Occupational Health and Safety in Fuel Stations: Hazard Analysis and Risk Assessment

Akaryakıt İstasyonlarında İş Sağlığı ve Güvenliği: Tehlike Analizi ve Risk Değerlendirmesi

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ABSTRACT

Fuel stations are fuel storage facilities located in urban and rural areas. The fuels sold at these stations have the potential to cause occupational diseases as well as fire and various accidents. In terms of occupational health and safety, the workload and risks that fuel station employees are exposed to vary. Employees handle not only basic tasks like refueling, sales, and communication, but also additional security and service responsibilities. This study identified hazards affecting employees and customers at a fuel station in Iğdır province and rated the resulting risks using the matrix method. It was determined that the probability (l:3) and the result (c:5) are high (r:15) for the risk of fire and explosion that may be caused by leaks that may occur during refueling of vehicles. Among the preventive measures, it has been revealed that the risk value r:15 should be aimed at eliminating the sources that may cause or create sparks. It has been observed that the fact that employees do not have adequate training on the risks arising from the conditions of the execution of the work (r:10) and that they are not adequate about what to do in emergencies (r:10) are among the important risks for the enterprise. In addition, the study recommended that deficiencies related to the existing electrical system (r:10) and equipment, which pose a high risk, should be eliminated. Establishing and properly implementing occupational health and safety strategies in the workplace can control unsafe actions and conditions in the stations.

Keywords: Fuel Station, Hazards, Occupational Health and Safety, Risk

ÖZ

Akaryakıt istasyonları, şehir içi ve kırsal bölgelerde bulunan yakıt depolama tesisleridir. Bu istasyonlarda satılan yakıtlar, yangın ve çeşitli kazalara yol açabildiği gibi meslek hastalıklarına neden olma potansiyeline de sahiptir. İş Sağlığı ve güvenliği açısından benzin istasyonu çalışanlarının maruz kaldığı iş yükü ve riskler çeşitlilik göstermektedir. Çalışanlar, sadece yakıt ikmali, satış ve iletişim gibi temel görevlerle sınırlı kalmayıp, aynı zamanda ek güvenlik ve hizmet sorumluluklarını da üstlenmektedirler. Bu çalışmada Iğdır ilinde hizmet veren bir akaryakıt istasyonu dikkate alınarak çalışanları ve müşterileri etkileyebilecek tehlikeler belirlenmiş, bu tehlikeler sonucunda meydana gelebilecek riskler matris yöntemi ile derecelendirilmiştir. Araçlara yakıt ikmali esnasında meydana gelebilecek sızıntıların oluşturabileceği yangın ve patlama riski için ihtimal (i:3) ve sonucun yüksek (c:5) olduğu (r:15) en riskli durumu oluşturduğu tespit edilmiştir. Önleyici tedbirler arasında risk değeri r:15 ile kıvılcım oluşması veya oluşturacak kaynakların ortadan kaldırılmasına yönelik olması gerektiği ortaya konulmuştur. Çalışanların gerek işin yürütüm şartlarından kaynaklı riskler konusunda yeterli eğitime sahip olmamaları (r:10) gerekse acil durumlarda yapılması gerekenler konusunda yeterli olmamaları (r:10) işletme için önemli riskler arasında olduğu gözlenmiştir. Ayrıca çalışmada işletmede yüksek risk ihtiva eden mevcut elektrik sistemi (r:10) ve ekipmanları ile ilgili eksikliklerin giderilmesi gerektiği önerilmiştir. Çalışanlar açısından iş yerinde iş sağlığı ve güvenliği stratejilerinin oluşturularak doğru bir şekilde uygulanmasıyla istasyonlardaki güvensiz eylemlerin ve koşulların kontrol altına alınabileceğini öngörmektedir.

Anahtar Kelimeler: Akaryakıt İstasyonu, Tehlike İş Sağlığı ve Güvenliği, Risk

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INTRODUCTION

In recent years, the continuous acceleration of urbanization and the rapid rise in people's living standards have led to an increase in the number of fuel stations. The fuel station sector, which is an important link in the petroleum industry chain, contributes significantly to the economy[1]. Fuel stations are places where motor vehicles meet their fuel needs. These stations are the places where the fuel stored by special devices is filled into the tanks or fuel containers of motorized road vehicles. In addition, vehicle tires, accumulators and market services are also offered at these stations[2]. Some fuel stations have repair departments that provide services such as vehicle washing, lubrication, vehicle inspection and brake system.

In Turkey, there are approximately 25.32 million road vehicles in January 2022[3]. During this period, 3.29 million tons of gasoline types, 24.54 million tons of diesel types, 253 thousand tons of fuel oil[4] and 3.91 million tons of LPG were consumed[5]. While the number of fuel stations was 12,429 in July 2023, it was approximately 12,500 as of November 15, 2023. In terms of market share, Petrol Ofisi has a 21% share[6]. According to Petder's 2022 report, the sector directly employs around 150,000 people, including around 95,000 forecourt workers, 45,000 transportation/other station staff and 10,000 distribution company employees.

The oil and gas industry is one of the world's highest-risk sectors and has played an important role in occupational health and safety. Occupational accidents occur frequently, especially in areas where fuel unloading and filling processes take place, and occupational diseases have become a widespread problem[7]. In the United States, 43 people lost their lives in this sector in 2022, with 2.5 occupational accidents per 100 full-time workers and 1.3 lost days[8]. 25 of 41 accidents at fuel stations in Korea between 1992 and 2003 resulted in fire and explosion[9]. The US National Fire Protection Association reported that they responded to an average of 4150 fuel or service station fires per year between 2014 and 2018, mainly caused by electrical, lighting and vehicle fires[10]. Similar fires, work accidents and near-miss incidents occur frequently in our country, but no statistics are kept for this field of activity. Gas measuring devices or early warning systems are not available or legally mandated at stations to detect explosion or fire situations[2]. However, there are automatic fuel cut-off systems to detect fuel leaks. In this context, workers need to be protected from potential harm from the types of fuel available, lubricants and equipment used. However, another important aspect in terms of occupational safety is the fact that these hazards can affect not only employees but also customers visiting the station[11]. This is a critical issue in the operation of fuel stations, emphasizing both staff and visitor health and safety.

