams, after determining the desired radiation intensities, the geographical areas in which the minimum radiation intensity is equal to the desired values are determined. As can be seen, for climatic conditions 2.3 F and radiation 4, 12.5, and 37.5 kW/m it continues

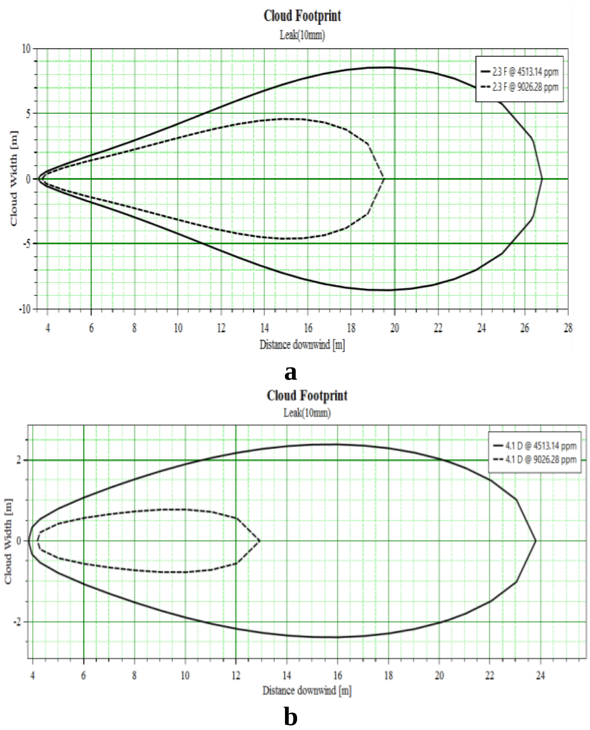


Figure 1. Vapor cloud emission range for the first scenario in **a**- 2.3 F, **b**- 4.1 D.

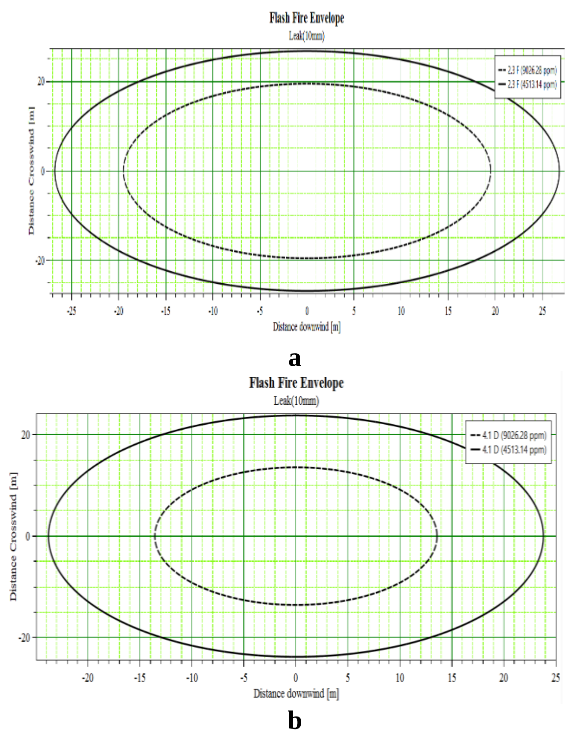
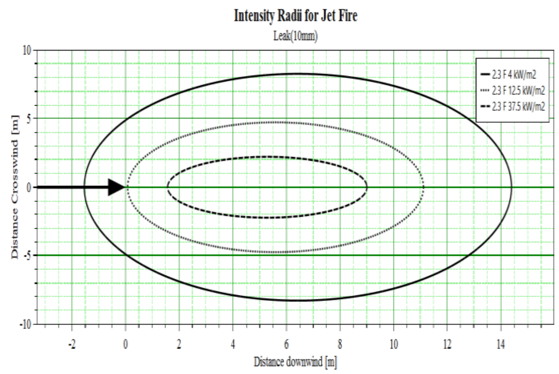


Figure 2. Sudden fire emission range for the first scenario in **a**- 2.3 F, **b**- 4.1 D.



a

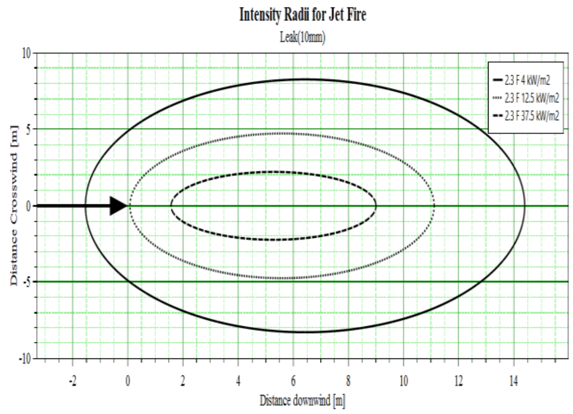


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Figure 3. Eruptive fire emission range for the first scenario in **a**-2.3 F, **b**-4.1D

