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Perceived Influence of Health Risk Assessment on Exposure to Occupational Hazards among Cryogenic Workers in Rivers State

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ABSTRACT

This study examined perceived influence of health risk assessment on 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 the study area. Results indicated frequent exposure to burns (57.2%), frostbite (59.7%), pressure-related injuries (66.2%), chemical exposure (62.3%), and fire hazards (67.6%), with 55.9% reporting work-related health issues. Descriptive findings further revealed high prevalence of respiratory problems (59.7%), skin irritations (57.1%), headaches (52%), neurological symptoms (52%), fatigue (57.2%), and overall health decline (54.6%). Inferential statistics showed significant correlations among 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 ($r = –.283$, $p < 0.05$). 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: *Perceived, Influence, Health Risk, Assessment, 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 (Hoffman, 2019). 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 (De Pasquale, 2020). 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. 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).

Workers are at risk of developing chronic respiratory issues, circulatory problems, and other cold-related health conditions. Long-term exposure to cryogenic environments without adequate protection can lead to chronic health issues, including respiratory problems, circulatory disorders, and musculoskeletal injuries due to the harsh working conditions (O'Hara, Goodman and Nelson, 2020). The specific socio-economic and environmental conditions in Rivers State, including high humidity and fluctuating temperatures, can further complicate the health risks faced by cryogenic workers. Globally, the management of these hazards is guided by comprehensive safety standards and regulations. In United State, the Occupational Safety and Health Administration (OSHA) mandates rigorous safety protocols for handling cryogenic liquids, including specific guidelines for personal protective equipment (PPE) and emergency response procedures (OSHA, 2021). Similarly, the European Unions Chemical Agents Directives (98/24/EC) requires detailed risk assessments and the implementation of safety measures for the handling of hazardous chemicals, including cryogenic materials (European Commission., EC, 2020).

Advanced safety practices are evident in various developed countries. For instance, in the Netherlands, stringent regulations and comprehensive training programs have been effective in minimizing workplace accidents related to cryogenic substances (Van Hirtum, Bekkering, & Molenaar, 2019). In Japan, industries standards and safety measures are rigorously enforced, resulting in a relatively low incidence of cryogenic-related accidents. In society today, 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. 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. 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 (Hägg, Laitinen, Paakkonen & Reiman (2021).

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. Furthermore, adhering to occupational health standards and regulations not only protects workers but also enhances organizational performance and compliance with legal requirements (Koh, 2023).

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 (McLaughlin, Jones & Roberts, 2020). 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 (Koh, 2023). 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 (Hägg et al., 2021). 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 (Odeyemi & Adegoke., 2022). 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 (Nguyen, et al., 2021).

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 (McLaughlin et al., 2020). 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 (Ogundele, 2021).

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).

Impact of Occupational Hazards on Worker Productivity and Well-being

The impact of occupational hazards in cryogenic environments extends beyond the physical and psychological effects on workers, significantly affecting their productivity, economic well-being, and overall quality of life. Understanding how these hazards influence workplace efficiency and the broader social implications for workers is essential for implementing effective safety measures and improving the conditions of cryogenic work environments.

Productivity Loss: Occupational health issues arising from exposure to cryogenic hazards directly influence worker productivity. Injuries such as cryogenic burns, frostbite, and musculoskeletal disorders caused by repetitive tasks or heavy lifting can lead to significant time off work, reducing the overall efficiency of workers (SRMC., 2020). In extreme cases, such injuries may result in long-term disabilities that prevent workers from returning to their previous roles, further exacerbating productivity loss (Ighodaro & Ogie., 2021). Additionally, workers who remain on the job but suffer from fatigue or stress may experience diminished performance, making them more prone to errors, which increases the likelihood of accidents and reduces operational efficiency (Bishop & Weir, 2019). A study by Morse et al., (2019) highlights that occupational health problems in high-risk environments like cryogenics lead to reduced output and higher accident rates, thus negatively impacting the entire workforce.