Personnel working in fuel stations experience high levels of exposure to chemical risks. Exhaust gases emitted around the station can increase the presence of highly toxic carbon monoxide gas, which is odorless and colorless[12]. Personnel may be at risk of inhaling this gas, especially in confined spaces and during maintenance operations when the engine is running[13].

Using the mouth to create a vacuum when pumping gasoline or ingesting gasoline through the mouth for similar reasons can increase the risk of pneumonia by workers inhaling gasoline vapors[14]. Benzene in gasoline can increase the risk of cancer for workers in case of long-term exposure[15]. Petroleum products that come into contact with personnel's bodies and hands can cause skin problems such as dermatitis[16]. During the control and maintenance of the brake systems of vehicles coming to the station, there is a risk of exposure to asbestos dust, which can be found in brake pads, especially in older model vehicles[17]. Personnel working in fuel stations may experience health problems related to the musculoskeletal system, especially due to manual lifting and transportation operations, as well as working in open areas[18].

The atmosphere in fuel stations contains volatile organic compounds from fuel vapors and combustion processes[19]. These compounds include substances such as benzene, toluene, ethyl benzene and xylene[20]. Gasoline can emit a vapor that can easily ignite even at low temperatures[21]. This characteristic makes fuel stations workplaces with a high risk of fire and explosion. If gasoline vapor comes into contact with a flammable heat source, sudden and large-scale fires and explosions can occur[22]. Research has shown that electrostatic charges are the main factor in fire formation[23]. Tanker trucks carry various risks during their use at stations and during maintenance, in structural additions and on personnel.

Various risk assessment criteria are currently applied in many organizations[24]. It has the potential to create undesirable scenarios while continuously uncovering factors that contribute to hazard during the operation and maintenance of fuel stations[25]. Therefore, risk assessment studies that prioritize hazards and calculate the risk value are required to assist health and safety professionals in decision-making[26]. Risk analysis criteria can be used to prioritize different risky activities, providing safety professionals with valid information to set the company's objectives. During operation, both the operator and the customer may engage in risky activities that could result in serious or minor injury. With the right approach and examination of accident causes, unsafe actions and conditions can be significantly reduced[27]. Adopting behavior-based safety strategies and identifying at-risk behaviors can significantly improve the safety situation[28]. Hazard identification and risk assessment is an important tool for prioritizing hazardous activities. They are ranked according to their consequence level and corrective and control measures are taken.

In our country, research on occupational risk factors of fuel station workers is very limited. These workers have a heavy workload that is not only limited to tasks such as refueling and sales, but also has additional safety responsibilities. Their work involves long periods of standing, shift work, and often exposure to noise, fumes and organic solvents[29]. It also requires a high level of focus and attention in order to work correctly and prevent accidents in the workplace. In addition, fuel stations are known to provide favorable conditions for occupational accidents. For these reasons, protecting the physical and mental health of fuel station employees, preventing accidents and improving their overall well-being is a critical issue[30]. In this context, taking concrete steps and implementing preventive measures are of great importance.

Occupational accidents are defined as events that cause occupational disease, injury, death or damage to the equipment used as a result of an unintended and undesired event. According to the Workplace Hazard Classes Notification on Occupational Health and Safety published in the official newspaper dated 26.12.2012, fuel stations are workplaces evaluated in the very dangerous class and the possibility of employees being exposed to occupational accidents is quite high. For this purpose, in order to evaluate the risks that occur during the work carried out in the station sampled in the study;

1. Are the health and safety measures at the fuel station selected for the study really designed to protect employees to the extent required by law?

2. How do employees perceive the performance of the measures taken?

3. Are there any hazards associated with the tools, machinery or equipment used?

4. Are workers exposed to excessive heat or cold?

5. Is there excessive noise or vibration?

6. Are they likely to be harmed or made ill by the effects of chemicals?

7. Is contact with hot, toxic or corrosive products possible?

8. Are workers exposed to airborne dust, gas, fumes, mist or vapors?

It was tried to find answers to the questions. A major problem is the lack of knowledge among workers about environmental accidents and occupational diseases and the lack of training in the sector. Basically, such studies are carried out in three stages of hazard identification and risk assessment. These are project phase, implementation (development and construction phase) and operation and maintenance phase[31]. The probability and consequence of hazards at each stage are different and varied. However, this study focuses on the factors that contribute to hazards in the operation and maintenance phase.

MATERIAL METHOD

Risk analysis starts with the identification of hazards arising from the execution of work or associated with material properties[32]. This phase identifies the sources of hazards and the risks they pose. Each risk is analyzed separately and the combined effects of these risks and their relationship with other jobs are considered[33]. Such studies require technical and scientific teamwork. Analytical methods are used to determine the level of identified risks or the consequences of hazards. The process of risk assessment involves the continuous review of risks in a cycle[34]. In line with risk assessments, appropriate measures are taken to prevent risks or to take into account the emergence of new risks[35]. Methods such as observation and interview were preferred as data collection tools. The observation method is based on meticulous monitoring of actions that take place in working conditions and increases employees' awareness of exposure to potential risk categories. In addition to observations, interviews and questionnaires with employees provided information on the types and dimensions of physical, chemical, biological, ergonomic and psychosocial risks occurring in the workplace. In addition to the data from the interviews, we used the matrix method to assess and analyze the risks.