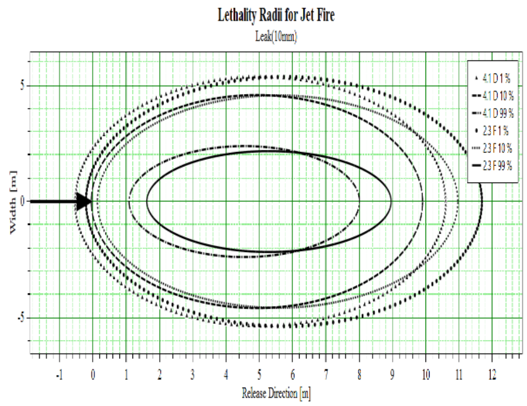
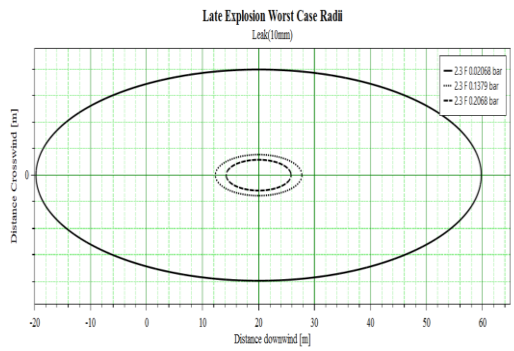
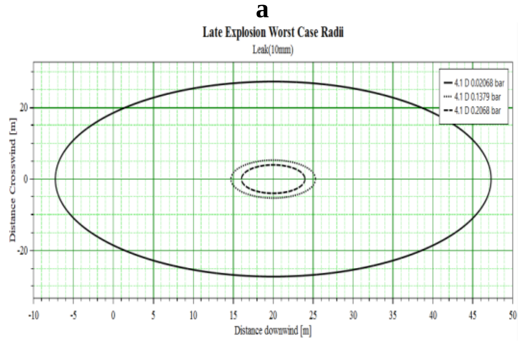


Figure 4. Eruptive fire emission range for the first scenario in 2.3 F and 4.1 D



a



b

Figure 5. Range of pressure increasing levels due to expulsion wave for the first Scenario in **a**-2.3 F, **b**-4.1D

up to radius 14.5, 11, and 9 meters, respectively, and for climatic conditions 4.1 D it continues up to a radius of 13.5, 10, and 8 meters, respectively.

Figure 4 indicates that three different levels of vulnerability for fire eruptive fire in 2.3 F and 4.1 D climates. According to the data obtained, people or equipment that are approximately 8.5 meters radius from the release source is going to be destroyed due to radiation from the eruptive fire. The vulnerability of 1% and 10% in this scenario occurs at intervals of approximately 11.5 meters and 10 meters for equipment and staff. Figure 5 (a and b) shows the ranges related to the increase of pressure created by the explosion in the direction of the wind and three different values of 0.0207, 0.1379, and 0.2068 bar at distances of 60, 28, and 26 m from the reservoir for climate conditions of 2.3 F, and 47, 25, and 24 m for the climate condition of 4.1 D. Explosion wave values are determined to indicate the areas affected by them and to determine safe distances in the model and based on the sources and their consequences (window breakage, partial and complete destruction of the building, death, and so on).

3. 2. The Second Scenario-Complete Rupture

The results of complete rupture modeling are reported as the worst case scenario in simulating possible consequences in climatic conditions (2.3 F and 4.1 D). According to the results, the width of the formed cloud for fire concentration was obtained 800 and 670 m, and the cloud of vapor rises to approximate heights of 4 and 2 m in climatic conditions 2.3 F and 4.1 D respectively. In addition, in 2.3 F climates, the fire concentration and half of this concentration are confined to the distances of 1600 and 930 m, but due to the fact that in 4.1 D climates, the wind speed is higher and the atmosphere is more unstable, the digits are reduced to 1200 and 800 m, respectively. The ranges related to the increase in pressure created by the explosion in the wind direction at three different range of 0.0207, 0.1379, and 0.2068 bar was obtained at distances of 2700, 1300, and 1200m from the reservoir for water conditions 4.1 D, respectively. These values are 3600, 2000, and 1850 m for 2.3 F weather conditions, respectively.

