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Research article

RISK MANAGEMENT OF GAS STATIONS THAT URBAN EXPANSION CREPT INTO IN THE GAZA STRIP.

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Abstract: The study aimed to understand and analyze the risks of indiscriminate urbanization around gas stations, the mechanisms for mitigating risks that affect buildings, and the most important risks affecting the surrounding area. The study followed a descriptive and analytical approach using chemical analysis software (ALOHA) to achieve the study objectives. The study found various risks and problems that threaten the community's safety and security in the Gaza Strip, and the presence of multiple factors that affect the safety system, especially the isolation of tanks that are exposed to the risk of ignition or explosion. It also concluded that the radius of the leakage, ignition, or explosion risks varies depending on the tank size, weather conditions, and the surrounding building density. The study recommended to narrow the gap between science and practical application in the field of safety and security, and also to work on correcting the conditions of gas stations to cohere with the protection of the internal front from accidents and risks of hazardous, flammable, or explosive chemicals.

Keywords: LPG Stations, Facility Correction, Risk Management, Chemical Analysis, Urbanization.

1. General framework

1.1 Introduction

The science of Risk management is considered one of the modern sciences that government institutions and international bodies are interested in; through developing guidelines, regulations, and legislation that strengthen the safety system, prevent risks, and reduce their effects. The United Nations has shown a keen interest in establishing scientific evidence that enhances the resilience of cities to withstand greater risks through urban planning, which sequentially improves infrastructure resilience and the sustainability of human activities, and that urban agglomerations must bear the risks and their resulting threats, analyze them, and develop control mechanisms and policies to reduce their level (UNDRR, 2017).

The Gaza Strip is characterized by its small area of 365 km^2, with more than 2.25 million inhabitants, making it the most densely populated area in the world. It is bordered to the east and north by the occupied Palestinian territories, to the south by the Arab Republic of Egypt, and to the west by the Mediterranean Sea (Awad, 2020). The Gaza Strip suffers from risks that threatens the urban environment and human gatherings due to the Israeli blockade of Palestinian society. The challenges of urban development related to the scarcity of land are the biggest threat to stability and balance, followed by encroachments on land uses by citizens (El-Mougher, 2016), which resulted in problems impacting the distribution of hazardous crafts and facilities, thus increasing the rates of risks that threaten the environment of the Gaza Strip.

The gas stations scattered throughout the Gaza Strip pose a threat due to various factors and associated problems, especially given the political, social, and economic vulnerabilities that make the Gaza Strip a place where expired gas tanks are assembled. Additionally, there is a prohibition on the entry of new and modern tanks to the Gaza Strip, along with a decline in both public safety indicators and the provision of preventive measures.

1.2 Study Problem

Land scarcity and high population density in the Gaza Strip represent a clear challenge, especially in the light of the indiscriminate urbanization that has increased the risks stemming from economic, social, and political vulnerability and the consequent increase in the level of hazard associated with the presence of gas stations in overcrowded residential areas. Based on the nature of the researchers' work and their direct observation of the regulatory violations of the safety distances between gas stations and residential facilities or the safety distances between fuel and gas stations, the following main question arose:

What are the risk management mechanisms for gas stations affected by urban expansion?

The following questions have been raised:

- What are the risks associated with gas stations?
- What are the risks of urbanization on gas stations?
- How to control the risks of urbanization around gas stations?

1.3 Objectives of the study:

The study aimed to understand and analyze the risks of indiscriminate urbanization around gas stations, the mechanisms for mitigating risks that affect buildings, and the most important risks affecting the surrounding area. Hence, the following objectives were derived:

– Identify the risks of liquefied household gas-filling stations.

– Analyze the risks of urbanization around gas-filling stations.
– Assessing the risk control of urbanization around LPG filling stations and mechanisms to minimize the proximity of residential buildings to them.

1.4 Importance of the study:

- The study contributes to solutions development to existing and accumulated problems at gas stations.
- Assists decision-makers in taking necessary measures to mitigate risks.
- Enhances the researchers' skill in dealing with risks associated with hazardous facilities, which reflects on improving their performance.

1.5 Study Methodology:

The researchers used the descriptive approach to describe the gas stations, their quantity, and the problems they face. They also used the analytical approach by using chemical beam programs to analyze potential accidents, and the constructive approach to develop mechanisms and a design model to mitigate the risks of gas stations deployed in residential areas.

1.6 Study Boundaries:

1.6.1 Spatial Boundaries: *Gaza's 365 km^2 area, which is characterized by high population and urban density.*

1.6.2 Objective Boundaries: *gas stations, hazardous chemicals, regulations and legislation, chemical analysis programs.*

1.6.3 Time Boundaries: *The time period extends from 2020 to date.*

1.7 Previous studies:

1.7.1 (El-Mougher, 2019) study, titled: Indicators for Risk Assessment and Management in Industrial Enterprises in Gaza Strip.

