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Araştırma Makalesi * Research Article

Identifying Causes of Accidents And Enhancing Safety Using the Fishbone Method: an Application in Excavation

Daha Fazla Güvenlik İçin Balık Kılçığı Yöntemi Kullanılarak İş Kazası Analizi: Hafriyat Çalışmasında Bir Örnek Olay İncelemesi

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Abstract: Excavation and earthworks are considered fundamental activities within the construction sector, and therefore, accidents occurring during excavation work cannot be separated from general accidents within the construction industry. These activities entail a range of hazards and risks, highlighting the critical importance of taking necessary precautions and providing training before commencing excavation work. The aim is to eliminate potential risks at their source by using appropriate equipment and adopting suitable excavation methods. If risks cannot be entirely eliminated, it is crucial to reduce them to acceptable levels by ensuring that workers use appropriate personal protective equipment, conducting regular maintenance of vehicles and equipment, and providing ongoing training. In this study, an incident that occurred during excavation work in Iğdır province was evaluated through a Fishbone analysis within the context of cause-and-effect relationships. The origins of the accident were thoroughly examined, and the results were assessed. Factors such as the absence of occupational health and safety measures, lack of workplace organization, and absence of trained personnel were identified as contributors to increased accident probability. Additionally, the study suggests that along with the absence of preventive measures, post-accident protective measures were also inadequate. It emphasizes that individuals lacking sufficient knowledge during rescue operations exacerbate the situation.

Keywords: Fishbone, excavation, accident, occupational health and safety.

Öz: Kazı ve hafriyat işleri, inşaat sektörünün temel faaliyet alanlarından biri olarak kabul edilir ve bu nedenle, kazı işlerinde meydana gelen iş kazaları genel inşaat sektöründeki iş kazalarından ayrı düşünülemez. Bu faaliyetler, bir dizi tehlikeyi ve riski içerir, bu yüzden hafriyat işine başlamadan önce gerekli önlemlerin alınması ve eğitimlerin verilmesi kritik önem taşır. Doğru ekipmanların kullanılması ve uygun kazı yöntemlerinin benimsenmesi, olası risklerin mümkün olduğunca kaynağında ortadan kaldırılmasını amaçlar. Eğer riskler tamamen ortadan kaldırılamıyorsa, kabul edilebilir seviyelere indirilmesi için çalışanların uygun kişisel koruyucu ekipmanları kullanması, araç ve ekipmanların düzenli bakımının yapılması ve düzenli eğitimlerin verilmesi son derece önemlidir. Bu çalışmada, Iğdır ilinde yürütülen hafriyat işleri sırasında meydana gelen bir iş kazası neden-sonuç ilişkisi çerçevesinde Balık Kılçığı analizi ile değerlendirilmiştir. Kazanın kökenleri detaylı bir şekilde incelenmiş ve sonuçlar değerlendirilmiştir. Olayın iş sağlığı ve güvenliği önlemlerinin alınmadan gerçekleşmesi, iş yeri düzeninin sağlanmaması ve eğitimli personelin görevlendirilmemesi gibi faktörlerin, kaza olasılığını artıran nedenler arasında yer aldığı belirtilmiştir. Çalışmada, kazayı önleyici tedbirlerin alınmamasıyla birlikte, kazadan sonra koruyucu önlemlerin yetersiz olduğu da öne sürmektedir. Özellikle

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kurtarma çalışmalarında yeterli bilgiye sahip olmayan kişilerin, kurtarma operasyonları sırasında zararın artmasına yol açtığı vurgulanmıştır.

Anahtar Kelimeler: Balık kılçığı yöntemi, kazı, iş kazası, iş sağlığı ve güvenliği.

INTRODUCTION

Excavation and earthwork operations are engineering activities that are highly critical and require meticulous attention in terms of occupational health and safety. As the excavation area deepens, the hazards and risks increase. Typically, in an excavation work, hazards such as sidewall collapses, material sliding into the excavation area, ventilation issues, working in confined spaces, electrical or equipment-related problems, water ingress, and the dispersion of dust during excavation are present (Çalışkan et al., 2016). Collapses occurring in the excavation area can be defined as the uncontrolled and sudden flow of excavated material into the dug void (Demirel et al., 2018). This situation can adversely affect the lives of workers in the excavation area. As a result of such accidents, besides loss of life, significant equipment and time losses can lead to disruptions in projects. The most crucial factor in preventing accidents is a good understanding of the characteristics of the excavated ground.

