

Contributory Factors and Implications of Excavation Accidents in the Rumaila Oil Field, Basra



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<https://doi.org/10.18280/ijsse.130417>

ABSTRACT

Received: 21 May 2023

Revised: 10 July 2023

Accepted: 5 August 2023

Available online: 28 September 2023

Keywords:

excavation accidents, Rumaila oil field, unsafe act, occupation hazards, soil collapse, gas releases

This study sought to elucidate the circumstances underpinning excavation accidents at the Rumaila oil field in Basra. A diverse cohort of 116 professionals, including site managers, safety officers, foremen overseeing excavation work, flagmen, operators, and laborers, were surveyed. Employing the Statistical Package for the Social Sciences (SPSS) version 24, hazards were ranked by relevance, and the rationale for these rankings was explicated using the relative importance index approach. The primary precipitators of accidents during excavation were identified as unsafe conditions, personal factors, unsafe acts, and occupational factors. The most pronounced consequences were damage to facilities and soil collapse, accompanied by the release of gases such as H₂S and CH₄. The ensuing human, environmental, and economic tolls were substantial, including the revocation of work permits and a sustained decline in oil output by 100,000 barrels per day.

1. INTRODUCTION

In the field of safety economics, the cost of safety forms a nexus between economics and safety [1]. Known for its distinct attributes, such as the continual alteration of project sites and conditions, the construction sector is recognized as one of the most dynamic industries [2]. The primary objective of excavation engineering is to establish a safe and suitable environment for subterranean construction. In recent years, escalating concerns have emerged due to the surge in accidents at excavation sites. Notably, excavation accidents can potentially inflict substantial damage on buried and surrounding structures. However, most excavation supports are designed to be temporary, and their safety and significance are often overlooked by owners [3]. The situation is further exacerbated by the complexity arising from various factors such as soil types, water levels, proximate buildings, and underground infrastructure like pipelines and cables. The involvement of different companies in tasks such as the construction of the excavation support system, soil excavation, on-site monitoring, and underground structure construction poses coordination and management challenges during the excavation process, leading to a higher incident rate. Given these circumstances, it is imperative to devise strategies to mitigate the risk of disasters during excavation. Excavation work, which involves the mechanical or explosive removal of earth and rock to form an open face, hole, or cavity, is a foundational aspect of the construction industry [4]. Recent studies indicate a stark escalation of excavation-related accidents [5]. Despite concerted efforts by safety experts, research initiatives, and regulatory legislation, the number of construction-related injuries and fatalities has seen little decline [6]. Excavation remains one of the most hazardous tasks with potential disasters including cave-ins, falls into pits,

operation of heavy machinery, oxygen deprivation, and flooding [4-7]. The frequency of accidents and fatalities due to geotechnical reasons has been increasing at an alarming rate [8]. Troubling statistics from the US reveal that approximately 30 workers lose their lives annually in digging operations [9]. Data accumulated from 2003-2011 indicates that 287 workers perished due to trench collapses [10]. These recurrent incidents significantly contribute to project delays and budget overruns [11]. In this research, we aim to identify the salient factors influencing excavation accidents and their ensuing consequences.

2. METHODOLOGY

In formulating the methodology for this study, consultations were held with safety specialists from BP-Kent. These interactions served to identify the most pertinent questions for inclusion in the questionnaire, areas for enhancement, and places where additional commentary would be beneficial. A total of 125 individuals were surveyed, yielding 116 valid responses. These responses were instrumental in discerning the factors contributing to excavation accidents in the Rumaila oil field. The cohort of respondents comprised a range of supervisory professionals, including site managers, foremen, safety officers, laborers, foremen responsible for excavation work, flagmen, and operators. The data gathered was subsequently analyzed using the relative importance index method. This approach facilitated the ranking of hazards in order of their importance. The Statistical Package for the Social Sciences (SPSS) version 24 was employed as the statistical tool for this analysis. The reasons underpinning the rank order of hazards were detailed and contextualized using the findings from this statistical analysis.

