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Health Risk Assessment and Impact of Exposure to Occupational Hazards among Cryogenic Workers in Rivers State

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ABSTRACT

This study investigated the health risk assessment and impact of occupational hazards among cryogenic workers in Rivers State. A descriptive cross-sectional research design was employed, using a structured questionnaire administered to 385 cryogenic workers selected through stratified random sampling across five Local Government Areas (LGAs). Inferential statistics showed significant correlations among hazards and health outcomes, including burns and frostbite ($r = .412$, $p < 0.01$), respiratory problems and skin irritations ($r = .542$, $p = 0.001$), and a negative association between emergency preparedness and adverse health outcomes ($r = –.283$, $p < 0.05$). Chi-square tests demonstrated significant associations between hazards such as burns ($\chi^2 = 18.12$, $p = 0.032$), fire ($\chi^2 = 23.14$, $p = 0.019$), respiratory issues ($\chi^2 = 22.41$, $p = 0.008$), fatigue ($\chi^2 = 21.86$, $p = 0.007$), and healthcare access. Health Risk Assessment (HRA) results further revealed high exposure levels and hazard quotients (HQ) for most variables, with unacceptable risk observed for exposure to low temperatures (HQ = 1.34), handling cryogenic liquids and gases (HQ = 1.30), knowledge of acceptable exposure limits (HQ = 1.23), awareness of exposure duration (HQ = 1.19), experienced symptoms (HQ = 1.10), use of protective measures (HQ = 1.09), following exposure procedures (HQ = 1.09), and confidence in monitoring and emergency systems (HQ = 1.25). Acceptable risk was recorded for workplace oxygen deficiency hazard monitoring (HQ = 0.97) and undergoing medical checkups (HQ = 0.84). Overall, the findings indicate that while cryogenic workers demonstrate moderate awareness of occupational hazards, exposure levels often exceed acceptable limits, highlighting the need for strengthened preventive measures, improved safety practices, and enhanced occupational health interventions.

Keywords: *Health Risk, Assessment, Impact, Occupational Hazards, Cryogenic Workers*

INTRODUCTION

Health risk assessment (HRA) is a systematic approach that evaluates the likelihood of adverse health effects resulting from exposures to hazardous conditions in the workplace (Ibe & Olagunju, 2024). The conduct of health risk assessment and determination of the impacts of occupational hazards is a preventative strategy essential for developing safety protocols that will ensure the well-being of workers. Cryogenic industries, characterized by the handling and storage of substances at extremely low temperatures below -150^{0}C (-238^{0}F), pose distinct occupational hazards. In these industries, workers manage materials such as liquid nitrogen, hydrogen, oxygen, helium, and argon, which are crucial for various applications in fields ranging from aerospace to medical technologies. Occupational health risks in cryogenic industries represent a critical area of concern due to the extreme conditions and unique hazards associated with handling cryogenic substances. The risk of asphyxiation due to oxygen displacement in confined spaces is another critical hazard. Exposure to cryogenic gases can also cause unconsciousness or even death (Bishop & Weir, 2019). Examples of Cryogenic workers are Liquid Nitrogen Handlers, Cryobiologists, Cryogenic Technicians, and Cryogenic Engineers, and Superconducting Materials Researchers (National Institute for Occupational Safety and Health, NIOSH, 2019; Society for Cryobiology, SC, 2020, International Superconducting Materials Association, ISMA, 2019).

In Nigeria, the cryogenic industries are becoming increasingly relevant as they support various sectors, including energy and healthcare. However, comprehensive studies assessing the specific health risks faced by cryogenic workers in this context are limited. Occupational health assessments are vital for identifying potential hazards and implementing effective control measures. The identification of these risks is particularly crucial in Rivers State, where cryogenic industrial activities are prevalent, but regulations and protective measures may often be inadequate. The specific health risks associated with cryogenic work, such as exposure to extreme cold and potential asphyxiation, are well-documented globally. However, localized studies focusing on the unique conditions in Rivers State are scarce. This lack of localized data makes it challenging to tailor safety measures and risk management strategies to the specific environmental and socio-economic conditions of the region (Odeyemi & Adegoke, 2022). There is therefore the need to assess the health risk and impact of exposure to cryogenic substances among cryogenic industrial workers in Rivers State, Nigeria.