According to data from the Occupational Safety and Health Administration (OSHA), it is stated that 61% of accidents that occur during excavation activities result in fatalities. The primary cause of these accidents is emphasized to be the lack of safety equipment as well as the contribution of unsafe behaviors (Kale & Eskişar, 2018). In a study examining accidents involving projects such as drinking water, irrigation water, wastewater, and rainwater on canal construction sites, it was concluded that the main cause of fatal accidents was the collapse of excavation edges (Müngen, 2011). It is known that the risk of fatality due to suffocation when a worker is trapped underground is less than three minutes as a result of being trapped under tons of load without air. However, serious injuries such as bone fractures and internal organ damage due to the weight on top further decrease the chances of survival (Önder & Önder, 2010).

The concept of total safety not only protects the health of workers in the excavation area, but also includes the safety of all living things around the excavation site (Thwala et al., 2018). People and vehicles near the excavation area should also be protected, and necessary precautions should be taken for this purpose. Emergency scenarios should be prepared in advance and readily available for use in any emergency situation in the excavation area (Rampuri, 2019). Employees should be informed about these emergency plans and evacuation procedures and necessary emergency equipment should be provided. Before starting excavation work, a risk assessment should be conducted to identify potential risks, and appropriate measures should be taken to mitigate these risks. The primary objective of risk management is to control risks, and these control strategies are generally classified into four main areas: risk avoidance, risk retention, risk transfer, and risk reduction (Smallwood, 2010).

The fishbone method, commonly used in the field of occupational health and safety, is recognized as an effective tool for identifying, analyzing, and preventing potential risks in workplaces (Nugroho & Sunbara, 2021). This method is particularly widely used in hazard analysis processes for identifying and evaluating potential hazards in workplaces. It is crucial to identify hazards in various areas such as work processes, equipment, work environment, and human factors (Atalay & Kılıç, 2015).

The fishbone method contributes to the effective management of risks in workplaces and also guides the development and implementation of occupational health and safety policies and procedures by facilitating processes such as identification, assessment, and prioritization of potential risks (Eraydın et al., 2019). Additionally, it can be used to identify the root causes of workplace accidents and incidents. When a workplace accident or incident occurs, a fishbone diagram can be created to investigate the root causes of the event, and measures to eliminate these causes can be identified (Şahin et al., 2022).

Recently, the fishbone method has also been utilized to increase awareness of occupational health and safety among employees and to encourage their participation. It is expected that employees will contribute to strengthening the safety culture in the workplace and taking on more responsibility. This

is intended to support better implementation of occupational health and safety standards in workplaces and prevent workplace accidents (Akdeniz, 2016).

An occupational accident is defined as an event that occurs due to the general structure of the workplace, the equipment used, or the conduct of work in the workplace, resulting in death or physical or mental impairment, causing damage to machinery, equipment, and consequently the workplace (Ceylan, 2011). When the causes of occupational accidents or incidents are categorized into main categories, they generally include 8Ms: machine, man (human), environment, material, method, management, measurement, and maintenance (Yorulmaz, 2022).

Potential malfunctions stemming from the use of machinery, equipment, and/or materials may encompass subtopics such as design issues, the presence of hazardous substances, or the availability of less hazardous alternative substances. The status of the environment or working conditions at the time of the incident includes factors such as weather conditions, extreme temperatures, noise levels, lighting levels, as well as the presence of toxic and hazardous gases, dust, and smoke in the environment (Demir, 2018).

Among personal reasons, factors such as individuals' personality traits, physical fitness for the job, level of experience, education level, health condition, fatigue, and stress play a role. Management-related issues include the manner in which safety procedures are implemented, ensuring adequate supervision, how the work is performed, employee training, risk assessment, rectification of unsafe conditions, and maintenance of machinery and equipment.

Such a accident investigation model guides the person conducting the accident investigation in uncovering all possible causes of the accident, thereby reducing a one-sided perspective. This ensures a comprehensive and fair review process, enabling effective measures to be taken to prevent the recurrence of similar incidents.