3. RELIABILITY AND VALIDITY

Cronbach's alpha approach is used to examine the reliability (α) of the questionnaire findings using Eq. (1), in which the typical value of Cronbach's coefficient (alpha) falls somewhere between (0.0) and (1.0). When Alpha is near to 1, it indicates that the data have a high degree of internal consistency [12].

$$\alpha = \frac{K}{K-1} \left| 1 - \frac{\sum_{i=1}^k S_i^2}{S_t^2} \right| \quad (1)$$

In most cases, the Alpha coefficient gives us a passing grade; we can use this technique to evaluate the continuity of one paragraph's performance relative to another, and we may use it to extract stability based on the results of that evaluation. Because this equation reflects the internal consistency of paragraphs, alpha value was 0.813 within acceptable bounds, with sufficient dependability, for inclusion in the analysis of the questionnaire data.

4. RELATIVE IMPORTANT INDEX

According to Özdemir [13], meaning of the relative importance index (RII) is used to rank the relative importance of different risk factors based on their perceived relevance or impact. The RII (Relative Importance Index) is a measure used in studies to assess and compare the relative importance of various factors or sources of risk. We utilize the five-point Likert scale on which responses can vary from 0 (not important) to 5 (extremely important) to calculate relative importance indices (RII) for every component of the survey.

$$RII = \Sigma W / (A * N)$$

where,

W-weighting sum for each characteristic.

A-top ranked (we used 5 here).

N-total of respondents for this feature.

5. RESULTS

The accident analysis results were formulated into the following parts: The causes responsible unsafe condition for excavation accidents; The causes responsible personal factors for excavation accidents; The causes responsible Unsafe acts for excavation accidents; The causes responsible job factors for excavation accident and the consequences of excavation accidents. The percentages represent the proportion of respondents who agreed with each statement and that the RII values indicate the relative importance of each factor.

5.1 Unsafe condition factors for excavation accidents

Table 1 and Figure 1 below show the results of the survey's polling of respondents. The results indicate that respondents strongly believe that operator error is a common cause of accidents, with 58.5% of participants acknowledging this factor. This suggests that human errors made by operators during excavation work play a significant role in accidents. Similarly, line detection errors are also perceived as common, with 57.7% of respondents acknowledging their prevalence.

This highlights the importance of accurate line detection to avoid pipe or cable damage, which can result in accidents with severe consequences, including multiple casualties.

Table 1. Unsafe condition factors

Unsafe Condition Factors	RII	Rank
Line detection	0.8862	1
Operator	0.8397	2
Flag man	0.419	3
Type of Soil	0.3914	4

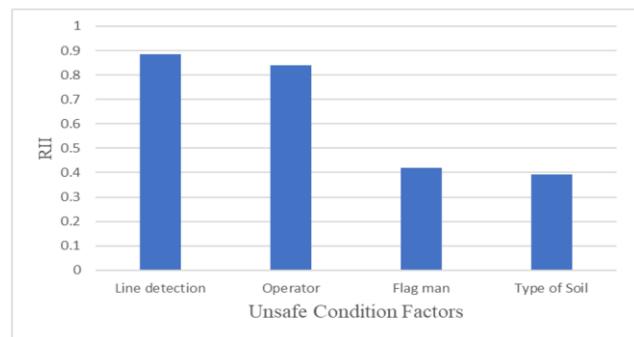


Figure 1. Unsafe condition factors

In contrast, the respondents expressed a belief that the presence of a flag man has no effect on accidents under unsafe conditions, with 43.9% of participants holding this view. This suggests that the role of a flag man in preventing accidents may not be considered significant in unsafe conditions, emphasizing the need to address other factors contributing to safety.

Furthermore, the findings indicate that the type of soil has no effect on accidents under unsafe conditions, as reported by 39.5% of respondents. This challenges the assumption that certain soil types may inherently contribute to a higher risk of accidents during excavation work. It suggests that other factors, such as human error or equipment failure, may have a more substantial impact on accident occurrence, regardless of the soil type.

Overall, the results highlight the crucial role of operator error and line detection accuracy in preventing accidents during excavation work. It emphasizes the need for proper training and supervision of operators and the importance of utilizing accurate line detection equipment and reports to mitigate the risk of pipe or cable damage. Additionally, the findings suggest that further examination of the role of flag men under unsafe conditions and the influence of soil type on accidents could provide valuable insights for improving excavation safety practices.

