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Revolutionizing Confined Space Work Practices in Thriving Oil and Gas Industry of Kertih, Terengganu

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Abstract

The oil and gas industry is inherently known for its riskiness, involving numerous activities and a variety of chemicals naturally present in the plant environment. Simultaneously, it has been observed that certain activities classified as critical, such as crane lifting, hydrostatics, excavations, hot work, and confined spaces, pose significant risks. Previous studies have shown that between the years 2009 and 2019, there were many reported incidents, with a total of 46 verified cases of deaths occurring in confined spaces in Malaysia. These incidents underscore deficiencies in the current system that need addressing. Therefore, this study aims to collect data on confined space incidents and issues in the oil and gas industry to propose a new intervention plan for employers and workers. The current working practices in confined spaces were analysed for this purpose. The data were gathered through survey questionnaires distributed to workers employed in confined spaces. The obtained data were analysed using the SPSS system to conduct reliability tests, ANOVA, and Pearson Correlation. The results of the ANOVA analysis indicated that there was no statistically significant difference at the $p < 0.05$ level for $n = 50$ concerning Age Categories, Position Categories, Years of Service, and Education Background in their perceptions of confined space work practices at Gas Processing Kertih (GPK). Additionally, Pearson Correlation analysis revealed a strong statistical correlation ($r > 0.5$, $n = 50$, $p < 0.05$) between Incidents in the Workplace and Health or Disease Problems. Based on the findings, suitable intervention plans have been proposed, such as transparency on Incident Reports by Management, quality training for confined space workers, and implementation of an efficient toolbox meeting to assist management in addressing the challenges associated with confined space working practices at GPK.

1. Introduction

The history of the oil and gas industry worldwide began in 1859, when Edwin Drake, an American employed by Pennsylvania Rock Oil Company with cooperation Seneca Oil Company to conduct drilling operations, discovered oil in Pennsylvania [1]. Nevertheless, in Malaysia, it was discovered and drilled in Sarawak in 1910 by Shell, one of the largest oil and gas companies, marking the beginning of the country's oil and gas industry [2]. Prior to 1974, Malaysia's oil and gas sector was managed by the Petroleum Mining Act 1996 (Act 95), which used the concession system to explore and produce petroleum in exchange for royalties and taxes [3]. The oil and gas business is known as risky, with various critical activities clustered as lifting using cranes, hydrostatic, excavations, hot work, and confined spaces. Since the Confined Space Guidelines were initially established in

1998 and followed by the Industry Code of Practice (ICOP) For Safe Working In A Confined Space 2010, incidents involving confined space have kept recurrence and most of the news reported fatal incidents continued to occur with the report revealing that the majority of the victims were fatal. Based on Fig. 1, between the years 2009 and 2019, there have been a total of 46 confirmed occurrences of people losing their lives within confined spaces [4]. Furthermore, according to Fig. 2, asphyxiation, poisoning, engulfment, oxygen deprivation, drowning, explosion, and electrocution are the seven leading causes of fatalities in confined spaces [5]. Then, the existing control measures for confined space work practices in the oil and gas industry were gas tests, medical checks, training, risk assessment, emergency response and preparedness, and permits to work (PTW). Furthermore, accidents that take place in the confined space are caused by the worker's continued exposure to a variety of dangers while they are working in the confined space. Additionally, if rescue operations are conducted without proper training and equipment, not only the workers but also those attempting to save them are exposed to risk. The nature of the working environment in a confined space that is exposed to heat, oxygen-deficient, and contains numerous hazardous gases will affect the physical and mental health of workers while they are performing their jobs there and after they have left. Besides, accidents in confined spaces are also attributable to the employees' lack of physical fitness because management neglected to conduct an employment health screening. So, the objectives of this study were to obtain historical data on confined space incidents and problems that occurred in the oil and gas industry, specifically at Gas Processing Kertih (GPK). Then, this study also analysed the current confined space work practices and implementations at the work site. In addition, this study proposed a new intervention plan to reduce the severity and consequences to the confined space workers and employers.

