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Safety Measures and Risk Management in Agricultural Confined Spaces: A Study on Farm in Iğdır Province, Using Bow tie and Matrix Methods

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Abstract

In agriculture, confined space operations present significant hazards and increased risks to workers and emergency responders. When designing training initiatives to reduce confined space fatalities, it is imperative to assess human characteristics such as skill levels, gaps in understanding and attitudes toward risk in order to formulate effective programs. The aim of this study is to determine the safety practices and risk levels of farm owners operating in agricultural confined spaces in Iğdır province. To accomplish this, the first step was to semi-quantitatively assess the risks that can occur when working in confined spaces such as manure and silage storage facilities using a five-tier matrix, and to visualize the results using a bowtie diagram. In these confined spaces, the lack of atmospheric conditions was identified as the greatest source of danger, and therefore, these risks were prioritized (l: 5, s: 5, RS: 25). The risk of fire and explosion, which can be caused by the presence of contaminants in such areas, was assessed as quite high (RS: 20). Structured protocols or comprehensive frameworks are essential for identifying and mitigating the risks inherent in indoor work environments. Currently, there is a notable lack of an organized and reliable methodology specifically tailored to assess and manage the risks associated with working in confined spaces in agricultural activities. Recognizing this deficiency, it is proposed to establish procedural guidelines aimed at preventing and managing the risks associated with confined space work within the agricultural domain. The methodologies employed herein combine concepts and requirements outlined in various regulatory frameworks governing safe practices in confined spaces, with the goal of facilitating both risk assessment and management efforts. In addition, it is suggested that the personal proximity of ranchers to potential injuries in the field may serve as a critical indicator for improving safe work practices and risk awareness. This approach has the potential to enhance the safety knowledge of owners and their perception of risk-taking behaviors, thereby reducing the likelihood of injuries associated with agricultural enclosures.

Keywords: Agriculture, confined space, occupational risks, bow tie method

INTRODUCTION

Crop and animal production activities are among the sectors that pose significant risks due to the nature of the processes carried out. Statistics for 2022 show that occupational accidents in this sector have reached serious levels. In that year, a total of 3113 occupational accidents occurred in enterprises operating in crop and animal production (SGK, 2024). The data on the consequences of these accidents are worrying; 19 of these accidents unfortunately resulted in fatalities. Data on the number of employees affected by occupational accidents further illustrates the extent of the problem. The vast majority of workers injured in accidents required more than five days of treatment, including 886 people. This situation shows that occupational accidents are not only limited to the loss of working hours, but also cause serious health problems (Güğercin and Baytorun, 2018).

Activities in the agriculture and livestock sectors come with a variety of jobs, materials and equipment. This diversity increases the risk of occupational injuries and illnesses. However, workers in the sector feel unable to avoid risky behavior even when they are aware of the risks (Özel and Güğerçin,

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2020). Research emphasizes the need to improve safety in agricultural confined space work. A study by Issa et al. (2013) shows that grain entrapment was a significant problem in the US between 1964 and 2013. More than 1650 fatal and non-fatal accidents have been documented in these scenarios. Additionally, there were 77 fatal incidents recorded in animal waste handling and storage operations (Riedel and Field, 2011). Another study conducted by Beaver and Field (2007) revealed that there were 77 fatalities associated with manure storage operations between 1975 and 2004. These incidents involved individuals engaged in rescue operations who were cognizant of the risks posed by manure storage facilities. Within the agricultural sector, numerous confined spaces exist, including bulk feed silos, grain storage silos, grain dryers, manure storage pits, above-ground manure storage tanks, silage ditches or bunkers, oxygen-limited vertical silos, milk storage tanks, methane digesters, liquid manure spreaders, gravity flow grain wagons, grain trucks, chemical storage tanks, transport vehicles, fermentation tanks, and bulk milk tanks. These areas present potential hazards to agricultural workers. Research indicates that fatalities in feed storage structures also constitute a significant concern (Riedel and Field, 2011).