5.2 Personal factors for excavation accidents

Table 2 and Figure 2 both show the responses received. The results indicate that a significant percentage of respondents hold certain opinions regarding personal factors and their impact on accidents during excavation work. Specifically, Accidents caused by an unqualified flag man are perceived as common by 33.6% of respondents. This suggests that the lack of qualifications or competence in a flag man can contribute to accidents during excavation operations. It highlights the importance of having trained and qualified personnel in flagging duties to ensure safe working conditions.

Regarding accidents caused by an untrained operator of the

equipment, 25% of respondents hold the opinion that such accidents are moderate in occurrence. This implies that accidents resulting from operators lacking proper training and proficiency in handling the equipment are considered a noteworthy concern. It underscores the significance of providing comprehensive training programs for equipment operators to minimize the risk of accidents.

In terms of accidents caused by an unqualified operator, 25% of respondents believe that such accidents are rare when personal factors are involved. This indicates that personal factors, such as the operator's qualifications, may not be considered a significant contributor to accidents. It suggests that other factors, such as external conditions or equipment-related issues, may have a greater impact on accident occurrence.

A majority of participants (68.1%) did not hold any of the aforementioned views, indicating that they have different perspectives or do not consider these particular factors as prevalent causes of accidents during excavation work.

Furthermore, it is alarming that a significant majority of respondents (RII 0.3276) believe that personal considerations like extreme heat or illness never play a role in distracting the driver or leading to accidents. This suggests a lack of awareness or underestimation of the potential influence of personal factors on the performance and focus of the equipment operator. Neglecting personal considerations in demanding working conditions can increase the risk of accidents, potentially leading to severe consequences such as equipment overturning, damage to underground facilities, and loss of lives.

These findings highlight the importance of addressing the qualifications and training of both flag men and equipment operators. Additionally, there is a need to raise awareness among respondents and industry professionals about the potential impact of personal factors on safe excavation practices. Implementing measures to ensure proper qualifications, training, and consideration of personal factors can contribute to preventing accidents, reducing equipment damage, and preserving the well-being of individuals involved in excavation operations.

Table 2. Personal factors

Personal Factors	RII	Rank
unqualified flag man	0.7569	1
untrained operator of the equipment	0.4672	2
unqualified operator	0.3828	3
extreme heat or illness play a role in distracting the driver	0.3276	4

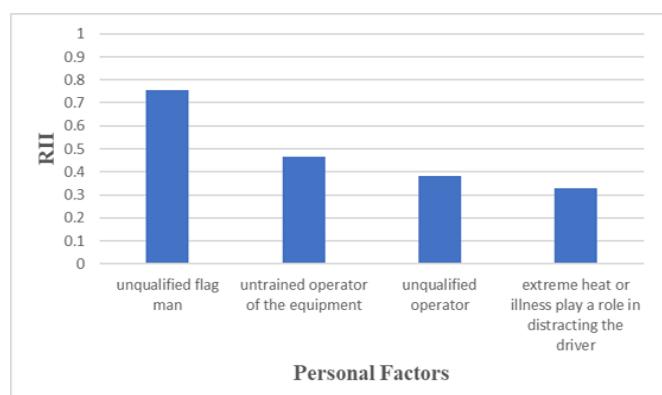


Figure 2. Personal factors

5.3 Unsafe acts for excavation accidents

Both Table 3 and Figure 3 show, the results reveal the opinions of respondents regarding certain practices or actions and their perceived effectiveness as causes of unsafe acts leading to excavation accidents. The interpretations of the results are as follows:

Crossing of people while the excavator is working: 51.7% of respondents agree that this practice is never effective in causing unsafe acts responsible for excavation accidents. This suggests that the act of people crossing the working area while the excavator is in operation is not considered a significant contributing factor to accidents. It implies that other factors may have a more substantial impact on unsafe acts and accident occurrence during excavation work.

Filling the equipment fuel: 58.6% of respondents agree that this practice is not effective in causing unsafe acts responsible for excavation accidents. This indicates that the process of filling the equipment fuel is not considered a significant factor leading to unsafe acts or accident occurrences. Other factors may be seen as having a more substantial influence on excavation safety.

A worker going up on the body of the equipment during its movement: 13.7% of respondents believe that this action is moderately effective in causing unsafe acts responsible for excavation accidents. This suggests that workers climbing onto the body of the equipment while it is in motion may be perceived as having a moderate impact on unsafe acts and accident occurrences. It highlights the potential risks associated with such actions and the importance of adhering to safe practices during equipment movement.