3. 3. The Third Scenario-Continuous Leakage with a Constant Release Rate

In this section, the results of modeling continuous release at a constant rate for 10 minutes in different climatic conditions (2.3 F and 4.1 D) are expressed. In this scenario, the cloud formation of the ignition concentration expands to a distance of 1025 m for weather conditions 2.3 F and to a distance of 460 m for weather conditions 4.1 D. According to the results in climatic conditions 2.3 F, the range with a radius of 1900 meters has a concentration of more than half of the lower flammability limit, and the range with a radius of 1050 meters has a concentration more than the flammability limit, while these distances are for climate 4.1 D, radius 700 and 450 meters. The modeling results show that with increasing wind speed and decreasing atmospheric stability, the scattered cloud concentration dilutes faster; therefore, the radius corresponding to the fire concentration parameter is less in 4.1 D. In addition, results indicate that, the intensity of radiation, which corresponds to the immediate death or destruction of equipment, occurs in climatic conditions (2.3 F and 4.1 D), at intervals of 180 and 160 meters, respectively. So, at an approximate distance of more than 290 meters almost no radiation is observed from this consequence. The areas related to the increase in pressure created by the explosion of the constant release scenario in the wind direction and in three different values: 0.0207, 0.1379, and 0.2068 bar are at distances of 2400, 1000 and 920 meters from the reservoir, respectively, for weather conditions 4.1 D. These values are 4700, 2400, and 2300 meters for 2.3 F.

The results of risk assessment regarding the occurrence of different scenarios is indicated using F-N curves, by calculating the amount of Probity Function and the probability of mortality, assuming that the number of people in the affected area are scattered with an average population distribution coefficient of 0.001. Figure 6 indicates that the F-N curve for the studied scenarios. The vertical and horizontal axes in this figure show the reproducibility of scenarios and the number of casualties due to accidents over a period of one year. In fact, at this stage, a combination of repeatability and consequences of scenarios and mortality rates is used to determine the risk. In this diagram, the upper diagonal line shows the high-risk criterion and the lower diagonal line shows the low risk criterion. The area between the two is the average risk area. The broken line between the two diagonal lines represents the desired process in the unit under study.

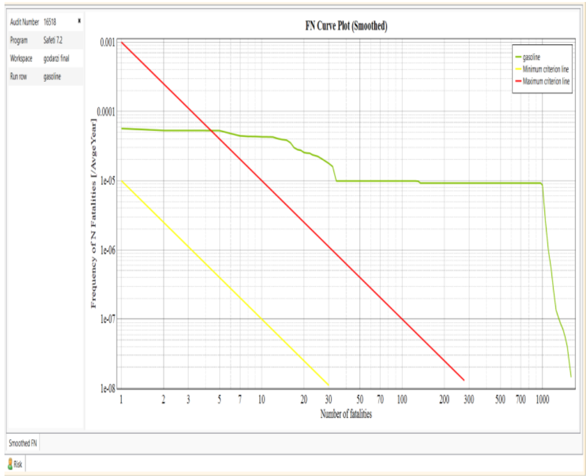


Figure 6. F-N Curve

4. CONCLUSION

The figure indicates that a high percentage of the process under study is in the high-risk area. To reduce the risk, two factors must be reduced, the consequence factor or its repeatability, or both. Many accidents occur due to corrosion and decay of connections and equipment. One of the strategies to reduce reproducibility includes increasing periodic inspections, thickness measurements, and monitoring. Given that the scenario of sudden discharge of tank contents and the consequence of explosion and fire is an instantaneous and unpredictable event, the time parameter has no effect on reducing the severity of casualties. In the contrary, the consequences of leakage events with a constant release rate or leakage of 10 mm is strongly dependent on the leakage time. Therefore, it is recommended that leak-sensitive sensors be installed near hazardous equipment to identify the leak as soon as possible and to eliminate it so that as a result, the amount of damage is minimized.

5. ACKNOWLEDGMENT

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6. REFERENCES

1. Wang, H., Khan, F., Ahmed, S. and Imtiaz, S., "Dynamic quantitative operational risk assessment of chemical processes", ***Chemical Engineering Science***, Vol. 142, (2016), 62-78. https://doi.org/10.1016/j.ces.2015.11.034
2. Wu, D. and Chen, Z., "Quantitative risk assessment of fire accidents of large-scale oil tanks triggered by lightning", ***Engineering Failure Analysis***, Vol. 63, (2016), 172-181. https://doi.org/10.1016/j.engfailanal.2015.11.029