The matrix method used in the study combines quantitative or semi-quantitative results and probability ratings to produce a risk level or risk rating. The structure and content of the matrix varies depending on the intended use and context, and it is of great importance to choose an appropriate design[36].

A consequence/probability matrix is used to classify risks, resources or control measures according to their risk level. This matrix is widely used as a screening tool in situations where many risks have been identified, to identify which risks need more detailed analysis, which ones should be addressed first, or which ones should be addressed by higher-level management[37]. In the study, this type of risk matrix was used to select which risks are prioritized. It is also often used to determine whether a particular risk is acceptable or unacceptable, depending on its position on the matrix. The consequence/probability matrix can help communicate a more general understanding of the qualitative levels of risks within the organization. The determination of risk levels and the decision rules for those levels should be consistent with the organization's risk tolerance. It can also be used when there is insufficient data for a detailed analysis or when the situation does not warrant a more quantitative analysis.

The inputs to the process consist of specific scales for consequence and likelihood, and a matrix that combines these two scales. The consequence scale should cover a range of outcomes from lost work time, lost work days, financial loss, loss of limb, or death (Table 1). These results should cover a wide range from the highest loss to the lowest result. The scale can be as large as the study requires, but 4 or 5-point scales are generally preferred. The probability scale can have any number of points[27]. Probability definitions should be chosen as clearly as possible. If numerical guides are used to express different probabilities, units should be specified (Table 1).

It is important that the probability scale reflects the scope of the study. It should be kept in mind that the lowest probability should be acceptable, corresponding to the highest outcome identified. Otherwise, a situation may arise where all activities with the highest outcome are considered unacceptable. In the second stage of the study, preventive actions were identified for each risk, and if they were taken, the probability and consequence values, and therefore the risks, were reduced to acceptable levels[32].

The matrix is constructed to represent consequence on one axis and probability on the other. The risk levels assigned to the cells of the matrix are determined by multiplying the quantitative values defined in the probability and consequence scales. This matrix can be arranged to place extra emphasis on consequence or probability, or it can be symmetrical depending on the application (Table 1). Risk levels can be linked to decision criteria such as levels of management attention or the need for intervention. This matrix can be used to identify which risks need to be more closely monitored in which situations. In this way, the management or implementation team can use the matrix as a guiding tool to identify which areas need more attention or resources[38].

Table 1. Risk assessment scales and decision matrix[32]

Consequence Scale

	Consequence	Rating
1	Should be Considered	No loss of working hours
2	Significant	No lost workdays
3	Serious	Minor injury
4	Very Serious	Death, Limb loss
5	Catastrophe	Multiple deaths

Probability Scale

	Probability	Rating
1	Remote	Once a year
2	Rare	Within 3 months
3	Unlikely	Within months
4	Possible	Weeks to month
5	Likely	Days to week

Risk assessment decision matrix

Probability \ Consequence	1	2	3	4	5
1	1 Very Low Risk	2 Low Risk	3 Low Risk	4 Low Risk	5 Low Risk
2	2 Low Risk	4 Low Risk	6 Low Risk	8 Significant Risk	10 Significant Risk
3	3 Low Risk	6 Low Risk	9 Significant Risk	12 Significant Risk	15 High Risk
4	4 Low Risk	8 Significant Risk	12 Significant Risk	16 High Risk	20 High Risk
5	5 Low Risk	10 Significant Risk	15 High Risk	20 High Risk	25 Very High Risk

When identifying risks, it first identifies the most appropriate outcome for the situation and then determines the probability of those outcomes occurring. The level of risk is determined using a matrix, taking into account the probability and impact of these identified outcomes. Different risk events can have a range of outcomes with varying degrees of probability. Often, small problems can be more widespread than large disasters. Therefore, choices can be made about which consequences to prioritize. Typically, focusing on the most serious and most credible consequences, as these consequences often pose the greatest threat and cause the most concern. In some cases, it may be appropriate to rank both common problems and unexpected disasters as separate risks[29]. It is important to use the probability associated with the selected outcome, not the probability of the event as a whole. The level of risk determined by the matrix can be linked to a decision rule on how to handle the risk.

RESULTS AND DISCUSSION

The work site considered in the study includes a vehicle fuel filling area, administrative building, tire and lubrication service, automotive service area, tanks area, car wash area and parking lot. In the study, high-risk regions and works were considered in turn, and risk situations were determined by assigning probability and consequence values to each. By expressing the standard and legislative requirements for the prevention of risks, the current situation in the tables and the new risk situations after the measures were calculated.

Fuel oil storage tanks used in stations are underground tanks with single or double walled structure, which are registered and approved by filling. Double-walled tanks aim to provide protection in this space in case of a possible leakage by surrounding the inner tank with the outer tank. TS 12820 standard includes safety details such as soil properties, corrosion measures, surrounding soil and stone properties, and covering of underground storage tanks. In the investigation area, the risk of fuel leakage due to the location of the liquid fuel tank and the lack of protection against corrosion after its placement was identified as a risk to be considered (l:2, c:5, r:10) (Table 2). Since this is a common occurrence, it can be eliminated by periodic inspections. In addition, due to the fact that this environment is a region with high vehicle traffic, the usual traffic-related risks (Table 4) should be reduced to acceptable levels.

Areas with underground tanks and filling points at fuel stations should be closed to vehicle traffic and surrounded by protective wire mesh or similar barriers with a minimum height of 100 cm[39]. Failure to ground the tanks to eliminate static electricity accumulation during filling (c:5) as it may cause very serious consequences. Proper grounding and periodic inspection of underground tanks is considered to have a very small probability (l:1) of the expected outcome. The absence of periodic controls of ventilation devices and emergency ventilation system of liquid fuel tanks will result in a very severe (c:5) result, while the accumulation of vapors and gases to be emitted to the environment will show the same level of consequence (c:5) (Table 2). To eliminate these risks, as stated in the standard, ventilation outlets should be located at a height of at least 3.6 meters from the filling pipes, outside the building and in a way to prevent flammable vapor accumulation[39].