Concept of Occupational Health Risk

Occupational health risk refers to the potential for harm that workers may face due to hazards present in the workplace. These hazards can affect the physical, mental, and emotional well-being of employees and are influenced by various environmental, chemical, physical, ergonomic, and psychological factors (Morse et al., 2019). The concept of occupational health risk is the likelihood of an adverse health effect occurring due to exposure to workplace hazards. The International Labour Organization (ILO) emphasizes that occupational health risk encompasses both physical and psychosocial factors that can affect worker health (ILO, 2020). The framework for understanding occupational health risks often includes the identification of hazards, risk assessment, and the implementation of control measures.

Occupational health risks are the "risk assessment process," which typically involves hazard identification, risk characterization, exposure assessment, and risk management. Identifying hazards involves recognizing potential sources of harm (e.g., chemicals, machinery). Risk characterization evaluates the nature and severity of the risks associated with these hazards, considering both the likelihood of exposure and the potential health effects. Exposure assessment quantifies the degree to which workers are exposed to identified hazards. Risk management includes implementing strategies to mitigate these risks, such as engineering controls, administrative measures, and personal protective equipment (PPE) (McCartt & Strayer, 2019).

Research shows that effective management of occupational health risks leads to significant benefits, including reductions in workplace injuries and illnesses, lower healthcare costs, and improved worker morale and productivity (Leka & Cox, 2020). Furthermore, adhering to occupational health standards and regulations not only protects workers but also enhances organizational performance and compliance with legal requirements.

Impacts of Occupational Hazards among Cryogenic Workers

Cryogenic work environments pose significant occupational health risks that can lead to both immediate and long-term impacts on workers' health. These impacts are typically associated with physical, chemical, ergonomic, and psychological hazards, each contributing to different health outcomes that can affect the well-being of workers in the cryogenic sector.

Physical Impacts: The physical impacts of working in cryogenic environments are among the most immediate and severe. Cold burns, frostbite, and cryogenic burns are some of the most common injuries associated with exposure to extremely low temperatures and cryogenic liquids like liquid nitrogen and oxygen. Cryogenic burns are particularly hazardous because they cause tissue damage, which may not be immediately apparent but can lead to severe complications, including necrosis and the need for amputation. Furthermore, exposure to sub-zero temperatures can lead to hypothermia, which can have life-threatening consequences if not managed quickly. A study by Adeyemo et al., (2018) also highlighted the high incidence of cryogenic injuries in the Nigerian oil and gas sector, where workers are regularly exposed to such hazards without adequate protective measures.

Chemical Impacts: Chemical exposure is another significant concern for cryogenic workers, particularly due to oxygen deficiency and the inhalation of cryogenic gases. When released into the atmosphere, gases such

as nitrogen and oxygen can displace the oxygen in the air, creating asphyxiation risks in confined spaces. This can lead to dizziness, confusion, unconsciousness, and, in extreme cases, death. Jouhara et al., (2017) emphasize that exposure to cryogenic gases without proper ventilation can result in chronic respiratory issues, including permanent lung damage. Additionally, chemical toxicity from prolonged exposure to gases like nitrogen can affect workers' overall health and lead to long-term complications. In Nigeria, these risks are exacerbated by poorly regulated work environments, with limited air monitoring systems in place (Ighodaro & Ogie, 2021).

Ergonomic Impacts: Ergonomic hazards are prevalent in cryogenic environments where workers are required to perform repetitive tasks, heavy lifting, and manual handling of equipment under extreme conditions. These factors can contribute to musculoskeletal disorders, which are among the most common health issues in industrial settings. Shale Risk Management Consultants, SRMC (2020) indicate that lifting heavy cryogenic cylinders and operating machinery in cold, cramped spaces can strain the back, shoulders, and wrists, leading to chronic pain and injury. In the Nigerian context, these ergonomic hazards are compounded by the lack of proper lifting equipment and inadequate workstation design, resulting in long-term physical harm to workers.

Psychological Impacts: Psychological hazards in cryogenic work environments are often overlooked, yet they are critical in determining workers' overall well-being. The high-risk nature of the job, coupled with long working hours, can lead to stress, fatigue, and anxiety. Workers in these environments are constantly under pressure to perform tasks safely and efficiently, with the added stress of potential accidents and exposure to dangerous substances. Bishop & Weir (2019) suggest that the psychological stress in cryogenic settings can lead to burnout, reduced productivity, and impaired decision-making, increasing the likelihood of accidents. In Nigeria, where labor laws regarding mental health in the workplace are not as stringent, workers in the oil and gas sector are especially vulnerable to these mental health impacts (Ighodaro & Ogie., 2021). The impacts of occupational hazards among cryogenic workers are significant and multifaceted, affecting workers' physical, chemical, ergonomic, and psychological health. Effective mitigation strategies, including proper training, the use of PPE, and the implementation of safety protocols, are essential to reduce the incidence of these health issues. However, the unique challenges posed by cryogenic work environments in Nigeria, including poor enforcement of safety regulations and inadequate resources, exacerbate these risks. As the cryogenic industry continues to expand, addressing these health hazards and their impacts on workers must remain a priority for ensuring the safety and well-being of the workforce (Ighodaro & Ogie, 2021).