In Turkey, statistics on occupational accidents and occupational diseases started to be kept regularly in the early 2000s. Accident statistics are not recorded in detail without classifying the type of accident and the point of occurrence. Since accidents occurring in the agricultural sector are classified in general activity areas, there is no statistics classified under the name of confined space. Actually, in 2023, 12 people were injured, 1 dead and 2 seriously injured, as a result of an explosion caused by a dust explosion in the grain storage areas of the Turkish Grain Board (TMO) in Derince District of Kocaeli Province (TRT, 2023). In a similar case in December 2023, a worker who went to a wheat silo for cleaning in Mardin fell into the silo, drowned and lost his life (TG, 2023). In August 2023, in Şanlıurfa, a worker who went down a water well to fix a malfunction in a water pump was electrocuted and lost his life (DHA, 2023). These incidents are quite tragic as they usually result in death. It is not known why workers continue to enter agricultural confined spaces despite knowing the potential hazards in the agricultural sector. Aktuna (2019) stated that the problems experienced by people during work in agricultural activities, their past experiences cause differences in accident precaution levels and occupational perceptions. This situation affects the level of accident perception, especially when they are less educated and older due to the nature of the sector (Günaydın et al., 2018). Unsafe acts are generally accepted to be caused by human factors such as employee behavior, skill or lack of knowledge.

Confined spaces are very hazardous environments where toxic-explosive gases or dusts are present that may be insufficient oxygen level of farmers with the agricultural methods used recently (Kirkhorn and Schenker, 2002). A farmer who enters a confined space, such as a manure pit, silo, grain silo, or a poorly ventilated building, may be at risk of exposure to gas or dust, which can cause permanent lung damage or death (Kirkhorn and Garry, 2000). Manure pits and silos, as well as grain elevators, are dangerous areas for farmers. Toxic gases involve several hazards, such as the risk of suffocation and crushing (Cheng and Field, 2016). Hydrogen sulfide can be asphyxiating and deadly; It can lose its smell over time, creating a false sense of security (Zhao et al., 2008). Ammonia has a pungent odor and can irritate the eyes and respiratory system (Kirkhorn and Garry, 2000). Carbon dioxide, on the other hand, is a colorless, odorless and suffocating gas, it can consume enough oxygen and lead to suffocation (Kirkhorn and Garry, 2000). Exposure to these gases can cause serious health problems in farmers. Dusts are a common hazard in agriculture and can seriously affect farmers' health (Murphy and Manbeck, 2014). Organic or toxic dusts can cause irritation to the respiratory tract and lead to permanent diseases such as "Farmer's Lung". These diseases can increase susceptibility to respiratory infections and permanently affect lung function (Hoppin, 2007). Working in dusty environments can reduce the elasticity of the lungs and significantly reduce respiratory capacity. Therefore, it is important for farmers to use proper respiratory equipment and avoid dusty environments.

Attitudes towards safety programs to be implemented in agricultural activities are often negative, especially when implemented by employees with no farming experience (Akpınar and Özıldırım, 2016). Therefore, there is a need to develop security programs that can be implemented by industry employees. Creating a training program that addresses potential deficiencies in employee safety awareness and risk tolerance could serve to reduce the likelihood of injuries and fatalities associated with agricultural fencing. When formulating training strategies to minimize confined space fatalities in agriculture, it is essential to evaluate human characteristics such as employee skills, depth of understanding and risk acceptance within the industry. This assessment is critical to developing programs that effectively address the needs of the workforce and promote a culture of safety (Yeşilbaş, 2021).

The primary objective of this research is to determine the prevailing safety protocols and hazards associated with confined spaces in agricultural settings among farmers and employees. The primary objectives of this study include: defining the concept of agricultural confined spaces, assessing the inherent risks associated with working in such environments, evaluating the use of safety and rescue equipment by farm owners and employees when entering agricultural confined spaces, and defining the necessary actions to be implemented through a model confined space risk assessment within the regulatory framework.

MATERIALS and METHODS

Qualitative risk assessment methodologies primarily rely on the experiential insights and judgments of the risk assessment team. These approaches utilize descriptive terms such as "rarely," "unexpected," "possible," "likely," or "almost certain" to characterize the probability of potential undesirable events, while emphasizing terms like "fatal" or "serious" to denote the anticipated magnitude of their impact. Conversely, terms such as "minor" or "insignificant" are commonly employed to describe the extent of potential damage (Yılmaz and Şenol, 2017). Qualitative methodologies often incorporate qualitative scales to evaluate subjective criteria. Consequently, risk assessment emerges as a subjective undertaking, inherently susceptible to errors.

The predominant representative of these risk assessment methodologies is known as the risk matrix or risk rating matrix. These methodologies essentially serve as foundational techniques within the realm of semi-quantitative and quantitative risk assessment methods. Risk matrices are frequently employed by risk assessors to establish a coherent correlation between the likelihood of hazards or harm and their potential consequences (Yilmaz, 2010). Moreover, they serve as a standardized approach for determining the degree or level of individual risk assessments.