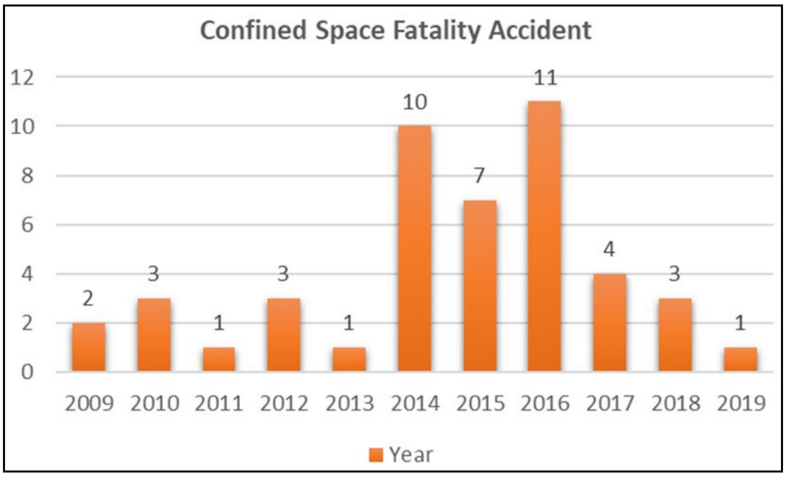

Fig. 1 *Confined space accident cases [4]*

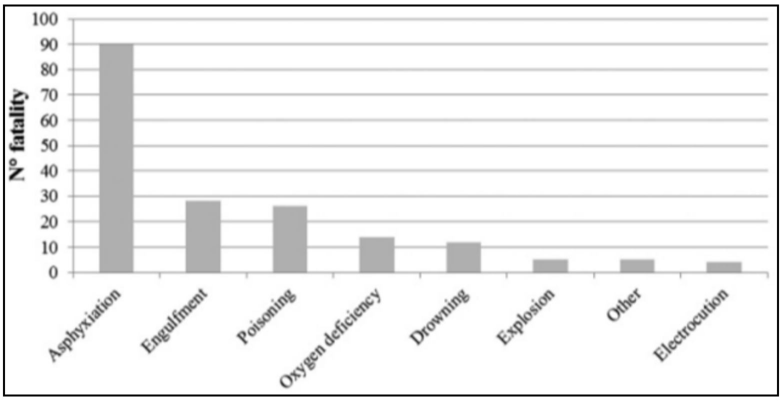

Fig. 2 *Classification of NIOSH confined space accidents according to causes and rate of fatalities [5]*

2. Methods

2.1 Research Design

In this study, a quantitative method was used throughout the data-gathering and analysis stages. The questionnaires were set to be handed out to 50 workers at Gas Processing Kertih. The targeted responders are in a variety of positions, from technician to management. Furthermore, the respondents' educational background, age, and year of service were collected to determine the correlation between their background and the point in question. In addition, it was decided to use the software Statistical Package for Social Sciences to analyse all of the data collected through survey questions.

2.2 Questionnaires

The development of survey questionnaires was influenced by the literature review process of previous researchers who have already pointed out sample questionnaires in their journals, like Ngah et al. [6], who conducted a study on working in confined spaces among male service workers in the central region of Malaysia [6]. The questionnaire was created to be concise, pre-planned, and comprised of a set of questions that would collect specific information that would meet the need for data from studies on a specific topic. In addition, questionnaires should be precise, straightforward, and comprehensible by respondents, not forgetting the appropriate selection of language. The questionnaire is divided into two sections, which are Section A and Section B. Section A gathers all information regarding the respondent's background, including age, position, year of service, and educational background. Section B will be divided into four subsections: Section B (A) to identify the roles and responsibilities of management and department, Section B (B) to identify the worker's behaviour, Section B (C) incident at the workplace; and Section B (D) the disease or health problems related to confined space works. The survey questionnaires will be collected from 50 respondents, all of whom are competent confined space workers at GPK.