Preventing workplace accidents and providing permanent solutions are only possible by addressing the root causes of accidents. The purpose of this study is to examine a workplace accident that occurred in the province of Iğdır and to uncover the true causes of the incident. In this context, it is essential to focus on the root causes of the accident rather than finding a culprit. To this end, the questions investigated in the study are as follows:

- Is the work environment safe enough for the work being performed?
- Have the necessary safety measures been taken during the work being carried out?
- Are the equipment and tools used suitable for the job?
- Do the employees have sufficient knowledge about the equipment being used?
- Are the employees using protective equipment against any risks?
- Have inspections been carried out to ensure full safety in the workplace?
- Have the employees received adequate training related to their work?

The investigation conducted within the framework of the above questions aims to determine the causes of the workplace accident. It is difficulties for researchers and investigators to determine the outcomes of workplace accidents and provide definitive answers. These limitations include inconsistencies in statements, significant changes in the workplace over time, and the lack of qualified personnel within law enforcement to prepare accident reports.

Materials and Methods

Cause-effect diagrams are used to identify possible causes of a specific problem or situation. By starting from the results obtained using statistical methods, the root causes of the incident are reached, and the relationships between these results are visually explained. On the other hand, the fishbone method is a problem-solving approach that aims to identify all factors affecting a problem and to determine and improve the factor that most affects the outcome (Kamrudins & Nugroho, 2022). This

method can be used in a wide range of issues, from individual problems to organizational issues, and is easy and effective to implement.

The fishbone diagram, developed by Kaoru Ishikawa in 1953, is also known as the Ishikawa diagram (Dolmacı & Duran, 2019). Its name comes from its resemblance to a fishbone when completed (Figure 1). This diagram helps identify and structure main and root causes in any problem (Akdeniz, 2016). Its purpose is to elaborate on the causes that produce results and to work on reducing problems by visualizing these causes. It is particularly used as a tool in quality studies to analytically identify factors affecting quality or causing a problem.

Fishbone analysis aims to organize factors contributing to the occurrence of an outcome by categorizing them into broad categories, considering all possible scenarios through a cause-effect analysis approach. After determining the main categories for factors leading to the outcome, each category is supplemented with sub-causes (Uluskan & Özyalıner, 2021). Each sub-cause is among the potential causes of the unwanted event or problem (Figure 1). However, this method does not solely point to the actual causes, as true causes can only be determined through the experimental testing of concrete evidence and hypotheses. This analysis method facilitates the identification of all possible causes, particularly to facilitate a proactive approach. The obtained data are typically visualized in the form of a fishbone diagram.

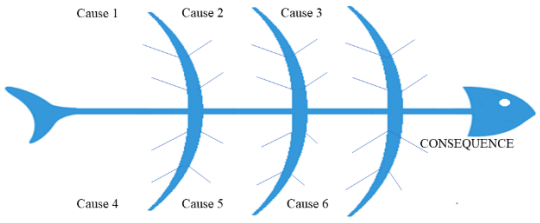

Figure 1. *Fishbone diagram model*

The diagram presents a structured representation of the causes of a specific effect. This effect can be positive (an objective) or negative (a problem) and typically allows for consideration of all possible scenarios and causes generated by an expert team. Subsequently, these causes can be empirically tested or evaluated through the assessment of available data to determine the most likely ones (IEC/FDIS 31010:2009E). It is crucial to brainstorm potential causes at the beginning of the analysis and then formulate hypotheses that can be further evaluated in a comprehensive manner (Dobrusskin, 2016).

Additionally, the fishbone diagram is used not only to identify the potential root causes of a specific outcome, problem, or situation but also to rank and establish connections among the factors affecting a specific process (El-Dogdog et al., 2016). Taking corrective actions in problem-solving helps focus employees on the issue, contributes to the recognition of the root causes of the problem, enhances team understanding, promotes systematic work, and helps identify possible causes of variations in processes (Tantri et al., 2024).

With the use of such graphics:

• The problem-solving process can be made more organized,

• All information regarding the problem can be systematically presented, leading to progress from known to unknown,

• Utilizing the expertise of those directly experiencing the problem becomes possible.

The occurrence of accidents is a result of the combined effects of internal and external factors. Although there is no specific accident model in the initial stages of accidents, if safety issues are present, these potential hazards gradually emerge during the development phase and eventually lead to accidents through sudden changes. The primary purpose of establishing safety assessment methods is to identify potential problems and take effective measures to prevent them. These methods prevent

potential hazards from turning into accidents before they occur. To ensure occupational safety and make preventive measures more effective, it is necessary to understand the evolution process of accidents. Therefore, mastery of accident causality theory forms the foundation of preventive efforts.