A three-step process is typically followed when constructing a risk matrix: first, vertical axes are designated to represent probabilities, followed by the assignment of horizontal axes to represent outcomes. The amalgamation of these axes culminates in the organization of risks, which constitutes the final step, as illustrated in Table 1. To obtain these data, it is imperative to gather information, which constitutes the foundational step for all risk assessment methodologies. Empirical evidence has underscored the efficacy of "checklists" as an optimal tool for identifying workplace hazards or risks. In order to garner a comprehensive understanding of all potential risks and hazards, thus enabling a more thorough risk assessment, all stakeholders in the work process (including management entities and end users/employees) should be engaged (Semerci, 2012).

The probability of an adverse event and its magnitude are delineated into five distinct levels when utilizing the risk matrix. These levels are categorized as follows: 1 - Very Unlikely, 2 - Unlikely, 3 - Possible, 4 - Likely, and 5 - Very Likely. In the context of the risk matrix, severity is assessed using five quantitative classifications: Negligible, Minor, Moderate, Significant, and Severe. If a risk is appraised as Very High or High, it is deemed unacceptable; however, if it falls within the Medium or Significant range, or if it pertains to the Low-risk category, it is considered acceptable (Özkilic, 2005).

Table 1. *Risk matrix method and evaluation table*

Likelihood		Severity				
		Negligible 1	Minor 2	Moderate 3	Significant 4	Severe 5
	Very Unlikely 1	Accep. Risk 1	Accep. Risk 2	Certain Risk 3	Certain Risk 4	Certain Risk 5
	Unlikely2	Accep. Risk 2	Certain Risk 4	Certain Risk 6	Signif. Risk 8	Signif. Risk 10
	Possible 3	Certain Risk 3	Certain Risk 6	Signif. Risk 9	High Risk 12	High Risk 15
	Likely 4	Certain Risk 4	Signif. Risk 8	High Risk 12	High Risk 16	Very High-Risk 20
	Very Likely 5	Certain Risk 5	Signif. Risk 10	High Risk 15	Very High-Risk 20	Very High-Risk 25

In this research, the bow tie method was used, which diagrammatically shows the process from the origins of the risks to the consequences after the risks in confined space have been dealt with by the matrix method. This methodology actually provides a synthesis between the concept of an error tree that analyzes the causes of the event and an event tree thought that studies its consequences. But the main emphasis of the bow tie is on the barriers between causes and risk and the links between risk and consequences. Bow tie diagrams can be derived from error and event trees; but rather, they are obtained directly from a brainstorming session.

When analyzing risk and security scenarios, it is very important to effectively consider threats and countermeasures. The bow tie method is a method that can be used to assess these threats and actions, prevent events from occurring, and avoid unintended consequences. This analysis has been successfully applied in various fields such as oil and gas industry, petrochemical industry, defense and security, shipping, mining, health care, aviation and emergency response (Afefy, 2015).

Bow tie analysis is used to visualize various possible causes and consequences of a risk (Figure 1). It is a method often resorted to when a complete error tree analysis is required, or when the focus is on identifying obstacles or checkpoints specific to each fault path. It is especially useful in scenarios where clear and discrete pathways that lead to failure exist (Jacinto and Silva, 2010). These barriers can be easily shown in works that are present in closed areas and involve a number of significant risks that require procedures. Bow tie analysis often stands out for being easier to understand compared to error and event trees, and can therefore serve as an effective communication tool where more complex analysis techniques are used.

Understanding the origins and consequences of a risk is important for identifying barriers and controls necessary to prevent, reduce or encourage that risk (IEC 31010, 2009).