2.3 Data Analysis

Statistical Package for the Social Sciences (SPSS) was used to interpret the process of analysing the raw data from the survey questionnaires. SPSS is one of the most widely used statistical software applications that can perform highly complex data manipulation and analysis with straightforward instructions. SPSS is developed and designed for both interactive and non-interactive (batch) applications. SPSS functions include analysing reliability tests, ANOVA, Pearson Correlation, and others [7]. The software improves the entire analysing process and generates more accurate results. However, in this study, the data is assessed using descriptive statistics, one-way ANOVA, Pearson's Correlation, and reliability tests.

3. Result and Discussion

3.1 Respondent Data

The total number of survey questionnaires prepared to collect the data from confined space workers at Gas Processing Kertih (GPK) is N = 50 According to Table 1, the reliability test for the 50 samples with 24 survey questionnaires achieved 0.72 for Cronbach's Alpha and 0.81 for Cronbach's Alpha based on standardized items. This means that the data collected is valid for further analysis and discussion on GPK's confined work practice.

Table 1 *Cronbach's Alpha value for the survey questionnaires*

Cronbach's Alpha	Cronbach Alpha Based on Standardized Items	N of Items
0.723	0.813	24

Fig. 3 illustrates the percentage of respondents' population divided by age categories, position, year of service, and educational background. The age between 26 – 35 years is the dominant group recorded at 54 % of the population, and the lesser group is between 46 – 55 years, which represents 6 %. The age group less than 25 years and between 36 – 45 years recorded the same population, which is 20 %. Next, the non-executive/technician position recorded the highest number of the population, which is 86 %, and executives/engineers recorded 10 % of the population. The least population for positions recorded is management, which is 4 %. Then, the years of service between 6 – 15 years recorded the highest population, which is 46 % and following that is less than five years, which is 38 %. The years of service between 16 – 25 and more than 26 years recorded 10 % and 6 % of the population.

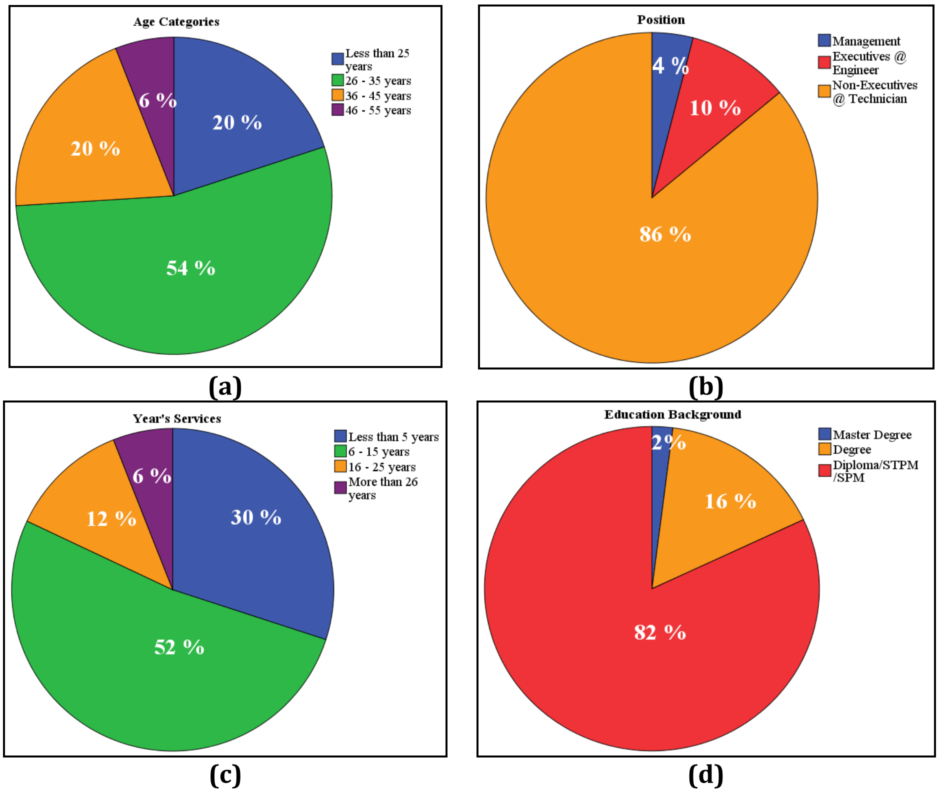

Fig. 3 *Respondent's population divided by (a) age categories; (b) position; (c) year of service; and (d) educational background*