While the cleaning of liquid fuel tanks by inexperienced personnel can lead to a severe consequence, the seriousness of the issue (l:1, c:5, r:5) should be taken into account and the risks can be reduced to an acceptable level through procedures (Table 2). Precautions should be taken against the risk of contamination or blockage of these outlets. The risk of explosion (l:3, c:5, r:15) due to exposure of the tank to sparks is an important consequence (Table 2). In order to prevent static electricity risks, tank filling and emptying instructions require the tankers and the tank to be free of static charge and to make connections to balance the static charge between them. Failure to do so will increase the possibility of ignition of explosive gases and leaking fuel vapors. It also includes procedures such as grounding the tank during filling, preventing the entry of customers or unauthorized persons, ensuring that the filling operator is free of static electricity, and checking the breathers frequently during the filling process.

In refueling stations, the use of ignition devices in the vicinity of fuel dispensers can increase the risk of explosion. This implies that the probability of an explosion is somewhat high (l: 3). If an explosion occurs, the consequences can be very serious (c: 5). Therefore, for the safety of fuel customers and employees, control and inspection systems should be continuously implemented. These facilities should be continuously inspected, safety protocols should be strictly enforced and staff should be continuously trained. In addition, clear rules must be established and strictly followed to prevent the use of ignition devices in these areas. These measures are important to minimize the risk of potential explosions and increase the level of safety in the facilities.

The risk of leakage as a result of fuel hoses decaying over time is a significant hazard (Table 2). To reduce this risk, only dispensers of a specific type and with a specific system approval should be used. Choosing only dispensers with type and system approvals minimizes the risk of leakage of fuel hoses. These approvals include compliance with certain standards and safety measures. In this way, the use of dispensers that comply with specified standards significantly reduces the risk of possible leakage and therefore explosion. These measures are vital to improve safety and minimize environmental risks at fuel stations.

Vehicles crashing into LPG dispensers are among the most common adverse incidents (Table 2). First of all, it is an effective measure to draw yellow barrier lines to mark the approach limits of vehicles to dispensers. These lines indicate the approach limit to drivers and attract their attention, thus helping to prevent accidents. These measures are important to reduce the potential hazards at LPG stations when vehicles collide with dispensers. Attracting the attention of vehicle drivers and protecting them with physical barriers can increase the preventability of such accidents and raise safety standards.

During the filling process, there is a potential hazard of fuel spillage when removing the fuel gun from the vehicle tank (Table 2). Similarly, there is a risk of fuel spillage if the hose is left on the vehicle and subsequently breaks (l: 3, c: 4). During LPG filling, there is a risk (l: 2, c: 4) of personnel inhaling the gas released at the moment of removing the gun. Likewise, there is a low probability of burns (l: 1, c: 4) as a result of the gas coming into contact with the hand and a risk of flames (l: 1, c: 5) as a result of the discharge of static electricity on the worker, but the consequences are quite serious and high impact. The solution to such problems can be achieved through worker training and regular inspections. Employees should be trained in the use of the gun during the filling process and necessary precautions should be taken. In addition, procedures should be established to prevent the hose from being left on the vehicle, and employees should be made aware of this issue on an ongoing basis.

Flammable and explosive vapors suspended in the air, especially when exiting the vehicle, can interact with the air, clothing and vehicle seat upholstery, resulting in electrostatic charges. Most incidents occur in low humidity conditions, so they are more common in cold weather. A significant number of these incidents involve a person getting in and out of the vehicle during the refueling process. The tendency in vehicles to build up a static charge can create a potential as high as 5-8 kV with a person getting in and out of the vehicle. Such a charge can be large enough to generate sparks. For those who are responsible for refueling, the American Petroleum Institute recommends not returning to the vehicle and emphasizes that the static electricity generated by touching the outer metal part of the vehicle should be discharged before exiting the vehicle[22]. In our country, since refueling is provided by personnel on duty, the probability of these conditions occurring is low and the number of incidents is quite low. However, since this event is likely, it should be considered in risk assessment studies and it should be stated that it will cause high severity outcomes.

In the absence of periodic inspections of electrical installations by authorized bodies, although the probability of occupational accidents is low (l:1), the potential consequences indicate a very high level of risk (c:5). Regular annual periodic inspections are vital to maximize safety (Table 3). Unauthorized interventions in electrical panels (l:2, c:5), especially without permanent contracts with authorized persons, increase the potential risk of accidents.