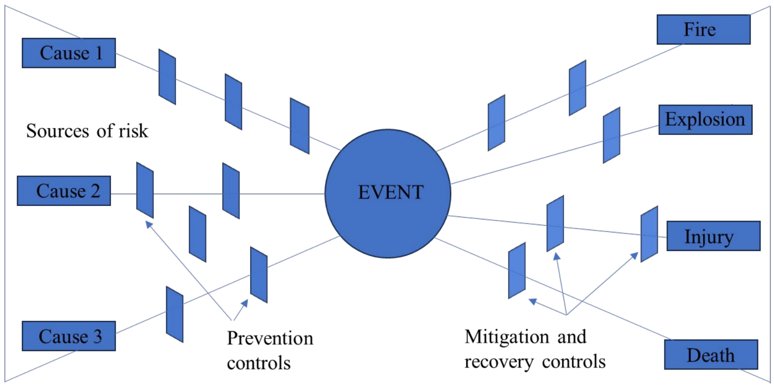

Figure 1. *Bow tie diagram for the unwanted consequences (IEC 31010, 2009)*

In general, a risk identified during the analysis process is shown as a central node in the bow tie diagram. The causes of the incident are identified, taking into account the origins of risks or threats to security, and are presented in a list. An indoor event may result in death, injury, or illness. The critical mechanism that caused the event that will cause these risks has been tried to be determined. For each cause, the flow of the event was determined by the lines showing successive events between the events on the left side of the bow tie diagram. Factors that may contribute to the growth of the problem are identified and added to the diagram. The obstacles necessary to avoid undesirable consequences from each cause are represented along the line in the form of vertical bars (Figure 1). In the presence of factors that could cause an increase, barriers were also used to stop the climb. With this approach, it can be seen that vertical obstacle bars reflect preventive measures that support positive outcomes (Saud et al., 2014).

On the right side of the bow tie diagram, as a rule, the various possible consequences of the risk are shown, the rays emitted from the risk event towards each possible outcome are sent to the result. Harm reduction measures in case of realization of the result are shown in the form of bars along the radial lines. Controls supporting management functions can be located at the bottom or top of the bow tie diagram and can be connected with the corresponding control points. In cases where the probability of a particular outcome or outcome is known and a prediction can be made for the effectiveness of a control, the bow tie diagram can be digitized to a certain degree (Khakzad, et al., 2012). However, the effectiveness of controls can be ambiguous, as often the paths and obstacles are not independent of each other. This makes the bow tie method procedural in most cases. Quantification is usually carried out more appropriately with techniques such as FTA (Failure Tree Analysis) and ETA (Event Tree Analysis). A bow tie diagram is a simple graph that shows the main risk pathways and barriers implemented to prevent, mitigate, or promote desired outcomes, and shows critical pathways (Garcia et al., 2019).

Bow tie analysis is an important advantage that it offers a clear visual representation that is easy to understand by focusing on the controls required for protection and mitigation and the effectiveness of these controls. In addition, the fact that it does not require expertise has made it easier to use despite other methods. But it can be considered a disadvantage that it has limitations in showing situations in which more than one factor occurs at the same time. When measurement is required, it can tend to oversimplify complex situations (IEC 31010, 2009).

RESULTS and DISCUSSION

This study was carried out in a family agricultural business operating in the province of Iğdır, and is interested in operating, farming and animal husbandry activities. In the farm where working workers are exposed to many hazards, jobs done indoors have the potential to lead to occupational accidents or occupational diseases, and are among the greatest hazards.

In instances where risk assessments conducted within the fertilizer storage facility, liquid fertilizer transportation vehicle, feed silo, and silage trenches, all commonly utilized within the farm premises, reveal the presence or potential presence of flammable or toxic gases or vapors, it becomes imperative to address the clearance of such gases or vapors from confined spaces. This clearance process typically involves the use of either air or inert gas to eliminate hazardous contaminants. However, it is crucial to note that when dealing with flammable contaminants, only inert gas should be employed for clearance, as the use of air may lead to the creation of flammable concentrations indoors (Kleinfeld and Feiner, 1966). Moreover, in cases where decontamination procedures are implemented, atmospheric testing becomes essential to verify the effectiveness of evacuation measures and ensure the safety of individuals prior to reentry (Sulardi and El-Ridho, 2019). Given the inherent risks associated with such environments, characterized by a heightened probability of work-related accidents or adverse events, the risk assessment yields a high probability (l:4) and severity (s:5) rating, resulting in an elevated risk value (RS:20), thereby warranting immediate intervention measures.

Employing inert gas, such as nitrogen displacement, may arguably represent the safest approach to mitigate the risk of flammable or explosive hazards (Wang et al., 2022). Moreover, alongside the establishment of comprehensive work permit procedures to delineate the requisite standards of protection for all individuals exposed to such risks, the utilization of full respirators can serve as a significant risk mitigation measure. Furthermore, precautions must be taken to safeguard individuals outside confined spaces from exposure to toxic, flammable, or irritant gases and vapors, particularly considering the potential for vented gases to affect workers or others present in the surrounding environment (Brown, 2011).