The study aimed to reach standards and indicators for risk management in industrial enterprises and to link problem-solving with risk management in industrial enterprises, depending on risk assessment and management indicators. The study used the descriptive and analytical approach to local standards for risk assessment and management. It found weak reliance on clear indicators in risk assessment and management, a lack of employers' interest in risk assessment and analysis, a lack of methodological evidence adopted to analyze and assess risks in enterprises that put them at risk and a weak response. The study recommended activating scientific research in the field of risk management, raising the level of training and sensitization of workers on the importance of safety and risk prevention, preparing an annual risk assessment for enterprises, and dividing risk management procedures into an exploratory assessment of risks, remedial measures that enhance risk prevention, and corrective measures that correct the risks in industrial enterprises.

1.7.2 (Beheshti, Dehghan, Hajizadeh, Jafari, and Koohpaei, 2018) study, titled: Modelling the Consequences of Explosion, Fire and Gas Leakage in Domestic Cylinders Containing LPG.

The study aimed to model the effects of LPG leakage from domestic cylindrical containers. It used the descriptive and analytical approach to describe the factors affecting LPG leakage in cylinders of the following volumes (26, 60, 78, and 107 liters). The ALOHA program was used to analyze leakage pathways and events resulting from ignition and explosion. The study found that a leaking cylinder of the studied volumes had a gas concentration of 33,000 ppm in a radius of up to 11 meters around the cylinder, which poses a risk of death and a direct threat to people's lives. Meanwhile, the gas concentration at a distance of 11-16 meters was about 21,000 ppm, which is equivalent to a low explosive level, leading to the combustion and explosion of the gas vapor cloud, which poses a threat to people in a radius of 15 meters. The study recommended that accident response plans should be based on a chemical analysis of leakage risks and work to reduce the adverse effects of the spread of gas vapor clouds or hazardous substances to protect people.

1.7.3 (Bariha, Mishra, & Srivastava, 2016), titled: Fire and explosion hazard analysis during surface transport of liquefied petroleum gas (LPG): A case study of LPG truck tanker accident in Kannur, Kerala, India.

The study aimed to simulate a collision accident between a truck tanker and a barrier that caused a crack in the bottom pipe, resulting in gas leakage for 20 minutes, forming a large vapor cloud in Kannur, Kerala state, India. The study used the descriptive and analytical approach to describe the scope of impact, ignition and explosion risks resulting from the vapor cloud, using the PHAST program and case study methodology for the actual incident that occurred and caused severe damage. The study concluded that the leakage resulted in a fireball and a boiling liquid expanding vapor explosion (BLEVE) in the tank, which caused a fire followed by an explosion, and the incident resulted in fatalities, injuries, as well as ignition of trees, houses, vehicles, and surrounding stores. The results of the analysis, modeling, and simulation of the fireball, jet flame radiation, and overpressure leading to the explosion were consistent, and an area with a radius of approximately 200 meters was severely affected, which is consistent with the actual loss of lives and property verified from ground data.

1.7.4 Commentary on the previous studies:

The previous studies have focused on examining the risks associated with domestic gas containers with a capacity of up to 107 liters, studying indicators of industrial enterprise risk assessment, and holding risk assessments using computerized programs of a roadway gas tank with a leakage followed by ignition and then an explosion. However, the current study works on developing mechanisms to deal with gas stations scattered in urban agglomerations and how to reduce the risks and damages which affect the urban environment. This study is characterized by providing a set of solutions to minimize risks at gas stations scattered among the population, given the multiple factors affecting urban change and land use in the Gaza Strip. Therefore, it can cover a research gap.

2. Theoretical framework

A hazard is a phenomenon, substance, or condition which is capable of damaging the infrastructure, services, community, property, natural environment, or surrounding environment; (UNESCO 2016) Sources of risk vary between human activity or dangerous conditions that can cause severe loss of life or health impacts that harm property, interrupt livelihoods or disrupt social and economic services and environmental damage (LPG Bottling Plant & BPCL Kappalur, 2017). The risks are the combination of the likelihood of occurrence and the effects of such occurrence with the potential to adversely affect activities, production objectives and work in the enterprise (Zhao et. al., 2017).

2.1 Risk Management:

Risk management is characterized by integrated processes that contribute to the development and improvement of the ability of institutions, departments, organizations, companies, factories, or enterprises to understand risk, its dimensions, the most important sources of risk, and the assessment of those risks, their resulting actions, levels of impact and expected damage to the surrounding environment, as well as assessing human, property and working environment vulnerability to damage affecting work streams and procedures to establish comprehensible mechanisms for managing and controlling their sources and limiting their impact on their surroundings.