3.2 One-way ANOVA Test Result

Table 2 shows the result of the ANOVA test for age categories regarding confined space works practices. The value of F is 1.136, and the significant value is 0.37. Since the significant value is more than 0.05, the null hypothesis is accepted. As a result, there are no significant differences in respondents' perceptions of confined space working practices between age groups. Table 3 shows the result of the ANOVA test for positions regarding confined space works practices. The value of F is 0.675, and the significant value is 0.82. Since the significant value is more than 0.05, the null hypothesis is accepted. As a result, there are no significant differences in respondents' perceptions of confined space working practices regarding their position, whether management, executives/engineers or non-executives/technicians.

Table 2 *ANOVA test result for age categories regarding confined space works practices*

Age categories	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.038	22	0.684	1.136	0.37
Within Groups	16.242	27	0.602		
Total	31.280	49			

Table 3 *ANOVA test result for respondent's position regarding confined space works practices*

Position	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.038	22	0.184	0.675	0.82
Within Groups	7.342	27	0.272		
Total	11.380	49			

Table 4 shows that the value of F for the year of services is 1.182, and the significant value is 0.33. Since the significant value is more than 0.05, the null hypothesis is accepted. The findings show that there is no significant difference in respondents' perceptions of confined space working practices based on their years of service. In addition, Table 5 shows that the value of F for respondent's education is 0.628 and the significant value is 0.86. Since the significant value is more than 0.05, the null hypothesis is accepted. The findings show that there is no significant difference in respondents' perceptions of confined space working practices based on their education level.

Table 4 *ANOVA test result for respondent's year of services regarding confined space works practice*

Year of services	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.103	22	0.732	1.182	0.33
Within Groups	16.717	27	0.619		
Total	32.820	49			

Table 5 *ANOVA test result for respondent's education background regarding confined space works practice*

Education background	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.383	22	0.154	0.628	0.86
Within Groups	6.617	27	0.245		
Total	10.000	49			

3.3 Pearson's Correlation and Interferential Analysis

To determine the significance of Pearson's Correlation, at least two continuous variables must be correlated. As shown in Table 6, the value of Pearson's Correlation can range from 0.00 (indicating no correlation) to 1.00 (indicating a perfect correlation). Correlations greater than 0.80 are generally found to be strong. It can be seen in the SPSS system.

Table 6 *Correlation strength [7]*

Correlation	Negative	Positive
None	-0.09 to 0.0	0.0 to 0.09
Small	-0.3 to -0.1	0.1 to 0.3
Medium	-0.5 to -0.3	0.3 to 0.5
Strong	-1.0 to -0.5	0.5 to 1.0

3.3.1 Analysis of Organization/Department Roles

Table 7 shows that the value of Pearson Correlation, $r = 0.337$, depicted that Organization/Department Roles and Responsibilities have no relationship with shift work problems. Since $p = 0.017$ is below the significant level, $\alpha = 0.05$, the null hypothesis is unaccepted. Therefore, there is a statistical correlation between Organization/Department Roles and confined space works practices at GPK. Based on the responses, management showed their essential roles and responsibilities in providing all necessary needs to confined space workers to perform their tasks, such as establishing confined space working procedures, reporting incident procedures, conducting HRA, and organizing a meeting to gather feedback from workers after working in confined space.

3.3.2 Analysis of Confined Space Worker's Behaviour

Table 8 shows that the value of Pearson Correlation, $r = 0.221$, depicted that Confined Space Worker's Behaviour has no relationship with shift work problems. Since $p = 0.123$ is greater than the significant level, $\alpha = 0.05$, the null hypothesis is accepted. Therefore, there is no statistical correlation between Confined Space Workers' Behavior and confined space works practices at GPK. Based on the responses from the workers, all respondents follow the working procedures and show good behaviour when working in a confined place. For example, the majority of the respondents are competent and have a certificate to enter and work inside a confined space. State that any workers who need to enter a confined area for work must attend a confined space safety course approved by the Director General and pass an examination to be considered competent. Then, the majority of the respondents also agreed to ensure the confined space rescue equipment and rescue team are on standby all the time, ensure the working procedures are fulfilled, and inform supervisors if the safety equipment is inadequate before starting work [8].