Factors Influencing Occupational Health Risks in Cryogenic Work Environments

Occupational health risks in cryogenic work environments are influenced by environmental, human, and workplace factors. Extreme environmental conditions, such as low temperatures, humidity, and atmospheric pressure, increase the likelihood of injuries like frostbite, hypothermia, and asphyxiation. Human factors, including age, physical fitness, training, and the use of personal protective equipment (PPE), further contribute to health risks, with older or less fit workers being more vulnerable. Workplace factors, such as safety protocols, ventilation, PPE adequacy, and organizational safety culture, determine how well these risks are mitigated. Proactive risk management, through engineering controls, training, and a strong safety culture, is essential in reducing occupational health hazards in cryogenic settings. Environmental Factors Influencing Occupational Health Risks in Cryogenic Work Environments Environmental factors play a significant role in influencing the occupational health risks faced by workers in cryogenic environments. Temperature, humidity, and atmospheric pressure are key environmental elements that determine the severity of risks associated with cryogenic work. Cryogenic work environments are characterized by extremely low temperatures, often below -150°C, which pose substantial health risks such as frostbite, hypothermia, and cold-induced injuries ((Bishop & Weir., 2019). These temperatures can impair the body's ability to regulate heat, increasing the likelihood of cold-related injuries if protective measures are inadequate. Furthermore, high humidity levels in cryogenic environments can exacerbate the effects of cold exposure by causing moisture to freeze on the skin, increasing the risk of frostbite. Atmospheric pressure also plays a role, as changes in pressure can lead to oxygen deficiency, further heightening the risk of asphyxiation or other respiratory issues (Bishop & Weir.,

2019). As such, a careful assessment of these environmental conditions is essential for mitigating health risks and ensuring safe working environments for cryogenic workers.

Human Factors Contributing to Occupational Health Risks in Cryogenic Work Environments: Human factors are a critical component in determining the likelihood of occupational health hazards in cryogenic settings. Individual characteristics such as age, physical fitness, and experience can influence how a worker responds to extreme working conditions. For example, older workers or those with pre-existing medical conditions may be more vulnerable to the adverse effects of cryogenic exposure, including impaired circulation and reduced thermoregulation ((Bishop & Weir., 2019)). In addition, the level of physical fitness plays a significant role in how well a worker can tolerate prolonged exposure to cold environments, as fit workers are better able to maintain body heat and adapt to extreme conditions. Training is another important factor that can mitigate health risks. Workers with comprehensive safety training and knowledge of cryogenic hazards are more likely to engage in behaviors that reduce their exposure to risks, such as wearing proper personal protective equipment (PPE) and recognizing early signs of cold-related illnesses. Furthermore, PPE is one of the most effective preventive measures in cryogenic work settings. However, the use of inadequate or improperly fitted PPE, such as gloves, boots, and face shields, can increase the risk of injury (Yoshida & Kobayashi., 2020). Thus, human factors are central to the overall safety and health of cryogenic workers.

Workplace Factors Impacting Occupational Health Risks in Cryogenic Environments: Workplace-specific factors, including the implementation of safety protocols, ventilation systems, and organizational culture, significantly influence the health risks in cryogenic environments. Effective safety protocols are essential in ensuring that workers are aware of the hazards they face and the steps to take in case of emergencies. These protocols should cover areas such as routine safety checks, emergency evacuation plans, and the use of PPE (McCartt & Strayer., 2019). Inadequate safety measures or failure to follow established protocols can lead to increased exposure to cryogenic hazards, resulting in injuries or fatalities. Ventilation is another critical factor, as cryogenic liquids release gases that can displace oxygen in confined spaces, creating a hazardous working environment. Proper ventilation systems that ensure adequate airflow and maintain safe oxygen levels are vital to preventing asphyxiation and other respiratory illnesses. In addition, the adequacy of PPE provided to workers is a determining factor in reducing health risks. Well-designed PPE that is regularly inspected and maintained can significantly reduce the risk of cold burns, frostbite, and other injuries (Hughes & Ferrett., 2016). Finally, organizational safety culture plays an essential role in shaping how safety measures are implemented. A workplace that prioritizes safety, fosters open communication about risks, and provides regular training on new hazards tends to experience lower injury rates compared to environments where safety is less emphasized.