2.1.1 Risk management methodology

To implement the practical methodology to start identifying the risks that threaten the enterprise, institution, or project, is done through a range of executive processes: (General Department of Planning and Development, 2020)

- Adopting practical tools used to identify risks.
- Adapting the tools to the environment, conditions and variables affecting the emergence and expansion of risks.
- Collecting information and data according to the approved tools, analyzing the information and identifying the risks.
- Building expected scenarios according to:
    - The worst-case scenario that can stop the normal activity.
    - The best-case scenario that aligns with risk avoidance.
    - The realistic scenario that chimes with the ability of hazard sources to influence the community's life cycle.
- Choosing the best alternative in the proposed scenarios, especially to mitigate the expected damages.
- Developing risk control and management plans, and assign tasks and responsibilities to stakeholders.
- Integrating risk response or mitigation plans with civil defence plans.

2.2 Liquefied petroleum gas (LPG)

LPG is a mixture of propane and butane with a quantity of hydrogen sulfide added to give a distinctive smell. It is classified as flammable gas and lies in category II by NFPA, UN, and the Globally Harmonized System for Hazardous Materials (GHS). LPG is a pressurized gas that goes through cooling processes to be transformed into a liquid state within containers. When LPG is released from its containers, it spreads in low-lying areas because it is heavier than air, which makes it hazardous when ignited and can affect people and property.

2.2.1 Hazardous Properties of LPG

2.2.1.1 The boiling point for LPG: is - 161.48 to - 0.5 °C. The boiling point is defined as the temperature at which the substance changes from liquid to gaseous state during each part of the liquid.

2.2.1.2 The flash point of LPG is - 104 to - 60 °C, where the flash point is defined as the lowest temperature at which LPG can form a flammable mixture with air in the presence of a source of ignition.

2.2.1.3 Lower ignition or explosion limit: It forms a risk of explosion or ignition at a minimum mixing rate of 1.8% with atmospheric.

2.2.1.4 The upper limit of ignition or explosion: It constitutes a risk of explosion or ignition at a maximum mixing rate of 9.5% with atmospheric air for the occurrence of ignition or explosion. If the percent exceeds this limit, then the mixture of gas and air is very rich in gas and the amount of oxygen in the air is insufficient for the occurrence of ignition or explosion.

2.2.1.5 Self-ignition temperature: LPG ignites at pressure (1.013) Bar and at temperatures (287-537 °C).

2.3 The explosion chemistry of LPG: (Wasel, 2010)

2.3.1 Propane:

$$C_3H_8\,(g) + 5\,O_2(g) \xrightarrow{\text{flame}} 3CO_2 + 4\,H_2O + E$$

$$44\text{ gram} \quad + \quad 160\text{ gram}$$

- (1)liter of propane gas needs (5) liter oxygen for explosion.
- Oxygen gas represents 20% of atmospheric air = one fifth of atmospheric air.
- (1) liters of propane gas need (5 * 5 = 25) liters of atmospheric air in pressure (1) bar for explosion.

2.3.2 البيوتان

2.3.2 Butane

$$2C_4H_{10}\,(g) + 13\,O_2(g) \xrightarrow{\text{flame}} 8CO_2 + 10\,H_2O + E$$

$$58\text{ gram} \quad + 230\text{ gram}$$

- (2) liters of butane gas need (13) liters of oxygen for the explosion to occur.
- Oxygen gas represents 20% of atmospheric air = one fifth of atmospheric air.
- (2) liters of butane gas need (13 * 5 = 65) liters of atmospheric air in pressure (1) bar for explosion.

3. Practical framework and study tools:

To achieve the study's objectives, researchers followed a descriptive and analytical approach and a case study methodology for applying clear mechanisms to reduce the risk of LPG stations to urban agglomerations in the Gaza Strip, where the study analyzed the content of reports and made chemical analysis through chemical package programs.

3.1 The Reality of Gas Stations in the Gaza Strip:

Successive Governments in the Gaza Strip have worked to regulate the issuance of licenses for gas stations in the Gaza Strip since the establishment of the Palestinian Authority until the present time. Due to urban expansion, the vulnerable state of society, high land prices, and the decline in the application of local authorities' regulations due to economic and social vulnerabilities, all of which have led to many violations of the system for establishing gas stations issued by the Central Committee for Buildings and Urban Planning in 2006 and the regulations for safety conditions, protection, fire prevention, firefighting equipment and alarms specification that must be available in gas-filling stations, transport and distribution vehicles, and storage locations for liquefied petroleum gas cylinders issued in 2000 as one of the explanatory regulations of Civil Defence Law No. (3) of 1998 have emerged.