Table 7 *Pearson Correlation between Organization/Department Roles and Confined Space Works Practices*

		Organization/Department Roles	Confined Space Works Practices
Organization/Department Roles	Pearson Correlation	1	0.337*
	Significance (2-tailed)		0.017
	N	50	50
Confined Space Works Practices	Pearson Correlation	0.337*	1
	Significance (2-tailed)	0.017	
	N	50	50

*Correlation is significant at the 0.05 level (2-tailed)

Table 8 *Pearson correlation between Confined Space Workers Behaviour and Confined Space Works Practice*

		Confined Space Workers' Behaviour	Confined Space Works Practices
Confined Space Workers' Behavior	Pearson Correlation	1	0.221*
	Significance (2-tailed)		0.123
	N	50	50
Confined Space Works Practices	Pearson Correlation	0.221	1
	Significance (2-tailed)	0.123	
	N	50	50

3.3.3 Analysis of Incidents at Workplace

Table 9 shows that the value of Pearson Correlation, $r = 0.831$, depicted that Incident at the Workplace has a relationship with confined space works practices. Since $p = 0.000$ is below the significant level, $\alpha = 0.05$, the null hypothesis is unaccepted. Therefore, there is a statistical correlation between incidents at the workplace and confined space work practices at GPK. Based on the response, 16% of respondents claimed to have engaged in an incident at work when working in a confined space. According to the previous study, the most common incidents in a confined area include chemical exposure, getting caught in equipment or machinery, being hit by equipment, falling, etc [9]. Furthermore, there were previous studies that state that the factors that contribute to a confined space incident include failing to recognize the entrance as a confined space, poor risk assessment, inadequate confined space entry training, etc [10].

3.3.4 Analysis of Health/Disease Problems

Table 10 shows that the value of Pearson Correlation, $r = 0.871$, depicted that Confined Space Worker's Behaviour has no relationship with confined space works practices. Since $p = 0.000$ is below the significant level, $\alpha = 0.05$, the null hypothesis is unaccepted. Therefore, there is a statistical correlation between Health/Disease Problems with confined space works practices at GPK. According to responses, 2% of respondents had difficulty breathing when working in a small area, 10% reported hearing problems, and 30% reported discomfort in their limbs. Chemical hazards and gases inside the confined space may have caused breathing difficulties [11]. Furthermore, it could have occurred due to broken or insufficient personal protective equipment (PPE) [12].

Table 9 *Pearson correlation between Incident at the Workplace and Confined Space Works Practices*

		Confined Space Workers' Behaviour	Confined Space Works Practices
Incident at Workplace	Pearson Correlation	1	0.831*
	Significance (2-tailed)		0.000
	N	50	50
Confined Space Works Practices	Pearson Correlation	0.831*	1
	Significance (2-tailed)	0.000	
	N	50	50

*Correlation is significant at the 0.01 level (2-tailed)

Table 10 *Pearson correlation between Health/Disease Problems and Confined Space Works Practices*

		Health/Disease Problems	Confined Space Works Practices
Health Disease Problems	Pearson Correlation	1	0.871*
	Significance (2-tailed)		0.000
	N	50	50
Confined Space Works Practices	Pearson Correlation	0.871*	1
	Significance (2-tailed)	0.000	
	N	50	50

*Correlation is significant at the 0.01 level (2-tailed)

3.4 New Intervention Plans

3.4.1 Transparency on Incident Reports by Management

The safety and well-being of confined space workers are critical in any industrial environment, especially in the oil and gas industry. Implementing an apparent incident reporting system monitored by management is crucial for identifying potential hazards, addressing safety issues, and consistently enhancing confined space work procedures [13]. Through the encouragement of incident and near-miss reporting among workers, management obtains valuable data and information regarding potential risk areas, which encourages the implementation of preventative measures before the incident occurs. Then, the management may implement an anonymous reporting option to encourage workers to report incidents through the proper channels and prevent them from being frightened of doing so. This is due to some workers being hesitant to report accidents because they are concerned about being punished or fired. Furthermore, some workers, particularly those of a younger age or in lower ranks, feel afraid of reporting an accident to their supervisors and superiors. Besides, the management can use the data obtained through the incident reporting system to take action by thoroughly studying and investigating the chronological facts of the case, including the contributing factors, the number of victims, and the damage caused by the incident. Furthermore, management or organizations could share findings from the incidents as an initial step towards raising awareness about the importance of safety while working in confined spaces.