Adequate ventilation and the provision of breathable air are paramount considerations when operating in enclosed spaces. Inhalation of an oxygen-deficient atmosphere or air exhibiting abrupt fluctuations in concentration (l:5, s:5, RS:25) can precipitate unconsciousness within mere seconds. This perilous scenario arises from the atmosphere's dual failure to deliver oxygen and its potential to displace oxygen within the bloodstream (Veasey et al., 2005). In instances where the inhaled atmosphere contains residual oxygen, oxygen depletion from the bloodstream occurs at a slower pace. Nonetheless, affected individuals will experience profound fatigue and encounter difficulties in self-assistance owing to oxygen deprivation-induced circumstances. Prolonged exposure to such conditions may culminate in loss of consciousness. The onset of unconsciousness following exposure to an inert atmosphere is often rapid, and endeavors to effect rescue without appropriate respirators or respiratory protective equipment in such environments may tragically result in fatality (Kleınfeld and Feüner, 1966).

The cleaning or removal of residues that may deteriorate or cause gas formation in indoor environments should be the main purpose of the work. Cleaning up the debris is necessary so that the planned work can be carried out safely. The risk of residues is an important source of risk for the resulting outcome (RS: 20) and is one of the first tasks to be done. For the possibility of exposure to hazardous substances such as hazardous gases, fumes or vapors (l: 4), it is important to have electrical ventilation equipment, specially protected electrical equipment for use in hazardous atmospheres, respiratory-related protective equipment and atmospheric monitoring (Table 2). Repeated cleaning or removal may be required to ensure that all residues are removed, and in some cases, residues trapped in mud, lime or other deposits, behind bricks or loose liners, in liquid traps, or in joints may be dealt with.

In situations where indoor air poses a risk of flammability and explosiveness, the presence of inadequate lighting (Table 2) or faulty installations can significantly compound the challenges. Lighting fixtures must receive special protection when deployed in areas prone to the formation of flammable or potentially explosive atmospheres, particularly in instances where standard illumination, including emergency lighting, is impractical. Moreover, the exposure of lighting systems' unprotected hot surfaces to various gases may lead to thermal decomposition, generating additional toxic byproducts. Therefore, it is imperative that lighting fixtures are both waterproof and shielded with wire meshes to mitigate impacts. Furthermore, in environments where water is present, the use of appropriate sockets and connectors capable of withstanding moisture is essential, coupled with the implementation of leakage current relays to safeguard against electric shock hazards (Burlet et al., 2015).

In the agricultural sector, confined spaces often need to be isolated from the entry of substances that may pose a risk to those working in the field (Riedel and Field, 2011). The most effective method for this is to completely separate the confined space from each element of the plant by removing part of the pipe or duct or placing gaps. If blanks are used, window channels must be created that will allow the inside to be visible. One of the alternatives, when disconnection cannot be done in this way, can be provided with a locked, convenient, reliable valve, provided that there is no possibility of letting anything through while locked or there is no possibility of unlocking when people are inside the confined space.

Occasionally, confined spaces feature single brick walls, water seals, shut-off valves, or partitions sealed with sand or slime, serving to partially isolate one area of the facility from another (Botti et al., 2018). However, these barriers are typically installed for routine operations and may not furnish the requisite level of safety protection demanded by the elevated risks often associated with confined spaces. Hence, a more robust insulation method may be necessitated. Irrespective of the chosen insulation approach, rigorous testing is imperative to ascertain its reliability, involving assessments to verify the efficacy of the insulation against pertinent substances (Figure 2).

In the event of potential flammable or explosive atmospheres within indoor settings, the mitigation of static discharges and all ignition sources is paramount, given the significant risk involved (Table 2). All conductive components, such as steel ducts and airways, must be interlinked and adequately grounded (Figure 2). Should cleaning operations be undertaken, it is prudent to assess the hazards associated with the presence or utilization of materials with high resistance, such as synthetic plastics, within or in proximity to confined spaces. Certain equipment, notably most plastics, is susceptible to static accumulation due to their insulating nature. Additionally, there exists a heightened risk of electrostatic discharge from equipment utilized for steam or water jet applications. Moreover, static discharges may also be induced by garments containing cotton or wool fibers. Hence, it is advisable to explore safer alternatives for equipment selection and consider the utilization of antistatic footwear and attire.

When operating within confined spaces, it is imperative to have suitable and sufficient provisions in place for rescuing individuals in the event of an emergency. This entails the availability of requisite equipment to facilitate the establishment and rehearsal of rescue procedures (Figure 2). It is essential that these arrangements are established prior to any individual entering or commencing work within a confined space.

In some enclosed areas, there are electrical and mechanical equipment, and the power is provided from outside the area. The risk assessment shall be based on the objectives of the mission undertaken, and shall inspect lighting, communications, fire protection, pumping or cables in places where there is a risk of flooding. It must be ensured that the power is locked with a switch until these works are completed and that the switch is officially secured in accordance with the work permit (Brown, 2011). Lock and tag systems, where each operator has its own lock and key, can be useful here, giving confidence in the mechanism or system being disabled. It is essential to check that there is no stored energy left in the system that may cause the equipment to operate incorrectly.