To achieve the objectives of the study, researchers analyzed the reports of the Central Committee for Buildings and Urban Planning as well as those of the Committee for Correction of Hazardous Facilities and Crafts. These reports indicated that competent government committees conducted field visits to gas stations and took decisions to either close the stations or halt operations.

The Central Committee for Buildings and Urban Planning established a system that outlines the regulatory requirements for gas stations in the Gaza Strip. However, this system did not consider the maximum limit for gas stations' capacity, daily operational capacity, or storage capacity that considers the relationship with the supplying entities, the closure of border crossings, and their impact on administrative and societal components. Moreover, the application of the system did not enforce citizens to refrain from expanding urbanization around gas stations, leading to an increase in hazards that affect urban and architectural development. Currently, the number of gas stations in the Gaza Strip is (51), distributed as follows: (5) gas stations in Rafah, one of which was closed for violating safety requirements; (7) gas stations in Khan Younis, one of which experienced a fire followed by an explosion and remains closed to this day; (14) gas stations in middle Governorate, one of which was moved for violating requirements; (16) gas stations in Gaza Governorate, one of which was closed due to the high urban density surrounding it; and (9) gas stations in the northern governorate, of which two were ordered to be moved for violating regulatory requirements.

Additionally, there are many gas stations that have construction permits but have not been completed due to the economic conditions experienced by the local community and the difficulty in providing the necessary extensions for installations and tanks, which impedes the establishment and development of gas stations to overcome the deterioration of equipment and tools.

3.1.2 Station violations to the system or regulation of safety and fire prevention requirements:

As a result of the multiple violations, and through field visits conducted by the researchers, they classified the violations as follows: (Committee for Correction of Hazardous Facilities and Crafts, 2021)

- **Regulatory problems:** These are related to the specific dimensions of the station, its location, or land-use requirements, and it violates the 2006 gas-filling system in the Gaza Strip, thus the station needs to change its location according to the system.
- **Urban Safety Problems:** These are related to violations of the dimensions and distances specified by the Civil Defence regulations, which require a distance of 100 meters between fuel and gas stations. These problems require a review of the corrective measures of these stations.

- **Tank-related Problems:** They are concerned with the nature of gas containers, and with modifying and welding them without proper heat treatment. All the international codes require the removal of tanks that have been modified from service and convert their use as fuel tanks. Moreover, these tanks have exceeded their expected lifespan, which is estimated at 20-25 years according to the specifications of each country, especially since the occupation prevents the entry of new tanks while allowing the entry of terminated tanks, or ones with rust and corrosion. In addition, to the lack of ability to conduct periodic technical inspections.
- **Problems related to the specifications of pumps and pipelines:** the occupation tightened its suffocating siege on the Gaza Strip, which contributed to the failure to provide pumps that comply with international standards and specifications. This has consequently led to the use of filling and discharge pumps that violate regulations and standards, as well as gas pipelines that extend from tanks to the filling points that do not conform to Palestinian standards and specifications, thereby using water pipelines that are not designed to withstand gas pressure or maintain their liquid state.
- **Problems related to the stored quantities:** it has been noticed that most of the stations violate the storage categories and maximum capacity specified for them according to the station construction system. There are stations whose capacity is classified as 50 tons, but they are storing quantities that exceed 100 tons, and there is a case of a station that has reached a capacity of more than 500 tons.
- **Problems related to the application of safety and protection measures:** a significant portion of fuel and gas stations lack the minimum safety and protection components required for the stations, whether in terms of cooling and covering tanks or the provision of fire and gas sensors, and other crucial measures to reduce risks at the stations.

3.1.3 Potential risks in gas stations:

In light of the above and based on the analysis of the report's content, the researchers have identified a range of significant risks associated with the hazardous material used in gas stations. These risks can lead to potential accidents according to their sequence scenarios, as shown in Figure (1). These risks can cause loss of life, assets, or property, in addition to occupational illnesses for workers.