Excavation while people are in or near the pit: 10.3% of respondents agree that this practice is effective in causing unsafe acts responsible for excavation accidents. This indicates that conducting excavation work while individuals are in or near the pit is perceived as a significant contributing factor to unsafe acts and accident occurrences. It emphasizes the need for clear safety protocols and ensuring that people are not present in hazardous areas during excavation operations.

Table 3. Unsafe act factors

Factors	RII	Rank
Filling the equipment fuel	0.381034	1
Excavation While people are in or near the pit	0.3603	4
A worker go up on the body of the equipment during its movement	0.3776	3
Crossing of people while the excavator is working	0.381	2

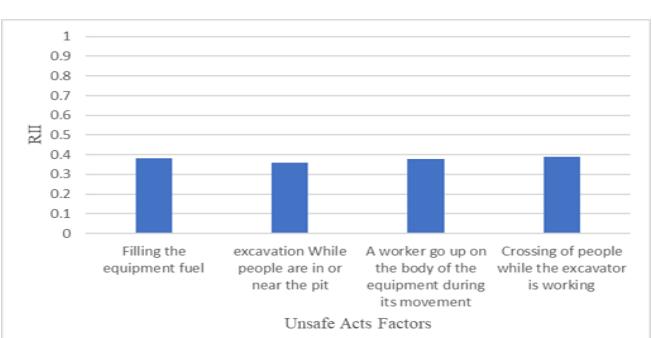


Figure 3. Unsafe act factors

Overall, the findings highlight varying perceptions regarding the effectiveness of certain practices or actions as

causes of unsafe acts leading to excavation accidents. It is important to note that the majority of respondents do not consider crossing of people, filling equipment fuel, or worker climbing on equipment as significant factors. However, a small percentage of respondents acknowledge the potential impact of these practices on unsafe acts and accident occurrences. These insights can assist in developing targeted safety measures and promoting awareness to mitigate risks associated with excavation operations.

5.4 The causes responsible job factors for excavation accidents

Both Table 4 and Figure 4 show the results indicate the opinions of respondents regarding specific job factors and their perceived effectiveness as causes of excavation accidents. The interpretations of the results are as follows:

Soil Collapse: 38.7% of respondents agree that soil collapse is the most effective cause responsible for excavation accidents. This suggests that respondents perceive soil collapse as a significant factor leading to accidents during excavation work. It highlights the potential dangers associated with unstable soil conditions and the importance of implementing proper safety measures to prevent soil collapse incidents.

Dusty Winds: 15.5% of respondents believe that dusty winds are moderately effective causes responsible for excavation accidents. This indicates that respondents perceive dusty winds to have a moderate impact on the occurrence of accidents during excavation work. Dusty winds can create visibility issues and affect the stability of the work area, potentially leading to unsafe conditions and accidents.

Table 4. Job factors

Factors	RII	Rank
collapsible soil	0.748276	1
Not enough lighting	0.396552	3
fog	0.363793	4
dusty winds	0.413793	2

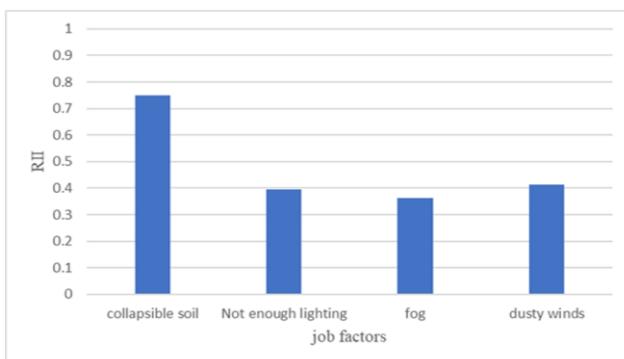


Figure 4. Job factors

Not Enough Lighting: 10.3% of respondents agree that insufficient lighting is an effective cause responsible for excavation accidents. This implies that a lack of proper lighting is seen as a contributing factor to accidents during excavation work. Inadequate lighting can hinder visibility and increase the risk of accidents, particularly in low-light or nighttime conditions.

Fog: 54.3% of respondents believe that fog is never an effective cause responsible for excavation accidents. This suggests that respondents do not perceive fog as a significant contributing factor to accidents during excavation work. It indicates that other job factors may have a more substantial impact on accident occurrence, and fog may not be considered a primary concern.