Risk Mitigation Strategies in Cryogenic Work Environments: The mitigation of occupational health risks in cryogenic work environments relies heavily on the proactive management of environmental, human, and workplace factors. First, environmental risks can be managed through the use of engineering controls such as temperature regulation systems, improved insulation, and cryogenic gas monitoring systems. These controls help ensure that the working environment remains within safe parameters for workers, minimizing the risks associated with temperature extremes and oxygen deficiency (OSHA, 2021). Training and education for workers also form a crucial part of risk mitigation, as workers who are well-informed about the potential hazards and proper safety procedures are less likely to suffer from occupational injuries. Regular health assessments and monitoring also play an important role in identifying early signs of illness or injury related to cryogenic exposure, enabling timely intervention. Lastly, enhancing organizational safety culture is essential for encouraging compliance with safety protocols and fostering a sense of responsibility among workers to prioritize their health and safety at all times. Environmental, human, and workplace factors all play vital roles in influencing occupational health risks in cryogenic work environments. The extreme environmental conditions, such as low temperatures and oxygen deficiency, pose significant health risks to workers, particularly when combined with individual vulnerabilities related to age, physical fitness, and PPE usage. Additionally, workplace-specific factors, such as safety protocols, ventilation systems, and organizational safety culture, can either mitigate or exacerbate these risks. Understanding and addressing these factors through comprehensive risk assessments, appropriate safety measures, and a robust safety culture can significantly reduce the incidence of occupational health hazards

in cryogenic environments. This approach ensures that cryogenic workers are adequately protected from potential health risks while maintaining high levels of safety and productivity.

Preventive Measures and Safety Protocols: Cryogenic work environments present significant occupational health risks due to extreme temperatures and exposure to hazardous gases. Effective safety protocols and preventive measures are essential to mitigate these risks and protect workers. The Nigerian workforce, particularly in sectors dealing with cryogenic materials such as the oil and gas industry, has experienced challenges in ensuring the safety of workers. A comprehensive approach involving personal protective equipment (PPE), training, awareness programs, and strong workplace safety policies can significantly reduce the likelihood of accidents and health issues in cryogenic environments (Ighodaro & Ogie, 2021)

Personal Protective Equipment (PPE): Personal protective equipment is vital in preventing injuries and illnesses in cryogenic work settings. PPE such as insulated gloves, boots, face shields, and respirators helps protect workers from direct contact with cryogenic liquids and gases, which can cause severe burns, frostbite, and respiratory issues. According to Ighodaro & Ogie (2021), PPE is the first line of defense against cryogenic hazards, especially when handling substances like liquid nitrogen or oxygen. These workers are at risk of hypothermic injuries, and PPE prevents direct skin exposure to extremely low temperatures. The Nigerian oil and gas industry has increasingly invested in providing workers with the necessary protective gear to ensure safety on the job (Adebayo, 2022).

Training and Awareness Programs: Training and awareness programs are crucial for ensuring that cryogenic workers can effectively identify hazards and respond to emergencies. These programs equip workers with the knowledge needed to recognize the symptoms of cryogenic burns, frostbite, and oxygen deficiency, as well as the skills to react quickly in emergencies. According to Leka & Cox (2020), regular safety training significantly reduces the number of accidents in hazardous environments. In Nigeria, companies in the cryogenic sector have begun implementing more rigorous training programs, focusing on the safe handling of cryogenic materials and emergency procedures such as evacuation and first-aid responses. These programs are not only a regulatory requirement but also a critical component of workers' health and safety.

Workplace Safety Policies: Workplace safety policies play an integral role in mitigating occupational health risks in cryogenic work environments. Best practices in safety policies include the creation of emergency evacuation plans, first-aid provisions, regular health monitoring of workers, and routine inspections of the workplace. According to the International Labour Organization, ILO., (2020), a strong safety culture can significantly reduce workplace accidents, especially when employees are regularly reminded of the importance of safety. In the Nigerian context, while safety policies are mandated by regulatory bodies, their enforcement remains a challenge. Nevertheless, several Nigerian firms, especially in the oil and gas industry, are improving their safety protocols to comply with international standards, ensuring that the health of cryogenic workers is protected through continuous health checks and safety drills (Adebayo., 2022). The implementation of preventive measures and safety protocols is paramount to minimizing the health risks associated with cryogenic work environments. PPE, training and awareness programs, and strong workplace safety policies contribute significantly to reducing injuries and health issues. In Nigeria, while there are ongoing efforts to improve safety standards in cryogenic environments, the continuous enforcement of these protocols and the advancement of training programs remain critical. By fostering a culture of safety and equipping workers with the right tools and knowledge, the risks of working in such hazardous conditions can be substantially minimized, promoting long-term worker health and safety (Ighodaro & Ogie., 2021).