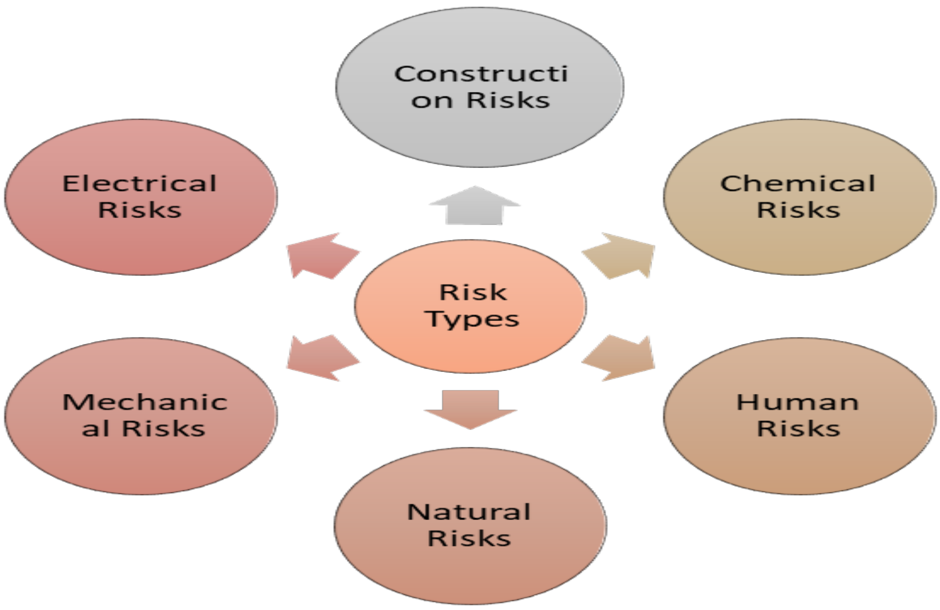

Figure (1): Potential risks at Gaz Station

3.2 Chemical Risk Analysis:

To achieve the study's objectives, chemical package programs were used to analyze potential risks according to scenarios of potential accident sequences, which are as follows:

3.2.1 Risk of gas leakage from 100-ton tank without fire

- **The areas where the gas is spread.** when a hazardous chemical (gas) leaks due to a malfunction in the tank, such as a faulty valve or a direct impact causing a large hole, or due to severe earthquakes or sudden soil collapse without explosion, the gas spreads in the surrounding areas as shown in Figure (2).

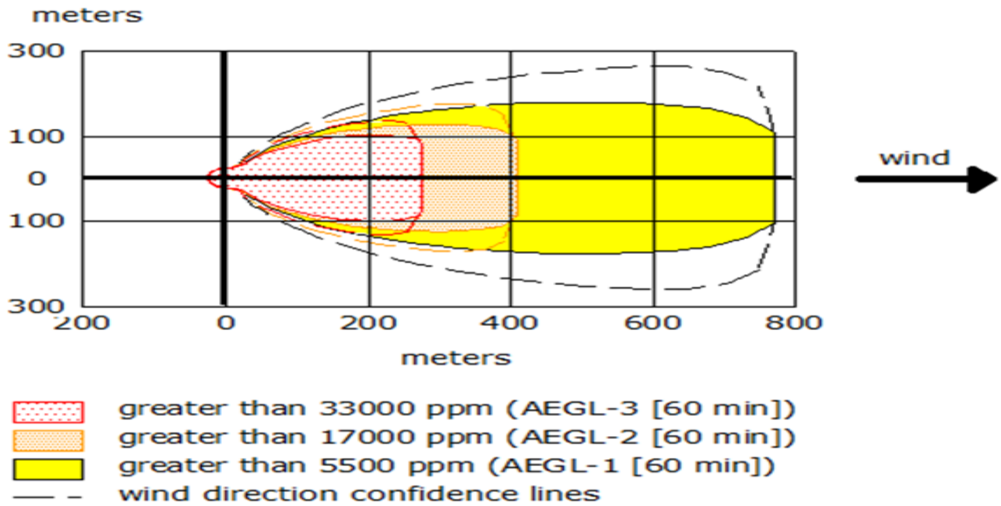

Figure (2) : Gaz spreading in the surroundings

Figure (2) shows that: the red threat zone, which poses a threat to human life, extends up to a distance of 275 meters, while the orange threat zone, where the people's abilities are impaired, is approximately 409 meters away. Whereas the yellow threat zone, in which the gas is barely felt and extends to around 772 meters downwind.

- **The Flammable areas:** In case of gas leakage and its subsequent ignition, in the red and orange threat areas combined together, there would be complete destruction of buildings, while the yellow threat area would be filled with toxic gases and fumes. Figure (3) shows the flammable areas.