Table 2. *Likelihood, severity and risk scores determined for a confined space*

Decision	Identified Risks	l	s	RS
Very High Risk	Not testing whether the indoor atmosphere contains gas, vapor and smoke	4	5	20
	Lack of knowledge of the properties of previously used chemicals	4	5	20
	Lack of a system to instantly monitor changes in the atmosphere	5	5	25
	Insufficient lighting	4	5	20
	Indoor air is flammable or explosive	5	5	25
	Insufficient cleaning of the atmosphere in the closed area	4	5	20
	Insufficient mechanical ventilation or inability to provide fresh air	5	5	25
	Insufficient cleaning of residues	4	5	20
High Risk	Presence of contaminants in liquid or solid form	3	4	12
	Lack of emergency alarms	4	4	16
	Presence of static electricity	3	5	15
	Not having enough drills for emergencies	4	3	12
Signif. Risk	No lookout person	2	5	10
	Manholes are closed	2	4	8
	No energy locks	3	5	10
	No grounding	2	3	6
	Lack of isolation from mechanical and electrical equipment	3	3	9
	Lack of fire extinguisher	2	4	8
Certain Risk	Lack of personal protective equipment and respiratory protective equipment	2	2	4
	Lack of employment of people with sufficient education and experience	2	3	6
	Failure to set educational standards	2	3	6
	Lack of determination of authority and responsibilities	1	3	3
	High temperature	2	2	4
Accep. Risk	Lack of means of communication	1	2	2
	Incompatibility of communication devices and equipment used	1	2	2
	Clutter on indoor floors prone to tripping and falling	2	1	2

Equipment intended for indoor use must be appropriately suited for its intended purpose. In scenarios where there exists a risk of flammable gas seepage into confined spaces, potentially leading to ignition by electrical sources, the utilization of specially protected electrical equipment becomes imperative. Examples include lamps approved for operation within explosive environments. It's crucial to recognize that even specialized low-voltage portable lights, while offering protection against electric shock, can still pose ignition hazards in flammable or potentially explosive settings. Therefore, careful selection of all equipment is paramount, accounting for prevailing conditions and associated risks. Grounding measures should also be implemented to mitigate the accumulation of static charges. Furthermore, in addition to isolation, mechanical equipment may require secure fixation to prevent unintended rotation, thereby averting potential hazards such as crushing or falling risks posed to individuals who may inadvertently step on or lean against them (Veasey et al., 2005).

To reasonably ensure the safety of working within confined spaces, it is imperative to acknowledge that reliance solely on personal protective equipment (PPE) and respiratory protective equipment (RPE) should be considered a last resort, except in cases of rescue operations (Figure 2). Within the context of risk assessment, there may arise circumstances where the necessity of employing PPE and RPE becomes apparent. In such instances, it is incumbent upon employers to furnish appropriate equipment and ensure its utilization by individuals tasked with entering and working within confined spaces. This provision of equipment is complementary to the implementation of engineering controls and adherence to safe operating protocols. The specific type of PPE provided will depend on the hazards identified, but may include, but is not limited to, safety ropes, harnesses and appropriate respirators. Careful selection of such equipment should factor in foreseeable hazards and the imperative for prompt evacuation should exigencies arise (Sulardi and El-Ridho, 2019).

The use of the RPE and PPE has the potential to induce heat stress in individuals. In severe cases, measures such as the provision of cooling air may be required to reduce the discomfort associated with wearing protective clothing. In addition, footwear and apparel may be required to have insulating properties to prevent softening of plastics, thereby preventing degradation of critical components such as visors, air hoses and crimped connections.

A secure pathway must be established both at the entry and exit points of confined spaces. Ideally, these pathways should facilitate swift, unimpeded, and readily accessible entry and exit. Additionally, the escape routes must be designed to facilitate quick egress for individuals entering confined spaces, ensuring suitability for emergency evacuation (Figure 2). The dimensions of openings leading into enclosed spaces should be sufficiently ample to accommodate safe passage. Furthermore, openings providing access to confined spaces, as well as pathways traversing partitions, compartments, or barriers within such areas, should be sufficiently wide and devoid of obstructions to enable the passage of individuals donning requisite protective attire and equipment, while also allowing for adequate access for rescue operations.