Table 2. Risk assessment of fuel tanks and dispensers

W	***Identified Hazard***	*Risk*	*l*	*c*	*r*	***Preventions***	*l*	*c*	*r*
Fuel Tanks	The accumulation of gas from liquid fuel tanks in certain areas creates an explosive atmosphere.	*ED*	1	5	5	Periodic checks of detectors.	1	5	5
	Visual level checks of liquid fuel tanks.	*ED*	1	5	5	Checking the indicators at certain intervals.	1	5	5
	Lack of periodic controls of ventilation systems of liquid fuel tanks.	*ED*	1	5	5	Periodic checks of the ventilation system.	1	5	5
	Entering liquid fuel tanks without the necessary measurements.	*ED*	1	5	5	Implementation of procedures and instructions.	1	5	5
	Cleaning of liquid fuel tanks by inexperienced personnel.	*ED*	1	5	5	Implementation of procedures and instructions.	1	5	5
	Overfilling liquid fuel tanks beyond their capacity.	*ED*	1	5	5	Each tank should store 300,000 liters in total, with a maximum of 50,000 liters.	1	5	5
	Failure of the normal and emergency ventilation system when filling with liquid fuel oil.	*E*	1	5	5	Periodic controls to be carried out.	1	5	5
	Fuel leakage as a result of failure to protect the liquid fuel tank against corrosion (rusting) after its positioning and placement.	*E*	2	5	10	Tanks are periodically checked once a year and measures are taken against corrosion.	1	5	5
	No grounding to remove static electricity accumulations during filling.	*ED*	1	5	5	Checking that the filling is carried out in accordance with the instructions.	1	5	5
	Explosion due to exposure of the tank to sparks.	*E*	3	5	15	Checking that earthing is done.	1	5	5
	Sniffing the gas released by opening the fuel tank.	*OD*	2	4	8	Training of personnel on the subject.	1	4	4
Dispensers	Leakage due to rotting of fuel hoses.	*EID*	3	5	15	Use of dispensers with type and system approval.	1	4	4
	Explosion due to the use of ignition lighters etc. near dispensers.	*EID*	3	5	15	Necessary controls are made to ensure that customers do not smoke.	1	4	4
	Vehicles hit LPG dispenser.	*EID*	3	5	15	Drawing yellow barrier lines indicating the approach limit of vehicles.	1	4	4
	Fuel spillage as a result of removing the gun from the tank as soon as the filling process is finished	*EID*	3	5	15	Training of employees on the subject.	1	4	4
	Do not continue to handle the gun when it is put into the tank for filling.	*OD*	1	4	4	Training of employees on the subject.	1	4	4
	Dispenser hose rupture due to being left on the vehicle. fuel spillage.	*EID*	3	4	12	Periodic checks should be made.	1	4	4
	Vehicles running over the feet of pump attendants	*I*	2	4	8	Check that shoes are worn.	1	4	4
	LPG filling personnel inhaling the gas released at the moment of removing the gun.	*I*	2	4	8	Training of staff.	1	4	4
	Burns as a result of contact of the gas coming out of the LPG filling personnel's hand at the moment of removing the gun.	*OD*	1	4	4	Supervision of appropriate glove use by staff.	1	4	4
	The static electricity on the pump discharges and creates a flame effect.	*OD*	1	5	5	A copper plate should be grounded and the sieve on the personnel should be discharged.	1	5	5

E: Explode, D: Death, W: Place, l: likelihood, c: consequences, r: Risk value, OD: occupational disease, I: injury

The absence of insulating mats in front of electrical panels (l:2, c:5) is a glaring deficiency that, although it can be remedied with small investments, increases the risk of electrocution in the event of an accident (Table 3). The personal protective equipment to be used by the maintenance team, such as hard hats, shoes, gloves, work clothes, etc., must comply with the relevant standards. This equipment must be insulating and must be kept clean and dry on a regular basis. These measures will help minimize potential risks by raising safety standards in electrical installations.

The presence of open parts in power cables and work carried out without power interruption (l:2, c:5) may bring the risk of electric shock (Table 3). In maintenance, repair and similar interventions, safety measures such as energy isolation, accumulated energy measurement and resetting, grounding, locking and labeling should be taken and necessary markings should be made. The risk of electric shock due to leakage in the electrical installation (l:1, c:5), especially during operation, even if there is no electric current, it is necessary not to ignore situations such as accidental energization, accumulation of static charges or induction voltage from high voltage facilities in the vicinity. At this point, the presence of a residual current relay is of great importance. A dysfunctional lightning rod increases the risk of exposure to lightning (Table 3). All electrical installations such as lightning rods, grounding systems, IP and Exproof rated equipment and residual current relays should be checked periodically by authorized persons. Neglecting earthing measurement and control (l:1, c:5) can lead to potential occupational accidents (Table 3).

Therefore, regular inspections in accordance with relevant standards are of great importance for the safety of electrical installations. Electrical installations, escape route illuminations, emergency illuminations, and fire detection/alarm systems should be planned and implemented in compliance with applicable regulations and standards. The malfunction of lighting fixtures or insufficient illumination in the working environment (l:2, c:4) can increase the risk of accidents. The occurrence of sparks in lighting fixtures (l:1, c:5) can have significant consequences for the operation, especially requiring extra caution in flammable or explosive environments (Table 3). Therefore, only equipment with Exproof specifications should be used in such environments. Exproof equipment, having explosion-proof features, can be safely used in these risky areas. Lighting equipment with Exproof specifications should be documented along with compliance certificates. This is crucial to verify the conformity of the equipment to specific standards and to provide access to documents for inspections when needed. These safety measures will assist businesses in ensuring safety in environments with explosion risks and achieving full compliance with applicable standards.

The depressions that may form around LPG tanks can increase the risk of gas accumulation (l:1, c:5), thereby raising the risk of explosion; therefore, these areas should be continuously monitored (Table 3). Due to the possibility of diesel and gasoline vapors accumulating on the ground and in depressions, fuel stations constructed after TS 12820 standard generally do not have basements. However, if a station with a basement was built before this standard, special measures need to be taken. Considering the potential for the accumulation of flammable vapors and the risk of explosion in basements, special safety precautions should be implemented. In these areas, specific observation points should be designated to monitor fuel vapors, especially in areas where different services are often provided outside the station. If tanks are not protected against corrosion, the likelihood of gas leakage increases (l:1, c:5), and if this goes unnoticed, it may lead to the risk of explosion. Therefore, gas alarm systems should be periodically checked (Table 3). These checks should be considered a crucial safety measure aimed at providing early warning for potential gas leaks and reducing the likelihood of explosions.