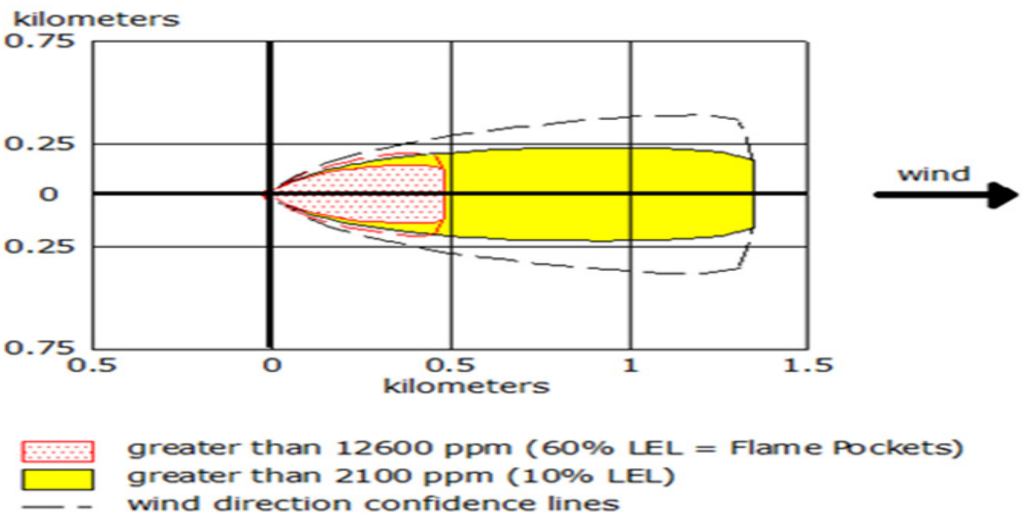

Figure (3) : Flammable areas due to Gaz spreading

Figure (3) shows that: the red and orange threat zones extend up to a distance of 486 meters, while the yellow threat zone, where building windows can be shattered, reaches a distance of approximately 1.4 kilometers. It is noteworthy that the area where buildings get damaged is very large.

- **Blast areas of vapor cloud:** the following figure shows the blast areas of the vapor cloud where the red threat zone is defined by a high impact level and accompanied by destruction of buildings. Figure (4) shows the blast areas of the vapor cloud.

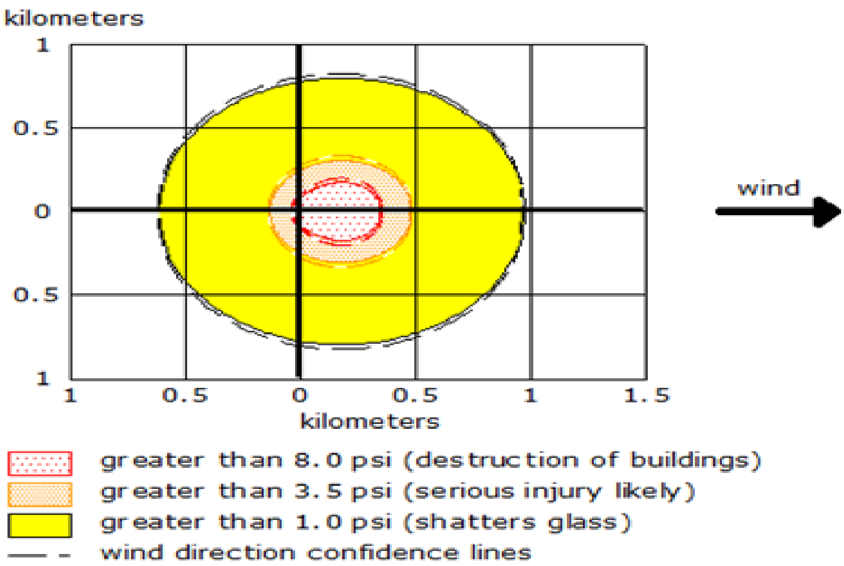

Figure (4):The threat zone of Gaz cloud blast

Figure (4) shows that: the red threat zone is estimated to extend about 356 meters in all directions, and the orange threat zone, which would likely cause serious injury, is predicted to extend to a distance of 488 meters. The yellow threat zone, where glass gets shattered, is estimated to extend up to 979 meters away.

3.2.2 Gas leakage risk from 100-ton tank accompanied by a jet fire

- In case of leakage of gas from the tank accompanied by a jet fire, the areas affected by thermal radiation resulting from the gas combustion are shown in figure (5).