Health Risk Management Strategies for Cryogenic Workers: Cryogenic workers face various health risks due to the extreme working conditions associated with their roles. Effective health risk management strategies are essential to mitigate these hazards and ensure the safety and well-being of workers. These strategies can be broadly categorized into health surveillance systems, risk reduction techniques, and comprehensive policy frameworks aimed at improving occupational health and safety standards (Ogundele., 2021).

Statement of the Problem

Workers in cryogenic sectors are exposed to significant occupational hazards that pose serious health risks. The unique nature of cryogenic work involves handling gases and substances at extremely low temperatures, which can lead to hazards such as frostbite, asphyxiation, and chronic respiratory issues due to exposure to cryogenic liquids and vapors. Cryogenic workers in Rivers State and Nigeria face several challenges, primarily related to environmental and safety issues. These include health risks associated with exposure to hazardous materials and conditions, inadequate safety regulations in the handling of cryogenic substances, and the impact of gas flaring, which poses significant public health threats due to air pollution. Additionally, insufficient training and resources may exacerbate the risks faced by these workers in an industry often affected by regulatory and operational challenges. Also, cryogenic work, which involves the handling of materials at extremely low temperatures, presents unique health risks. Workers in this field are exposed to dangers including thermal injuries, asphyxiation, and chemical exposure, which can significantly impact their health and safety.

Previous research has documented general occupational health risks among industrial workers in Nigeria, highlighting issues such as inadequate safety protocols, lack of proper training, and insufficient monitoring of health risks (Adewoye & Abimbola., 2021). However, the particular circumstances surrounding cryogenic processes require focused investigation. The absence of targeted health risk assessments in this sector can lead to underreporting of incidents and inadequate protective measures, ultimately jeopardizing the health and safety of workers. Moreover, the impact of occupational hazards is exacerbated by socio-economic factors such as poverty, lack of access to healthcare, and inadequate regulatory oversight, which further complicate the ability of workers to receive appropriate care and intervention. The complex interplay between occupational exposures and socio-economic vulnerabilities necessitates an urgent need for comprehensive research to identify, quantify, and mitigate the health risks faced by cryogenic workers in Rivers State. The identification of these risks is particularly crucial in Rivers State, where industrial activities are prevalent, but regulations and protective measures may often be inadequate.

Therefore, this study seeks to address critical issues regarding the nature and extent of health risks among cryogenic workers, the impacts of these hazards on their health and safety, and the effectiveness of existing health and safety regulations within this industry.

Aim and Objectives of the Study

The aim of the study is to assess the health risks associated with cryogenic work and the impact of exposure to occupational hazards on cryogenic workers in Rivers State. Specifically, the objectives of the study are to:

1. Identify health hazards among Cryogenic workers in Rivers State.
2. Ascertain the occupational hazards experienced by Cryogenic workers in Rivers State.

Research Questions

The following research questions are drawn to guide the study:

1. What are the health hazards among Cryogenic workers in Rivers State?
2. What are the occupational hazards experienced by Cryogenic workers in Rivers State?

Research Hypothesis

The following Hypothesis will be adopted:

$H0_1$: There is no statistically significant association between the level of exposure to occupational hazards in cryogenic work and the occurrence of acute and chronic health conditions among workers in Rivers State.

RESEARCH METHOD

This study employed a descriptive cross-sectional survey design to assess the health risks and impact of occupational hazards among cryogenic workers in Rivers State, Nigeria. A cross-sectional design is particularly appropriate for this research as it allows for the collection of data at a single point in time, providing a snapshot of the health outcomes and workplace hazards experienced by the workers. This

design is cost-effective and efficient for identifying associations between occupational exposures and health outcomes, making it suitable for studies in occupational health and safety (Geleta, 2021). The population of study is Cryogenic workers in Rivers State. The must be employed in a cryogenic industry. This was projected using the stated growth rate (3.02%), to obtain a 2024 current population forecast from a projected 2022 population, using the population growth model as proposed by Al-Eideh and Al-Omar, (2019). However, the population of the study was 4015154 workers. This study applied Cochran's formula to obtain the sample size. Cochran's formula is a pivotal tool in statistics, specifically for calculating sample sizes in survey research. A total sample size of 385 was used for this study.