Neglecting grounding during LPG filling does not eliminate the potential explosion risk (l:1, c:5). Conversely, leaving the area around the LPG tank without wire mesh enclosure can increase the risk of potential collisions (l:1, c:5), thereby raising potential accident risks. Therefore, it is crucial for the tanker and equipment to comply with ATEX standards to enhance safety during tank filling. Underground tank lids should be made of special materials designed to prevent sparking. To increase safety during tank filling, a safety disconnect and audible alarm system should be installed. Additionally, automatic cut-off devices should be used, ensuring they do not interfere with the operation of ventilation systems. Dispensers should be mounted on a 20 cm high concrete base and surrounded by a fixed protection at least 50 cm high, protecting the dispenser column and not obstructing airflow, at the entrance and exit directions of the dispenser island. Areas where vehicles for LPG filling will stop should be marked with yellow lines or reflectors, and other vehicles should be kept outside these designated areas. Smoking should be strictly prohibited within the filling station. These measures are of critical importance to maximize safety and prevent potential hazards at LPG filling stations.

The incorrect pressure setting of compressors and malfunctioning safety valves (l:1, c:5) can increase the risk of explosion. Therefore, it is of great importance that these equipments are inspected annually by authorized institutions. These inspections are necessary to minimize potential explosion risks and ensure safe working conditions.

In the filling and emptying processes of tanks (l:3, c:3), it is critical to have experienced and skilled personnel working to prevent falls from tanker tops for cleaning purposes. The use of safety belts and the implementation of necessary safety measures by these personnel are vital to ensure the physical safety of the workers. The use of safety belts by employees is an effective way to reduce the risk of falls and is important in meeting occupational safety standards. In addition, careful adherence to safety procedures in situations involving working at height is essential to prevent accidents and maintain a safe working environment in the workplace. This ensures the minimization of potential risks and the provision of health and safety for the personnel in the workplace.

To minimize the risk of fuel station personnel being exposed to exhaust gases from vehicles (l:2, c:4), it is essential to enhance their training levels, especially regarding this specific hazard. The rapid entry of vehicles into the station must not overlook the risk of accidents (l:3, c:4). Therefore, a sign should be placed at the station entrance, indicating that vehicles should enter at a maximum speed of 10 km/h (Table 4). To prevent accidents (l:2, c:4) that may occur due to the loss of control when vehicles enter the station on slippery surfaces to refuel, regular cleaning of the station floor and the placement of appropriate warning signs at specific points are necessary. Warnings should be provided to station personnel when a vehicle receiving fuel starts moving before the process is complete (l:2, c:4) and when a vehicle that has finished refueling leaves the station in an uncontrolled manner (l:2, c:4).

The failure to engage the handbrake (l:2, c:4) or its forgetfulness by the driver may cause the vehicle to move within the station without control. To minimize this risk, stations built in compliance with standards should ensure that such incidents do not occur, and parking positions should be correctly adjusted. The irregular parking of waiting vehicles within the station (l:2, c:4) should be prevented by designating specific parking areas and installing appropriate warning signs in these areas (Table 4) to prevent accidents resulting from disorderliness.

Table 3. Risk assessment of electricity and various sources

W	*Identified Hazard*	*Risk*	*l*	*c*	*r*	*Preventions*	*l*	*c*	*r*
Electrical installation	Occupational accident as a result of failure to periodically check the electrical installation by authorized institutions.	*I*	1	5	5	Annual periodic controls to be carried out.	1	5	5
	Everyone interfering with the electrical panels.	*ID*	2	5	10	Only the authorized person should be allowed to intervene in the electrical panels.	1	5	5
	Electric shock due to lack of insulating mat in front of electrical panels.	*ID*	2	5	10	Placing insulating mats in front of the panels.	1	5	5
	Electric shock due to the presence of open sections in power cables.	*ID*	2	5	10	Checking the electrical cables and replacing the worn ones.	1	5	5
	Electric shock as a result of working without power cut.	*ID*	2	5	10	Personnel working on the power line must de-energize.	1	5	5
	Electric shock due to possible leakage in the installation.	*ID*	1	5	5	Leakage current role in electrical fuses.	1	5	5
	Exposure to lightning due to a broken lightning rod.	*EID*	1	5	5	Having the lightning rod checked every year.	1	5	5
	Occupational accident as a result of not performing earthing measurement and control.	*ID*	1	5	5	Checking the earthing installation every year.	1	5	5
	Lighting lamps not working.	*ID*	2	4	8	Make sure that the lighting lamps are working properly.	1	4	4
	Explosion caused by sparks from lighting lamps.	*EID*	1	5	5	Lighting lamps and electrical installations must be Exproof.	1	5	5
LPG tank	Explosion as a result of the presence of pits around the tank where gas can accumulate.	*E*	1	5	5	The tank must be constantly checked around the perimeter.	1	5	5
	Gas leakage due to lack of corrosion protection.	*ED*	1	5	5	Measures must be taken against corrosion.	1	5	5
	Failure to recognize gas leaks that may occur-explosion.	*ED*	1	5	5	Gas alarm systems should be periodically checked	1	5	5
	No grounding during filling.	*ED*	1	5	5	Checking that the filling is done in accordance with the filling instructions.	1	5	5
	Not enclosing the LPG tank with a wire fence.	*E*	1	5	5	The wire mesh and gate must be constantly checked.	1	5	5
Comp.	Explosion as a result of malfunction of pressure regulating autom. and safety valve	*ID*	1	5	5	To have an annual control.	1	5	5
	Malfunction of the drain valve. moisture formation due to water accumulation at the bottom of the tank.	*I*	2	3	6	Periodic maintenance.	1	3	3
W. at height	Fall from height due to climbing on the tanker during filling & unloading.	*I*	3	3	9	Experienced and skilled personnel should be on board the tanker.	1	3	3
	Fall as a result of climbing to the upper parts of the pumps for cleaning purposes.	*I*	3	3	9	If climbing above 3 meters, safety belts must be worn.	1	3	3
	Fall as a result of climbing on tanker hatches for maintenance purposes.	*I*	3	3	9	If climbing above 3 meters, safety belts must be worn.	1	3	3

E: Explode, D: Death, W: Place, l: likelihood, c: consequences, r: Risk value, OD: occupational disease, I: injury

This way, maintaining order within the station and ensuring a safe working environment can be achieved.