Adjacent to any openings permitting safe access, if present, clear and prominently displayed safety signage should be installed to deter unauthorized entry from alternative points of access. It is imperative to impose strict time limits on individuals working within confined spaces. Such limitations may be particularly warranted in scenarios involving the use of respiratory protective equipment or in environments characterized by extreme temperature and humidity conditions. This principle also applies to confined spaces of limited dimensions where mobility is severely constrained. In instances involving expansive enclosed spaces with multiple entry points, the implementation of a registration or tallying system may be necessary to monitor the ingress and egress of all personnel and track entry times effectively.

For a safe working system to be efficacious, it must be documented in writing. Such a system delineates the tasks to be undertaken and the corresponding precautionary measures to be observed. When formalized in writing, there should exist an official record confirming the proactive consideration of all foreseeable hazards and risks. The safe procedure encompasses the implementation of all pertinent measures in the appropriate sequence. However, the practical efficacy of a safe working system ultimately hinges on its implementation (Selman et al., 2019).

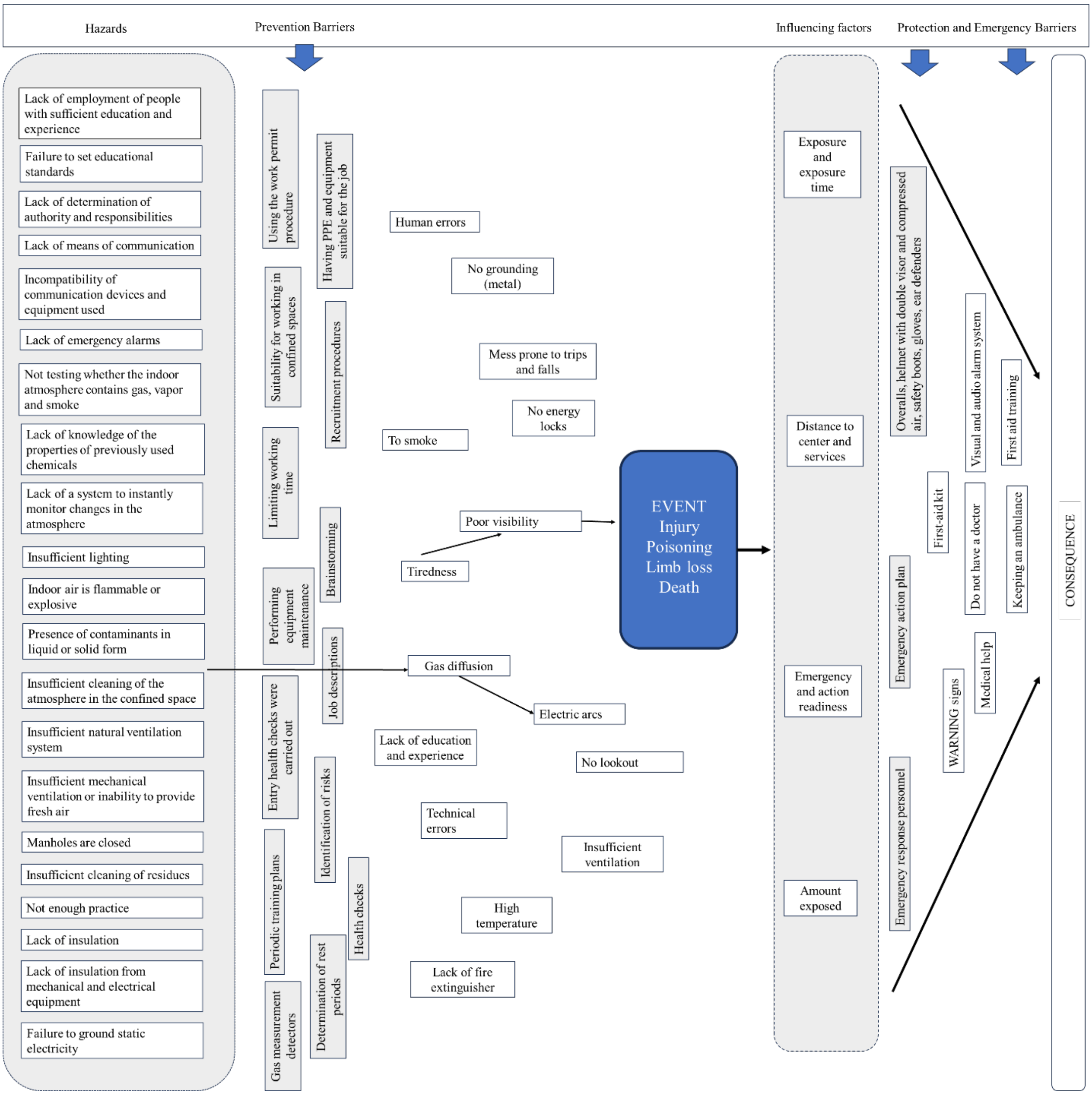

Figure 2. *Schematic representation of hazard, barrier and event in the bow tie method*