Accident causality theory is based on the 4M method used by analysts and includes (Bowo, & Mutmaınnah, 2020 Yoon et al., 2024; Kim et al., 2020; Chunying & Xiuwen, 2017) four main factors: man, machine, material, and milieu (environment). These fundamental factors are frequently preferred to identify and analyze the causes of accidents. However, in this study, a more detailed approach has been adopted by adding the factors of method, measurements, material, and maintenance to the 4M method. This expanded approach is referred to as the 8M method and is used to examine the causes of accidents in greater detail.

In the 8M method, an accident can occur if any two factors that can cause an accident are present simultaneously; if three or more factors are present at the same time, the likelihood of an accident increases even further. The analysis of this theory not only forms the basis of safety management but also provides a solid foundation for formulating effective measures to prevent accidents. Therefore, the use of the 8M method is crucial for preventing accidents and ensuring occupational safety.

The causes of accidents in the area of investigation can be categorized into various groups. Among human factors, physical causes (e.g., fatigue, insufficient sleep), occupational causes (e.g., lack of training, lack of competency), psychological causes, and communication problems can be listed. The main equipment-related causes include design flaws in mechanical equipment, deficiencies in safe working arrangements, and inadequate provision of safety protection equipment. Methodological causes generally involve poor working environments and areas, as well as operational information not being accurate.

There are many management-related causes. Generally speaking, these include incomplete safety rules and regulations, inadequate safety management plans, lack of safety inspection guidance, unreasonable personnel allocation, and defective occupational health management. Each of these factors plays a significant role in the occurrence of workplace accidents and should therefore be considered when developing effective safety management strategies.

To identify the causes of an accident, reports prepared by law enforcement agencies, statements from eyewitnesses, forensic reports, and on-site investigations have been utilized.

Results and discussion

This study presents a detailed analysis of a workplace accident that occurred within the boundaries of Iğdır province. The causes and effects of an incident resulting in the loss of life during irrigation channel excavation works were examined. The factors leading to the incident were subjected to a detailed analysis using a fishbone diagram. In the examined accident, one of the significant factors was the failure to dump the excavated soil sufficiently far away from the working area. This led to the formation of a larger soil pile as the excavation process progressed. Additionally, the dry and easily excavatable nature of the soil contributed to the occurrence of unexpected situations during the excavation process. Another significant factor contributing to the workplace accident was the reduction in the operator's visibility and intervention opportunities. Especially as the excavation process progressed, the operator's intervention area narrowed, and the risk factors increased. The use of a tracked excavator also influenced the accident. The vibration caused by the movement of the tracked excavator during both excavation and lowering of pipes into the well facilitated the movement of the soil pile. In general, in the conducted operation, there was no need for any worker at the bottom of the well during the lowering of the pipe and pipe joining activities. However, when there was an issue with joining the pipes, a worker was lowered into the well upon request, and the joining process was carried out under the instructions of the machine operator. The absence of a third person in the work area significantly hindered communication opportunities. During the worker's intervention due to the jamming of the pipes, a soil collapse occurred, trapping the worker between the pipe and the soil. The worker's lower body being completely buried under the soil occurred while the worker was conscious. The rescue operation began with the excavation of the surrounding soil. However, this method proved inadequate, and an alternative approach was adopted to extract the worker.

In this alternative method, an attempt was made to pull the worker out from under the soil using a machine by attaching a rope to the worker's chest area. However, despite several attempts, this pulling operation failed while the worker was trapped between the pipe and the soil. After being pulled up multiple times, the worker was eventually successfully extracted. The worker's health condition was found to be positive during on-site examinations, and they were immediately transported to a hospital by ambulance.

However, unfortunately, despite the medical interventions performed at the hospital, the worker passed away. This situation has been associated with medical complications following the unsuccessful outcome of the rescue operation. A detailed examination of the incident serves as an important source of data for preventing similar situations and enhancing the effectiveness of rescue operations.

The primary goal of occupational health and safety is to ensure that workers are aware of the risks that may arise during excavation and to establish and implement safe working methods (Cerev & Yıldırım, 2018). Generally, about 88% of the causes of workplace accidents stem from unsafe behaviors, or human factors, while 10% arise from inappropriate conditions, with the remainder originating from factors that cannot be prevented (Horozoğlu, 2017). In the incident at hand, there is a significant lack of information not only regarding the failure to take appropriate measures in response to changing conditions during the execution of the work, starting from the preparation stage, but also about what needs to be done to rescue the victim in the event of an accidents.