Effective measures should be taken to minimize the risk of slipping due to wet floors after rainfall throughout the station (l:2, c:3). In this context, directing water accumulations to rain drains and applying non-slip tape on the ground in front of the office to prevent slippery surfaces is necessary. The immediate filling of depressions in the station floor is important to eliminate the risk of falls and hole openings (Table 4). This way, ensuring the safety of employees can prevent potential accidents. To minimize the risk of night-shift personnel going unnoticed and being hit by a vehicle (l:2, c:4), the use of reflective clothing should be regularly monitored. This increases visibility, preventing potential hazards in advance. Failure to use personal protective equipment during welding processes (l:2, c:3) can pose serious risks. Therefore, care should be taken to use the necessary protective equipment during welding processes. Performing only direct current welding processes in tight, enclosed, and humid spaces ensures compliance with safety standards. Unauthorized individuals conducting maintenance and repair activities (l:2, c:3) and the risk of maintenance and repair personnel touching hot surfaces or getting burned (l:2, c:3) require that all maintenance tasks be performed by authorized personnel (Table 4). Additionally, it is important to ensure that the personal protective equipment used bears the CE marking, ensuring the use of equipment that complies with standards and is reliable.

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Tablo 4. Station overall and maintenance risk assessments

W	*Identified Hazard*	*Risk*	*l*	*c*	*r*	*Preventions*	*l*	*c*	*r*
Station overall	Inhalation of gas from the exhaust of a refueling vehicle.	*OD*	2	4	8	Training of employees on the subject.	1	4	4
	An accident caused by a vehicle entering the station too fast.	*I*	3	4	12	Maximum 10 km. sign at the station entrance.	1	4	4
	A vehicle coming to refuel went out of control on slippery ground.	*I*	2	4	8	Hanging warning signs about the subject at certain points of the station.	1	4	4
	The fueled vehicle moves before the process is finished.	*I*	2	4	8	Staff should be warned to be careful about this issue.	1	4	4
	Accident occurrence as a result of uncontrolled exit of the filled vehicle from the station.	*I*	2	4	8	Placing warning signs at certain points.	1	4	4
	The movement of the vehicle as a result of not pulling the parking brake of the fueled vehicle.	*I*	2	4	8	Staff should warn the driver of the vehicle.	1	4	4
	Accident occurrence due to irregular parking of waiting vehicles inside the station.	*I*	2	4	8	Parking areas should be designated and warning signs should be placed.	1	4	4
	Fall due to slippery wet ground after rain.	*I*	2	3	6	Puddles should be directed to storm drains.	1	3	3
	Slip and fall due to wet floor in front of the office.	*I*	2	3	6	Gluing anti-slip tape on the front of the office.	1	3	3
	Tripping over potholes in the station floor.	*I*	2	3	6	Immediate filling in case of a pit opening.	1	3	3
	Vehicle collision as a result of unrecognized personnel working at night.	*ID*	2	4	8	The use of reflective clothing should be controlled.	1	4	4
Maintenance	Not to use PPE (Personal protective Equipments) during welding works.	*ODI*	2	3	6	To make sure that the PPEs used are CE marked.	1	3	3
	Maintenance and repair personnel touching hot surfaces – burns.	*I*	2	3	6	To make sure that the PPEs used are CE marked.	1	3	3
	Maintenance and repair activities carried out by unauthorized persons.	*I*	2	3	6	Ensuring that all maintenance is carried out by authorized persons.	1	3	3

E: Explode, D: Death, W: Place, l: likelihood, c: consequences, r: Risk value, OD: occupational disease, I: injury

Regarding warehouse organization, it is crucial to take preventive measures against the risk of materials falling due to incorrect stacking (l:2, c:3) and the potential risk of shelves tipping over due to not being secured (l:2, c:3) (Table 5). Regular checks and employee training on this matter are mandatory to minimize these risks and prevent potential accidents. The use of improper handling techniques by employees (l:2, c:4) can lead to ergonomic issues within the warehouse (Table 5). These problems can be addressed through proper training. Therefore, employees should receive detailed training on correct handling techniques and safe work practices. Failure to store chemical substances properly within the warehouse can lead to potential risks (Table 5). Therefore, thorough knowledge of the storage conditions for chemicals used in the warehouse is essential, and employees should be trained on this matter. The safe storage and use of chemical substances are crucial for both protecting the health of employees and ensuring environmental safety. In this context, measures taken for warehouse organization and safety should be supported by regular training, and employees' knowledge on these matters should be continuously updated. This way, compliance with warehouse safety standards can be ensured, and an effective system can be established to prevent potential accidents.

The lack of adequate equipment to intervene in a fire poses a significant safety risk in workplaces (Table 5). It is crucial that firefighting equipment used in activities involving flammable or explosive atmospheres complies with standards. Regular inspection, control, and maintenance of this equipment should be carried out by experts in the field. In workplaces where there is a risk of fire or explosion, controls for electric motors, thermal starters, circuit breakers, relays, and similar components should be located in fireproof and insulated compartments. The absence of proper training for teams tasked with firefighting is also a serious risk factor (l:2, c:5) (Table 5). Emergency plans in the workplace should not include enclosed spaces that obstruct access to firefighting equipment, which is critical for the effectiveness of emergency plans. The proper type of fire extinguishers (l:2, c:4) with easy accessibility and unobstructed visibility is essential (Table 5). It is important to place appropriate warning signs in the distribution, filling, and ventilation areas to address potential hazards. In fuel stations, 6 kg dry chemical powder fire extinguishers conforming to TS 862-7 EN 3-7 standards, as well as at least 30 kg wheeled fire extinguishers, must be present. Having these extinguishers near the distribution unit island and in specific locations within buildings allows for quick and effective intervention. Additionally, obtaining 30 kg or larger dry chemical powder wheeled fire extinguishers for every 6 distribution units and placing them in designated locations is essential. Regularly inspecting fire extinguishers and marking the inspection dates on the labels will ensure that the equipment remains functional and reliable.