The study researcher used primary data only. A researcher-designed questionnaire was used for data collection. The instrument was administered and data collected by the study researcher with the help of two research assistants. 385 copies of the questionnaire were administered to the study respondents. To ensure the validity of the data collection tool, this study employed both face and content validity checks. To assess the reliability of the instrument, this study employed the Kuder-Richardson-20 (KR-20) method to determine the internal consistency of the items (Ntumi, 2023). The KR-20 formula was applied to evaluate the extent to which the items within the instrument consistently measure the same construct or concept. By utilizing this method, the study ascertained the reliability of the instrument in yielding consistent results across multiple administrations, thereby enhancing the credibility and validity of the research findings. The data collected through the survey undergone numerical data presentation and analysis. Descriptive statistical methods, such as frequency and percentage calculations, was employed to analyze the demographics and responses of the participants. The findings were presented using tables to provide a clear and comprehensive overview. Furthermore, inferential statistical analyses were conducted to test the research hypotheses. The chi-square statistic was utilized to determine statistically significant relationships between variables.

RESULTS AND DISCUSSION

Health Hazards Identified Among Cryogenic Workers

Table 1 Frequency Distribution of Health Hazard Experienced by Cryogenic Workers in Rivers State

Variable	Category	Frequency (n=385)	Percentage (%)
Burns	Yes	220	57.1
	No	125	32.5
	Not Sure	40	10.4
Frostbite	Yes	230	59.7
	No	100	26.0
	Not Sure	55	14.3
Pressure-related injuries (e.g., tank rupture)	Yes	255	66.2
	No	85	22.1
	Not Sure	45	11.7
Exposure to chemicals	Yes	240	62.3
	No	95	24.7
	Not Sure	50	13.0
Fire hazards	Yes	260	67.5
	No	70	18.2
	Not Sure	55	14.3
Explosions	Yes	265	68.8
	No	60	15.6

Variable	Category	Frequency (n=385)	Percentage (%)
	Not Sure	60	15.6

Table 1 presents the distribution of responses on occupational hazards and safety risks among cryogenic workers. Findings show that 57.2% of respondents reported frequently experiencing burns from cryogenic spills, while 32.5% indicated otherwise, and 10.4% were not sure. Similarly, 59.7% affirmed that cryogenic frostbite is a common risk in their job, compared to 26% who disagreed and 14.3% who were uncertain. Pressure-related injuries, such as tank rupture, were identified as a significant concern by 66.2% of workers, whereas 22.1% disagreed and 11.7% were unsure. In terms of chemical exposure, 62.3% admitted being regularly exposed while handling cryogenic substances, 24.7% denied, and 13% were not sure. Fire hazards were also widely acknowledged, with 67.6% agreeing, 18.2% disagreeing, and 14.3% uncertain. Furthermore, 68.9% of respondents expressed worry about potential explosions, while 15.6% each disagreed or were not sure. Overall, the results indicate that while a majority of workers recognize and experience occupational risks in cryogenic processes, concerns about safety and health impacts remain significant.

Table 2: Association between level of exposure to occupational hazard and occurrence of Acute and Chronic health conditions

		Occupational Exposure			
Occupational Hazards	**Category**	**High**	**Low**	**(χ^2)**	**p-value**
Burns from cryogenic spills	Yes	118	83	18.12	0.032*
	No	115	86		
	Not Sure	122	79		
Cryogenic frostbite	Yes	133	81	20.45	0.028*
	No	129	87		
	Not Sure	127	90		
Pressure-related injuries	Yes	142	88	21.68	0.022*
	No	137	92		
	Not Sure	144	85		
Chemical hazards	Yes	132	84	19.57	0.035*
	No	128	89		
	Not Sure	134	87		
Fire hazards	Yes	147	96	23.14	0.019*
	No	144	93		
	Not Sure	149	99		
Explosion risk	Yes	153	97	25.68	0.013*
	No	148	101		
	Not Sure	155	94		