The Occupational Health and Safety Law No. 6331 stipulates the regular conduct of occupational safety training in the workplace and assigns the responsibility for this matter to the employer (Korkmaz & Avsallı, 2012). The law mandates the establishment of occupational health and safety procedures in workplaces, from training to the implementation of safety measures, making it a legal obligation. This obligation applies to all public and private sector employees (Kılkış, 2013). Failure to comply may result in severe legal consequences, even if conducted on a voluntary basis.

All factors that could lead to the accident are shown in Figure 2 in the fishbone diagram. In the work area, they have been examined under the headings of 8M, which are machine, man, media, method, management, measurements, material, and maintenance.

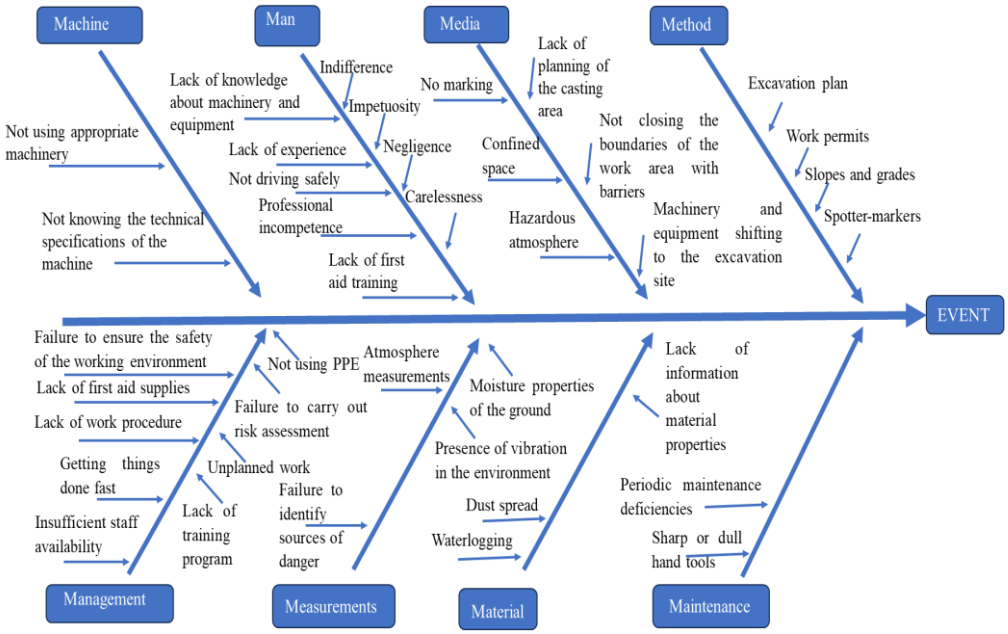

Figure 2. *Representation of the causes contributing to the accident in the fishbone diagram*

According to the findings of the investigation, both the machine operator and the worker in the well did not have basic occupational health and safety training. In accordance with the Regulation on the Principles and Procedures of Occupational Health and Safety Training in our country's legislation,

employees are required to receive job training, and the employer is responsible for monitoring these trainings. Additionally, employees are required to undergo necessary health examinations before starting work and to work as insured within the framework of legal obligations.

Safety procedures for excavation works should be explained in detail before starting work and before leaving the work area. Training should be refreshed in case of changes in the work area. To prevent accidents, hazardous areas in the excavation site should be clearly marked with appropriate signs and barriers so that workers can avoid these areas. Health and safety signs should be provided using colored, audible, and/or illuminated signals, verbal communication, or hand signals. These signs should be signs that indicate a specific purpose, activity, or condition and warn against hazards (Korkmaz, 2019). Hazardous areas should be marked with these signs and entrances/exits should be controlled. Unauthorized persons should be prevented from wandering in excavation areas using barriers and tapes. Audible and visual warnings should be used when necessary.

Effective communication protocols have not been established in the work environment. The importance of communication in reducing occupational accidents is emphasized as the basis of the safety culture to be created in the workplace (Ranganathan, 2022; Yoon et al., 2024; Musarat et al., 2024). Employees lack complete harmony in terms of teamwork as they have not previously experienced and met each other. The high temperature level in the environment has increased fatigue and exhaustion levels. Furthermore, employees tend to exhibit a rushed attitude due to the completely call-based nature of their work and the fact that it often takes place outside of regular working hours, beyond their usual areas of responsibility. This desire to complete the work as quickly as possible has increased the likelihood of making mistakes (Leclercq & Thouy, 2004).