The absence of a comprehensive emergency plan or undefined emergency response teams (l:2, c:5) can lead to confusion among employees and a lack of effective intervention in coping with emergencies. In this context, creating emergency action plans and regularly training personnel are of great importance. In the event of an emergency, it is essential to use systems that not only provide fire suppression and emergency lighting, but also shut down power and fuel flow to the fuel system and provide audible warnings. These systems should operate effectively with electric, hydraulic, or pneumatic valves on the supply and return lines. Station employees should undergo training organized by relevant instructors on health, safety, and firefighting interventions[29]. The goals of the program to be implemented should be determined by determining the training needs. Observations can be made after training to see how overall behavior has changed. However, this should be done after determining the conditions under which it should be done and the required skill levels. Instructions on what to do in emergencies should be prominently displayed in visible areas of the station for easy access by employees. The absence of emergency buttons to stop fuel flow poses a significant risk, and employees entering the wrong areas due to a lack of training (l:2, c:5) can lead to serious risks. Therefore, the establishment and training of emergency response teams are crucial. The absence of intervention teams during an accident (l:2, c:4), the lack of necessary tools and equipment for first aid (l:3, c:3), and the absence of a vehicle for emergencies in the operation (l:1, c:5) also pose risks (Table 5). To minimize these risks, the necessary precautions should be clearly outlined in a detailed emergency plan. This plan should be effectively communicated to all employees and regularly updated.

Table 5. Fire, warehouse and emergency situations risk assessments

W	*Identified Hazard*	*Risk*	*l*	*c*	*r*	*Preventions*	*l*	*c*	*r*
Warehouse	Dropping of material due to improper stacking in the warehouse.	*I*	2	3	6	Providing training to the employee on the subject.	1	3	3
	Accidents caused by tipping over due to unsecured shelves.	*I*	2	3	6	Continuous control of the shelves.	1	3	3
	Warehouse personnel apply incorrect handling methods.	*IOD*	2	4	8	Providing training to the employee on the subject.	1	4	4
	Accident caused by improper storage of chemical substances.	*I*	1	4	4	Storage conditions of chemicals should be constantly checked.	1	4	4
Fire	Insufficient equipment to respond to a fire that may break out.	*ID*	1	4	4	Checking the fire extinguishers.	1	4	4
	Lack of necessary training of the team to intervene in the fire.	*ID*	2	5	10	Fire response teams have training certificates.	1	5	5
	The fronts of fire extinguishing equipment are closed.	*ID*	1	5	5	Elimination of materials that make it difficult to reach fire extinguishers.	1	5	5
	Lack of suitable extinguishers for possible types of fire, further growth of the fire.	*I*	1	4	4	Appropriate cylinders in appropriate places.	1	4	4
	Failure to carry out periodic checks of fire extinguishers.	*ID*	1	5	5	Periodic checks of fire extinguishers.	1	5	5
	Lack of a water system fire extinguisher in cases where fire extinguishers are insufficient.	*ID*	1	5	5	Regular checks of water system extinguishers.	1	5	5
Emergency	Lack of a plan for what to do in the event of an emergency.	*ID*	2	5	10	The emergency action plan should be posted for all to see.	1	5	5
	Failure to identify emergency teams.	*ID*	2	5	10	Training on emergency situations	1	5	5
	Lack of emergency buttons that cut off the fuel flow.	*ID*	1	5	5	Check that the emergency buttons are working.	1	5	5
	Workers entering the wrong areas in emergency situations.	*ID*	2	5	10	Emergency assembly signage should be posted.	1	5	5
	No personnel to provide first intervention in case of a possible occupational accident.	*I*	2	4	8	Encouraging first aid certification.	1	4	4
	Lack of first aid equipment.	*I*	3	3	9	To eliminate the deficiencies of first aid supplies.	2	3	6
	Lack of transportation for first aid.	*ID*	1	5	5	Having vehicles on standby for emergencies.	1	5	5

E: Explode, D: Death, W: Place, l: likelihood, c: consequences, r: Risk value, OD: occupational disease, I: injury

CONCLUSION

Risk assessment studies should be conducted, especially during the design phase, to achieve effective and satisfactory results. In the operational process, it is possible to anticipate failure scenarios in human behaviors and potential hazards in their processes. This study has considered the role of human behavior in developing hazard scenarios. Risk assessment has been conducted on the probabilities of the identified hazards occurring at gasoline stations. The consequence and probability of each risk have been calculated. Due to the high risk of fire and explosion in the working environment, the study emphasizes the need to take preventive measures against these risks as a priority. Gasoline stations, being complex environments with employees and customers, require the continuity of controls and training. Specifically, measurements of cathodic protection, lightning rods, and grounding should be performed annually by authorized individuals or organizations.

Due to the nature of the fuel station industry, employees often work long hours on a daily basis, typically operating on a shift system. Shift work is a common working arrangement involving hours outside the traditional 8-hour workday, and this schedule can lead to various adverse outcomes, including health issues such as cancer and cardiovascular diseases[40]. In addition to contributing to a decrease in occupational safety and efficiency, shift work can notably lead to the development of a sense of intense exhaustion among workers.

It is recognized that there are many occupational health and safety risks associated with all activities performed at service stations. These risks can lead to fatalities such as explosion and fire. The matrix method can be chosen to carry out risk assessments for companies because it is simple and applicable. The method to be used and the procedures to be developed should be determined and implemented in advance. The study will contribute to the literature in terms of ensuring that the measures to be taken as a result of the determination of the work and risks at fuel stations comply with the standards and legislation.

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