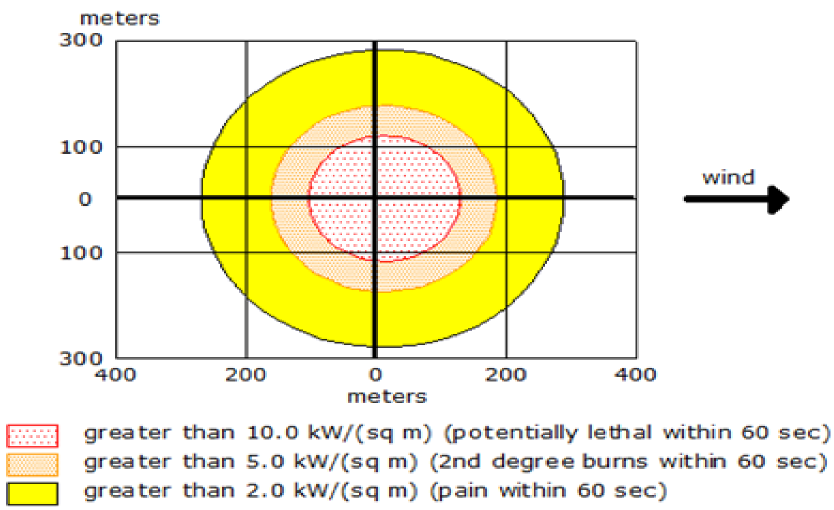

Figure (5):Gaz leakage spreadings

Figure (5) shows that: The red threat zone, where there is a high risk of death for individuals exposed to thermal radiation within 60 seconds, is estimated to extend up to 160 meters. The orange threat zone, where there is a moderate risk of second-degree burns for individuals exposed to thermal radiation within 60 seconds, is estimated to extend up to 190 meters. The yellow threat zone, where individuals may experience pain due to exposure to thermal radiation within 60 seconds, is estimated to extend up to 240 meters.

3.2.3 Risk of 100-ton gas tank explosion in the form of a fireball, (BLEVE).

- **The tank explodes and chemical burns in the form of a fireball.** Figure (6) shows the tank explosion and the gas burning in the form of a fireball, releasing thermal radiation that affects a wide area.

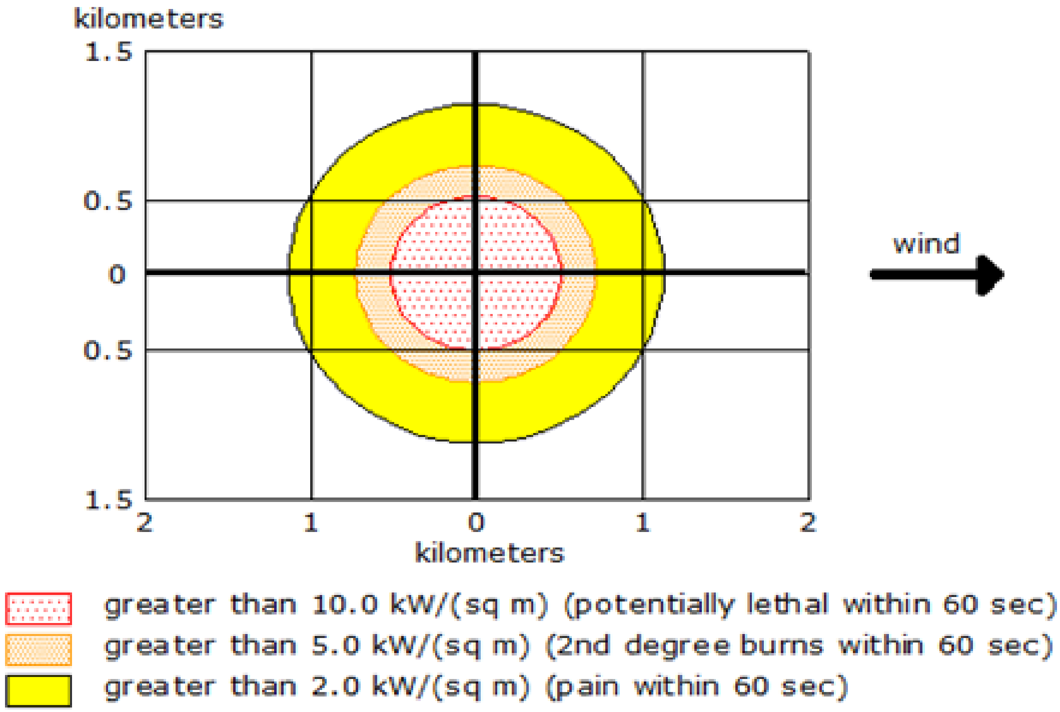

Figure (6) : Vessel Gaz explosions

Figure (6) shows that: the red threat zone extends up to 513 meters, the orange threat zone reaches up to 724 meters, and the yellow threat zone extends up to 1.1 kilometers.