3.4.2 Quality Training

In the dynamic and high-risk environment of the oil and gas industry, confined space workers' safety is essential. This intervention approach focuses on improving safety by implementing a comprehensive and high-quality training programme modified exclusively for oil and gas confined space workers. For example, during confined space entrance programmes, the instructor must ensure that all participants remain focused along the course. It is essential because failure to obtain and understand the input will lead to an incident while working. The previous study stated that one of the factors that led to the incident in a confined space was unsafe acts due to insufficient and inadequate training. The workers often make decision errors, perceptual errors, and routine violations [14]. Furthermore, the enhancement of training for supervisors is necessary to ensure that supervisors are knowledgeable and aware of the risks and harmful conditions that may be present before or during their work in confined spaces. In the context of activities that take place in confined spaces, supervisors are accountable for ensuring that the procedures are adhered to and providing a safe environment in accordance with the requirements of the Permit to Work (PTW) legislation. There are three types of unsafe supervision: insufficient supervision, inappropriately planned activities, and violations of supervisory procedures [14]. In addition, to improve the quality of confined space training, management should utilize current training technology. The technologies include simulation, virtual reality (VR), and the use of drones in limited spaces. According to previous studies, using 3D Virtual Reality (VR) training in confined space could generate different emergency situations that precisely respond to the needs of real-world operators [15]. Then, the training environment is constructed on a 3D Virtual, Immersive, and Interactive Simulation that allows participants to experience a genuine simulation.

3.4.3 Implementation of an Effective Toolbox Meeting

Toolbox meeting is a term used for short and informal safety briefings, procedures that need to be adhered to by the safety officer or safety supervisor of the project before starting the work [16]. Implementing effective toolbox meetings for oil and gas confined space workers is crucial for creating a safe culture and ensuring the workforce's well-being. These regular meetings provide essential opportunities for the sharing of crucial information, covering anything from recent incidents to changes in processes and emergency response procedures. An efficient confined space toolbox meeting will focus on specific topics regarding the work activities that will be performed later inside the confined space. The common highlighted topics during a toolbox meeting included safety precautions, work procedures, activities planned, and hazards present in the confined space. Next, the safety officer must ensure all the workers understand the planned activities, remember the safety precautions, and follow the procedures. To ascertain the workers' comprehension of the previously mentioned details, the safety officer needs to conduct a test by asking each worker assigned to the confined space and requesting that they repeat all the information given during the toolbox meeting. Only workers who possess a comprehensive understanding of the previously mentioned requirements are permitted to participate in work inside the confined space. On the other hand, workers who are unable to recall or comprehend the information delivered at the toolbox meeting are explicitly forbidden from entering and performing tasks inside the confined space.

4. Conclusion

In conclusion, this study successfully fulfilled the first research objective, which was to obtain historical data on confined space incidents and problems that occurred in the oil and gas industry. Based on the response, although the percentage of workers who experienced or saw an incident inside a confined space is 16% and 28%, it still indicates that an incident occurred at GPK. Then, there are certain workers who suffer from a variety of health issues, including 2% having difficulties breathing, 10% having hearing problems, and 30% experiencing limb discomfort. Furthermore, the current confined space works practices and implementation at the worksite are being achieved during the literature review process. It is known that a few intervention plans have been established to minimize and reduce the severity of impacts on confined space workers. In addition, the proposed new intervention plan involves adherence to existing procedures, including quality training for the confined space entry programme, supervisor training to ensure competence, implementation of an efficient toolbox meeting, and transparency of the incident report by management. Overall, all the intervention plans proposed will improve safety environments for the organization and its workers.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

All authors have contributed to this work.

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