3. Dadashzadeh, M., Kashkarov, S., Makarov, D. and Molkov, V., "Risk assessment methodology for onboard hydrogen storage", ***International Journal of Hydrogen Energy***, Vol. 43, No. 12, (2018), 6462-6475. https://doi.org/10.1016/j.ijhydene.2018.01.195
4. Fuentes-Bargues, J.L., González-Cruz, M., González-Gaya, C. and Baixauli-Pérez, M., "Risk analysis of a fuel storage terminal using hazop and fta", ***International Journal of Environmental Research Public Health***, Vol. 14, No. 7, (2017), 705. https://doi.org/10.3390/ijerph14070705
5. Ahmed, M.M., Ibrahim, M.M. and Al Ghabshawi, O.M., "Risk assessment for hydrocarbon fuel storage and handling facilities at gaili area, khartoum north-sudan", ***IRA-International Journal of Applied Sciences***, Vol. 10, No. 2, 18-26.
6. Swick, D., Jaques, A., Walker, J. and Estreicher, H., "Gasoline risk management: A compendium of regulations, standards, and industry practices", ***Regulatory Toxicology Pharmacology***, Vol. 70, No. 2, (2014), S80-S92. https://doi.org/10.1016/j.yrtph.2014.06.022
7. Badri, N., Nourai, F. and Rashtchian, D., "Quantitative risk assessment to site cng refueling stations", ***Chemical Engineering Transactions***, Vol. 19, (2010), 255. https://doi.org/10.3303/CET1019042
8. LaFleur, A.C., Muna, A.B. and Groth, K.M., "Application of quantitative risk assessment for performance-based permitting of hydrogen fueling stations", ***International Journal of Hydrogen Energy***, Vol. 42, No. 11, (2017), 7529-7535. https://doi.org/10.1016/j.ijhydene.2016.06.167
9. Khakzad, N., Dadashzadeh, M. and Reniers, G., "Quantitative assessment of wildfire risk in oil facilities", ***Journal of Environmental Management***, Vol. 223, (2018), 433-443. https://doi.org/10.1016/j.jenvman.2018.06.062
10. Xu, X., Wang, F., Huang, M., Bai, J. and Li, L., "Security quantitative risk analysis of ethylene horizontal tanks of a petrochemical company", ***Procedia Engineering***, Vol. 45, (2012), 489-495. https://doi.org/10.1016/j.proeng.2012.08.191
11. Nelson, T.P., "An examination of historical air pollutant emissions from us petroleum refineries", ***Environmental Progress Sustainable Energy***, Vol. 32, No. 2, (2013), 425-432. https://doi.org/10.1002/ep.11713
12. Khan, F.I. and Abbasi, S., "Modelling and control of the dispersion of hazardous heavy gases", ***Journal of Loss Prevention in the Process Industries***, Vol. 12, No. 3, (1999), 235-244. https://doi.org/10.1016/S0950-4230(98)00009-6
13. Taghehbaf, M.A., Givehchi, S., Ardestani, M. and Baghvand, A., *Modeling the consequences of potential accidents in one of the gasoline storage tanks at oil storage of yazd, in terms of explosion*. 2014, IJEIR.
14. Bouafia, A., Bougofa, M., Rouainia, M. and Medjram, M.S., "Safety risk analysis and accidents modeling of a major gasoline release in petrochemical plant", ***Journal of Failure Analysis Prevention***, Vol. 20, (2020), 358-369. https://doi.org/10.1007/s11668-020-00826-9
15. Zhou, J., You, Y., Bai, Z., Hu, Y., Zhang, J. and Zhang, N., "Health risk assessment of personal inhalation exposure to volatile organic compounds in tianjin, china", ***Science of the Total Environment***, Vol. 409, No. 3, (2011), 452-459. https://doi.org/10.1016/j.scitotenv.2010.10.022
16. Golbabai, F., Avar, N., Mohammadfam, I.J.H. and Journal, t.E., "Modeling propane leak in an industry publication", Vol. 20, (2012).

Persian Abstract

چکیده

در این مقاله ارزیابی ریسک مخزن بنزین شرکت ملی پخش فرآورده های نفتی منطقه ساری به کمک نرم افزار PHAST با توجه به داده های محیطی و فرآیندی واحد مورد ارزیابی قرار گرفته است. مدل سازی پیامدهای ناشی از سناریوهای مختلف مانند نشتی کوچک ، نرخ رهایش ثابت و پارگی کامل صورت گرفت و سپس محدوده مربوط به هریک از آن ها با توجه به شدت تشعشع یا موج فشار بدست آمد و فواصل ایمن هریک از آن ها مشخص گردید. با توجه به پیامد انفجار، بدترین نتایج آن مربوط به شرایط آب و هوایی F ۲/۳ به ترتیب ۴۷۰۰، ۲۴۰۰ و ۲۳۰۰ متر می باشد. همچنین، بر اساس داده های آتش فورانی و ناگهانی، شدت تشعشع که متناظر با مرگ آنی و یا تخریب کامل تجهیزات می باشد، در شرایط آب و هوایی (F ۲/۳ و D ۴/۱)، به ترتیب در فواصل ۱۸۰ و ۱۶۰ متر اتفاق افتاد و فواصل اشتعال پذیری در این دو شرایط آب و هوایی به ترتیب ۱۰۵۲۰ و ۴۵۰ متر بوده است. در ادامه، با ترکیب شدت این حوادث با توزیع جمعیت و احتمال رخداد آن ها سطح ریسک این مخازن تعیین شد.