Overall, the findings highlight the varying perceptions of respondents regarding job factors and their effectiveness in causing excavation accidents. Soil collapse is identified as the most effective cause, emphasizing the importance of addressing soil stability and implementing appropriate safety measures. Dusty winds and insufficient lighting are seen as moderately effective or effective causes, emphasizing the need to manage these factors to ensure safe working conditions. However, fog is generally perceived as less significant in causing accidents during excavation work.

6. CONSEQUENCES OF EXCAVATION

In the excavation work, the consequences are serious and cost a lot of money when it occurs, as when damage occurs to the facilities, there will be possibilities for five types of accidents, and they are divided into:

Both Table 5 and Table 6 show, as 43.3% confirmed that damage to facilities is the most common consequence of excavations, by RII 0.7775. As for soil collapse, it comes after it with a RII of 0.7568, where most of the participants agreed that soil collapse is the most common with a rate of 39.6%, and the liberation of gases had the lowest percentage, as the participants agreed that gas leakage is the most common with a rate of 10.3% with a RII of 0.5017.

Table 5. Consequences of accident

Conseq uence	Health and Safety	Environment	Commercial Impacts
A	Multiple fatalities. More than 10 serious injuries	Spill more than 1,000 barrels of crude	Loss of licence to operate Long term loss of production capability of 100,000 bopd Long term loss of production capability of 10,000 bopd
B	Single fatality. Multiple serious injuries but less than 10	Spill more than 100 barrels but less than 1,000 barrels of crude	Short term loss of production capability of 100,000 bopd
C	Permanent disability	Spill more than 10 barrels but less than 100 barrels of crude	Short term loss of production capability of 50,000 bopd
D	DAFWC (Days Away From Work Case)	Spill more than 2 barrels but less than 10 barrels of crude	Short term loss of production capability of 10,000 bopd
E	First aid	Spill less than 2 barrels of crude	Minor equipment damage less than \$10,000

Table 6. Consequences of excavation

Factors	RII	Rank
Release of Gases	0.5017	3
Facilities Damage	0.7775	1
Soil Collapse	0.7568	2

7. CONCLUSION

The main findings in relation to the research objectives can be summarized as follows:

1. Under unsafe conditions, the research indicates that operator error and line detection errors are commonly identified causes of excavation accidents. These factors were reported by 58.5% and 55.7% of respondents, respectively. Interestingly, the presence of a flag man was perceived to have no effect on accidents under unsafe conditions by 43.9% of respondents. Similarly, the type of soil was considered to have no significant impact on accidents by 39.5% of respondents.

2. In terms of personal factors, the opinions of respondents varied. Approximately one-third (33.6%) believed that accidents caused by an unqualified flag man are common. Regarding the operator's qualification, 25% perceived accidents caused by an untrained operator to be moderate, while 25% believed accidents caused by an unqualified operator are rare. A majority of respondents (68.1%) did not hold any of these views.

3. The research findings shed light on specific unsafe acts related to excavation accidents. The majority of respondents (51.7%) agreed that crossing paths with working excavators is never an effective cause of accidents. Similarly, 58.6% agreed that filling the equipment fuel is not a significant contributing factor. However, a notable percentage (13.7%) believed that a worker going up on the body of the equipment during its movement is moderately effective in causing accidents. Additionally, 10.3% of respondents agreed that excavation while people are in or near the pit is an effective cause of accidents.

4. Job factors related to excavation accidents elicited varied responses. The largest proportion of respondents (38.7%) agreed that soil collapse is the most effective cause of such accidents. Dusty winds were perceived as moderately effective by 15.5% of respondents. Additionally, 10.3% agreed that insufficient lighting is an effective cause. However, the majority (54.3%) believed that fog is never an effective cause of excavation accidents.

These findings imply that operator error, line detection errors, personal factors, specific unsafe acts, and job-related factors all play roles in excavation accidents. It is worth noting that the research results may differ from previous research or expectations. For example, the perceived lack of influence of a flag man and the type of soil on accidents under unsafe conditions could challenge previous assumptions. Similarly, the diverse opinions on personal factors and the varying effectiveness attributed to different unsafe acts and job factors highlight the complexity of understanding and addressing the causes of excavation accidents.

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