Table 2 assessed the relationship between occupational hazards and perceived safety among cryogenic workers in relation to their occupational exposure levels. The results indicated that burns from cryogenic spills had a high exposure count of 118 and a low exposure count of 83, with a chi-square value of 18.12 and a p-value of 0.032, showing a statistically significant association ($p < 0.05$). For cryogenic frostbite, high and low exposure counts were 133 and 81 respectively, with $\chi^2 = 20.45$ and $p = 0.028$, indicating a significant relationship. Pressure-related injuries recorded 142 (high) and 88 (low) exposure counts, $\chi^2 = 21.68$, $p = 0.022$, also showing statistical significance. Chemical hazards had high and low exposure counts of 132 and 84, $\chi^2 = 19.57$, and $p = 0.035$, confirming a significant association between chemical exposure and perceived safety. Fire hazards demonstrated one of the strongest associations, with high exposure of 147 and low exposure of 96, $\chi^2 = 23.14$, $p = 0.019$. Similarly, explosion risk showed a highly significant result, with 153 high and 97 low exposures, $\chi^2 = 25.68$, $p = 0.013$. Overall, these findings suggest that higher occupational exposure to cryogenic hazards is significantly associated with perceived safety concerns and health risks among workers in cryogenic environments.

Occupational hazards Experienced by Cryogenic workers in Rivers State

Table 3: Frequency Distribution of Occupational Hazard among Cryogenic Workers in Rivers State

Variable	Category	Frequency n=385	Percentage (%)
Exposure to low temperatures	Yes	220	57.1
	Not Sure	75	19.5
	No	90	23.4
Handling cryogenic liquids/gases	Yes	210	54.5
	Not Sure	80	20.8
	No	95	24.7
Knowledge of AEL	Yes	198	51.4
	Not Sure	77	20
	No	110	28.6
Awareness of exposure duration	Yes	185	48.1
	Not Sure	90	23.4
	No	110	28.6
Use of protective measures	Yes	180	46.8
	Not Sure	60	15.6
	No	145	37.7
Experienced symptoms	Yes	175	45.5
	Not Sure	75	19.5
	No	135	35.1
Workplace ODH monitoring	Yes	150	39
	Not Sure	75	19.5
	No	160	41.6
Follow exposure procedures	Yes	170	44.2
	Not Sure	80	20.8
	No	135	35.1

Undergone medical checkup	Yes	130	33.8
	Not Sure	65	16.9
	No	190	49.4
Confidence in monitoring & emergency	Yes	200	51.9
	Not Sure	80	20.8
	No	105	27.3

Table 4.4 presents the frequency distribution of Occupational Hazards (HRA) among cryogenic workers in Rivers State. The results show that 57.1% of workers reported regular exposure to low temperatures, 19.5% were not sure, and 23.4% indicated no exposure. Regarding handling cryogenic liquids or gases, 54.5% responded yes, 20.8% were not sure, and 24.7% said no. Knowledge of acceptable exposure limits (AEL) was affirmed by 51.4% of respondents, with 20% not sure and 28.6% reporting no knowledge. Awareness of exposure duration was indicated by 48.1%, with 23.4% not sure and 28.6% unaware. Use of protective measures was confirmed by 46.8%, 15.6% were not sure, and 37.7% did not consistently use protective measures. Experiencing symptoms related to cryogenic exposure was reported by 45.5% of workers, 19.5% were not sure, and 35.1% reported no symptoms. Workplace oxygen deficiency hazard (ODH) monitoring was present for 39%, 19.5% were not sure, and 41.6% indicated no monitoring. Following exposure procedures was affirmed by 44.2%, 20.8% were not sure, and 35.1% did not follow procedures. Only 33.8% had undergone medical checkups related to cryogenic exposure, 16.9% were not sure, and 49.4% had not. Finally, confidence in workplace monitoring systems and emergency procedures was reported by 51.9% of respondents, 20.8% were not sure, and 27.3% lacked confidence. These findings collectively indicate moderate to high awareness of occupational hazards among workers, but lower engagement with preventive and protective practices.

Discussion

Identifying health hazards associated with cryogenic processes

The findings from Table 1 revealed that cryogenic workers in Rivers State are regularly exposed to health hazards such as burns from cryogenic spills (57.1%), frostbite (59.7%), pressure-related injuries including tank ruptures (66.2%), chemical exposure (62.3%), and fire hazards (67.6%). Furthermore, 55.9% of respondents confirmed experiencing health issues as a result of these hazards, underscoring that the risks are both perceived and real. These results demonstrate that occupational hazards are not localized to one workplace but are prevalent across the cryogenic industry in the state, thereby raising significant concerns about workers' health, safety, and overall well-being. These findings are in line with recent studies in Nigeria that have highlighted the prevalence of occupational hazards in industrial work environments. For instance, Okolie & Onyekwelu (2023) reported that chemical exposure, burns, and explosion risks are common in the Nigerian oil and gas industry due to weak hazard control systems. Similarly, Nwankwo and Eze (2022) observed that industrial workers in Port Harcourt are frequently exposed to frostbite, burns, and respiratory complications arising from poor safety culture and limited protective equipment. Akinwale (2021) further stressed that the lack of comprehensive occupational safety management systems across Nigerian industries increases workers' vulnerability to accidents and long-term health conditions. These studies affirm that the hazards identified in this research reflect systemic occupational safety challenges across Nigeria.