4. Discussion of results, treatment idea, and risk management to reduce the risks

Due to the fact that ignition or explosion factors require oxidation and reduction, and thus a reaction between oxygen and the combustible material, researchers believe that the first step in treatment is to provide an oxygen-free environment in the surrounding area of the tank. In case of leakage, appropriate measures should be taken to prevent gas from spreading and leaking, or a suitable spatial environment should be designed to withstand the vibrational pressure resulting from the gas vacuum explosion. This can be achieved through the following steps:

4.1 Placing gas tanks in reinforced concrete chambers underground, and covering them with sand, as shown in figure (7).

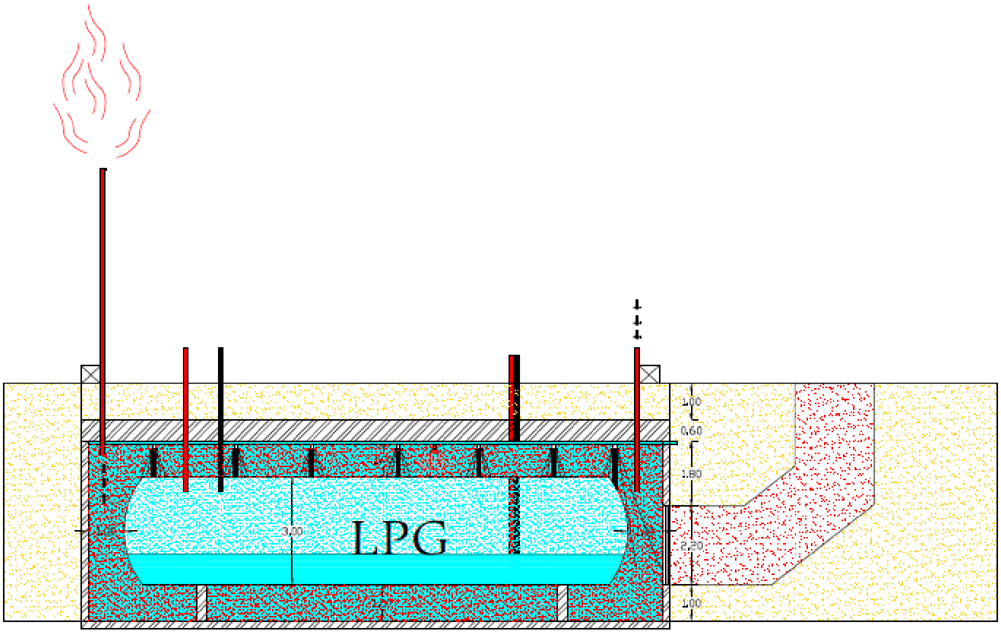

Figure (7) : LPG Vessel under ground room

Figure 7 shows that:

- The Room volume = 400 m^3, the tank volume = 98 m^3, the pressure in the tank ≈ 25 bar.
- To calculate the vacuum volume required to convert the diffused gas pressure to (1) bar = 25 * 98 = 2450 m^3.
- The required volume for homogenizing LPG gas with atmospheric oxygen = 2450 * 25 = 61250 m^3.
- Any leaked liquid gas inside the concrete pool is disposed of by pumping in air and suctioning the liquid gas and igniting it in the open air. Water is also used through water sprinklers and immersion systems to dissolve the gas in water and prevent its ignition.

4.2 Operational risk reduction:

Operational risks are the most prominent cause in the records of accidents associated with gas stations, including poor electrical extensions -which are one of the main causes of fires-, poor mechanical extensions or inability to perform periodic inspections of extensions and tanks. It is vital to continuously adhere to the Palestinian regulations, specifications and standards which require periodic inspection of gas extensions every six months and gas tanks every two years at most. Additionally, pressure relief and automatic sprinkler systems, early fire alarm systems, and flame detection sensors must be installed. Leakages can be detected through sensors connected to an alarm system, which can activate water immersion systems that push gas upwards to prevent accidents.

5. Conclusion

Based on the analysis of the findings, the researchers reached the following conclusions:

- There are several factors that contribute to enhancing the security and safety system, particularly isolating tanks that are at risk of ignition and explosion through concrete rooms.
- Ignition, explosion and leakage factors vary according to different weather conditions.
- Negligence plays a prominent role in expanding the cycle of risks, leading to recurring accidents.
- There is an urgent need to update the legal system in the field of safety, prevention and regulatory requirements for gas stations.
- The weakness of the regulatory system and the diversity of problems related to the regulatory requirements.

Recommendations

- The Safety Data Sheets (SDS) for imported chemicals should be attached to their containers, to identify their components and methods of handling during storage, transport, disposal, and prevention and safety measures.
- The need for a comprehensive system for Hazardous Materials management among the relevant ministries; that addresses Hazardous Materials from their point of entry into the Gaza Strip until their disposal.
- The need to narrow the gap between science and practical application in the security and safety field.
- The need to correct the conditions of gas stations, to cohere with the protection of the internal front from accidents and risks of hazardous, flammable, or explosive chemicals.

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