Employees should be informed about the machinery and equipment used, and especially certified by independent institutions. This will increase the perception of reducing accidents in the workplace (Mursid & Herawati, 2023). Employees are not knowledgeable about the type of vibration the 30-ton excavator will cause on the ground while in motion in the inspection area. Additionally, there is insufficient awareness that rescue operations cannot be performed with an excavator with a capacity of over 15 tons, but can only be used by expert and trained individuals in rescue operations.

The incident unfolded like an unplanned domino effect. During the excavation process, it is necessary for the dumping area to start from a distant point according to the characteristics of the soil. With the progression of work and deepening of the excavation, proper management of the extracted material would not pose a problem, and the risk of it flowing into the well would be minimized. However, in the current situation, such planning was not made, and there was a risk of the extracted material filling the well. No barriers were created around the work area, allowing unauthorized individuals to enter the scene or excavation site. Furthermore, informative markings about potential hazards present in the workplace were not provided. The crucial use of a spotter was neglected for such operations, and the operator was unable to monitor the developments in the excavation process in real-time.

Employers are responsible for taking necessary health and safety measures in the workplace. However, even if all precautions are taken, in situations where risks cannot be reduced, employers are obliged to provide their employees with personal protective equipment and supervise their correct use (Ateş, 2020). Employees are also obligated to use the protective equipment provided by the employer correctly and completely.

According to the Regulation on Hazard Classes, activities such as ground and land preparation, site cleaning, excavation and earthworks, preparation of agricultural land, blasting and rock removal, drainage of areas such as construction and agriculture, and excavation, digging, and filling works are classified as highly hazardous. However, it has been determined that necessary precautions were not taken despite the highly hazardous nature of the work (Kale & Eskişar, 2018).

The investigation findings indicate that the victim, lacking legal obligation, failed to demonstrate the requisite sensitivity and attention to the task at hand, acted in a careless, absentminded, and negligent manner despite warnings. Both the victim and the heavy equipment operator were found to lack the requisite professional qualifications. In particular, it was determined that a spotter should have

been present when the operator's field of vision was obstructed. However, there was no spotter present at the time of the accident.

Additionally, it has been noted that the employer failed to have a certified first aider present at the worksite as required by the first aid regulations (Eravcı, 2019). It was also mentioned that due to ongoing soil collapses, the accident site could not be clearly observed, and inconsistent statements were identified in the records regarding the rescue operation, indicating that the injured person passed away at the hospital despite being rescued.

The primary objective of occupational health and safety efforts is to protect workers from workplace accidents and occupational diseases, ensure a harmonious working environment, and conduct safe work activities. It is of great importance for businesses to establish their own internal audit mechanisms and procedures. Regular inspections should be conducted in excavation sites by security personnel or authorized individuals within the workplace. Audit activities provide a systematic and organized approach to assess and improve the effectiveness of risk management, control, and management processes, thereby assisting a business in achieving its objectives and goals. Based on audit results, errors should be identified and rectified, and necessary corrective measures should be taken.

Conclusion

When examining the underlying causes of an accident, personal factors are often identified as key contributors. This is evident in the study in question, where factors such as inadequate employee education, low awareness levels, and hasty attitudes were found to be significant. The shortcomings of managerial planning and occupational health and safety awareness, as observed in the study, resulted in the failure to meet essential standards in the working environment. It is evident that there is a necessity to enhance the awareness and perception levels of employees, particularly within the public sector, with regard to occupational health and safety.

The fishbone diagram method offers a number of advantages in the field of occupational health and safety. The study served as a systematic and schematic tool to identify and prevent the root causes of the accident while helping to better understand and identify potential hazards in the workplace.

By ensuring the participation of employees in occupational health and safety activities in the workplace, the development of a safety culture in the workplace can be achieved. In addition, the studies will contribute to reducing risks in workplaces and increasing occupational health and safety performance by informing risk management processes and policies. Therefore, the fishbone diagram method can be considered a valuable tool in the field of occupational health and safety. Its effective use can contribute to reducing risks and protecting the health and safety of employees.

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