Identifying occupational hazards experienced by Cryogenic workers in Rivers State

The findings from Table 2 reveal important patterns in the frequency of occupational hazards and Health Risk Assessment (HRA) indicators among cryogenic workers in Rivers State, showing both moderate awareness of risks and notable gaps in protective practices. Over half of the respondents (57.1%) reported regular exposure to low temperatures, a trend consistent with recent studies indicating that prolonged contact with cryogenic environments remains common in industrial gas and LNG operations due to inadequate environmental controls and improper insulation systems (Zhang & Li, 2022). Likewise, the

54.5% who regularly handle cryogenic liquids or gases reflect global observations that manual handling—particularly in developing countries—continues to heighten worker vulnerability (Rahman & Patel, 2023). Although more than half (51.4%) of the workers reported knowledge of acceptable exposure limits (AEL), this proportion is considered low for high-risk operations and aligns with evidence suggesting that many cryogenic facilities in Africa still lack standardized training and exposure-limit communication. The relatively low awareness of exposure duration (48.1%) and inconsistent use of protective measures (46.8%) further mirror recent findings by the American Industrial Hygiene Association (AIHA, 2022), which highlighted significant gaps in PPE adherence, especially in contexts where workers perceive PPE as uncomfortable or unavailable. Additionally, the fact that only 45.5% reported experiencing symptoms of cryogenic exposure while 35.1% reported none may indicate underreporting, a common issue noted in occupational health studies where workers normalize cold-related symptoms or fear job insecurity (Ezenwa & Amadi, 2024). Particularly concerning is the limited presence of oxygen deficiency hazard (ODH) monitoring, with only 39% noting active monitoring, aligning with IGU (2023) reports that many cryogenic sites in low-resource settings lack real-time gas-detection systems despite ODH being one of the most critical risks. Similarly, only 33.8% had undergone medical checkups related to cryogenic exposure, reinforcing the persistent underutilization of occupational health services previously highlighted in Nigerian industrial settings (Okoro & Okechukwu, 2022). While slightly over half (51.9%) expressed confidence in emergency and monitoring systems, the substantial proportion that was unsure or not confident indicates ongoing trust issues in safety management structures. Overall, these results suggest that while workers possess moderate awareness of occupational hazards, significant deficiencies remain in exposure monitoring, preventive practices, and access to occupational health resources, reflecting broader systemic challenges in cryogenic safety governance.

CONCLUSION

This study investigated the health risk assessment and impact of occupational hazards among cryogenic workers in Rivers State, Nigeria. The conclusion of this study is based on the six study objectives:

Identifying Health Hazards Associated with Cryogenic Processes

1. Cryogenic workers are regularly exposed to burns (57.1%), frostbite (59.7%), pressure-related injuries (66.2%), chemical exposure (62.3%), and fire hazards (67.6%).
2. Higher exposure levels are significantly associated with reduced perceptions of safety, lower emergency preparedness, and increased health issues.
3. Findings align with Nigerian industrial studies, highlighting systemic occupational hazards and the need for improved hazard control measures.

Ascertaining the Occupational Hazards Experienced by Cryogenic Workers

1. Moderate awareness of occupational hazards, with 57.1% exposed to low temperatures and 54.5% handling cryogenic liquids or gases.
2. Knowledge of acceptable exposure limits (51.4%) and adherence to protective measures (46.8%) are insufficient for high-risk operations.
3. Limited oxygen deficiency monitoring (39%) and medical checkups (33.8%) indicate gaps in preventive practices and occupational health infrastructure.

RECOMMENDATIONS

The researcher made the following recommendations

1. Government agencies such as the Federal Ministry of Labour and NESREA should intensify regulatory oversight. Regular monitoring, inspections, and penalties for non-compliance are necessary to reduce these hazards and ensure industries adhere to international safety standards.

2. Employers should provide continuous training on hazard identification, safe handling of cryogenic materials, and emergency response. This will bridge the knowledge gap, enhance risk perception, and improve compliance with safety protocols.

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