The work permit system constitutes a formal written protocol typically mandated in situations where there exists a reasonably foreseeable risk of serious injury upon entry into a confined space or while conducting work within such an area (Figure 2). It is essential to recognize that the work permit procedure serves as an extension of, rather than a substitute for, the overarching safe system of work. Merely relying on the work permit system does not inherently render the work environment safe; rather, it functions to bolster the safety framework by facilitating the documentation of essential findings and obtaining necessary authorizations for entry. This documentation encompasses crucial details such as entry time limits, results of gas testing, and other pertinent information crucial in emergencies, while also preserving historical data on initial entry conditions for post-work assessment. A work permit system is deemed appropriate in several scenarios, including: (a) ensuring that individuals engaged in confined space work are cognizant of associated hazards and the specific nature and scope of their assigned tasks; (b) confirming the adequacy of safety measures through official verification before permitting entry or commencement of work; (c) coordinating or restricting access of other individuals and their activities in a controlled manner that may impact indoor work conditions; (d) instances where work necessitates authorization from multiple parties or imposes entry time constraints. Additionally, the implementation of a work permit system may be warranted when direct communication with external parties is unavailable, or when specialized respirators and/or the PPE are mandated. It is imperative that activities covered under the work permit are promptly revoked upon completion (Selman et al., 2019).

The extent of procedural requirements for obtaining a work permit varies according to the nature of the work and the associated risks. For instance, when (a) risks are deemed to be low and easily manageable, (b) the work system is characterized by simplicity, and (c) it is assured that concurrent business activities will not compromise safety within the workspace, unrestricted entry may be considered if a risk is effectively eliminated and the likelihood of its recurrence is deemed negligible, provided that the aforementioned conditions are met (Botti et al., 2018).

The individual tasked with conducting the risk assessment for confined space work must evaluate the suitability of personnel in relation to the specific tasks at hand. In instances where the risk assessment identifies significant physical constraints, the responsible individual may be required to ascertain whether the individuals possess the necessary physical attributes. This consideration is essential for safeguarding both the well-being of the individual worker and others who may be impacted by the nature of the work. Furthermore, the authorized personnel may need to take into account additional factors concerning individual suitability, such as claustrophobia or the ability to wear respiratory protective equipment. In such cases, seeking medical guidance may be warranted to assess the individual's fitness for the assigned work.

CONCLUSION

In essence, the methodology outlined here comprises two primary stages. The initial step involves a semi-quantitative assessment of risk, employing a five-level risk matrix. To mitigate the influence of subjective judgment, predefined scoring criteria for probability and severity are applied. Within this phase, the probability and severity scores are multiplied to generate a composite risk score. The subsequent step is predominantly qualitative in nature, employing the Bowtie diagram as a visual aid to delineate the causative factors and potential consequences of the evaluated risk. A notable advantage of this tool is its ability to facilitate a clear differentiation between preventive measures and mitigation strategies/barriers aimed at eliminating, mitigating, or alleviating the impact of a specific accident risk.

Understanding the mechanism behind accidents that may occur through the bowtie method requires a challenging experience and statistical knowledge. The bowtie diagram necessitates the analyst to identify the necessary barriers for each specific scenario. Employees within an organization can identify which barriers are missing or not being utilized properly, and which ones are failing. Thus, although there may not be a numerical way to evaluate the impact of such improvements, it provides a way to enhance safety conditions. In any case, the diagrams assist in determining risk controls and aid in their implementation before measurement.

This article explores the application of the bowtie methodology in conducting a semi-quantitative assessment of occupational accident risks. The proposed approach illustrates a systematic risk evaluation pertaining to a specific category of accidents commonly encountered in confined spaces within the agricultural sector. In the study, the risks caused by the atmosphere in confined space (RS: 20) were evaluated in the high-risk group, while the risks caused by chemical substances or their residues were also evaluated in this group. While the very high-risk score for explosion and poisoning of gases that are likely to be found in confined spaces is 25, it has been revealed that they must be ventilated before starting work. In addition, the issue of providing the necessary training and making measurements before starting to work in these areas is highlighted.

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