Economic Impact: The economic impact of occupational hazards is felt both by workers and employers. For workers, the medical costs associated with treating injuries, such as cryogenic burns or respiratory problems from exposure to cryogenic gases, can be substantial. In addition to direct medical expenses, workers may also experience a loss of income due to illness or injury-related absenteeism (McLaughlin et al., 2020). Employers, too, bear the financial burden through compensation claims, insurance premiums, and the cost of hiring and training replacements. According to Yoshida & Kobayashi (2020), the indirect costs of workplace accidents, such as damage to equipment or loss of productivity during recovery periods, can significantly affect an organization’s bottom line. Moreover, employers must invest in regular safety training and equipment to prevent injuries, further increasing operational costs. These economic implications underscore the importance of proactive safety measures and worker health management.

Worker Well-being and Quality of Life: The impact of cryogenic work hazards also extends to the broader social and emotional aspects of workers' lives. Physical injuries and chronic health issues, such as musculoskeletal disorders or respiratory conditions, can have long-lasting effects on a worker's quality of life. Workers may experience persistent pain, limited mobility, or decreased ability to engage in everyday activities, which can strain family relationships and social participation (SRMC., 2020). Furthermore, psychological stress caused by high-risk working conditions and long hours can lead to mental health challenges, including anxiety, depression, and burnout. These issues can, in turn, affect workers’ social interactions, leading to isolation and reduced social support (Bishop & Weir., 2019). For workers in Nigeria’s cryogenic and industrial sectors, these problems are compounded by a lack of comprehensive healthcare and mental health support services, as well as insufficient attention to work-life balance, which worsens their overall well-being (Ighodaro & Ogie., 2021).

The occupational hazards associated with cryogenic work environments not only threaten the immediate health and safety of workers but also have far-reaching effects on their productivity, economic stability, and overall quality of life. Understanding these impacts is critical for developing more effective safety measures and workplace policies aimed at mitigating these risks. Addressing these issues can reduce productivity losses, limit economic burdens on both workers and employers, and improve the well-being of cryogenic workers, ultimately benefiting the broader workforce and society.

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. Health Surveillance Systems: Health surveillance

systems are crucial in identifying early signs of work-related health issues before they escalate into severe conditions. Routine medical checks are necessary to monitor the workers' health status and ensure they are not suffering from cold-induced injuries, such as frostbite or cryogenic burns, which require immediate attention (Adebayo & Dada, 2021). For example, wearable temperature monitoring devices can be used to continuously track body temperature, preventing hypothermic conditions (Williams, Olugbenga & Adewale, 2020). Additionally, temperature regulation devices and personal monitoring systems help mitigate exposure to extreme cold and oxygen-deprived environments. In cases where injury does occur, rapid access to medical care is vital to address acute conditions and reduce the long-term effects of exposure.

Risk Reduction Strategies: To reduce the exposure to occupational hazards in cryogenic environments, a combination of engineering controls, administrative procedures, and physical modifications to the workplace is essential. Engineering controls such as enhanced ventilation and cryogenic gas detection systems can ensure air quality and reduce the risk of oxygen deficiency. Ventilation systems work to disperse harmful gases, preventing accumulation to dangerous levels in confined spaces. Administrative controls, like instituting mandatory rest periods and regulating work shifts, also play a critical role in reducing physical and mental stress that could contribute to workplace accidents (Oluwaseun, Adeyemi & Chukwudi, 2020). Furthermore, physical environment modifications, such as ergonomic workstation designs and temperature-controlled equipment, help minimize the physical strain on workers, thereby reducing the risk of musculoskeletal injuries.

Policy Recommendations: At the organizational and national levels, there is a need for clear and enforceable health and safety policies to protect cryogenic workers. Organizations should establish a safety culture that prioritizes employee well-being, integrating safety protocols into everyday operations. Regular safety training should be mandatory for all workers to ensure that they are well-prepared to handle emergency situations, such as cryogenic gas leaks or accidents involving liquid nitrogen (Ibrahim & Adebayo, 2021). Government regulations should focus on enforcing occupational health and safety standards and ensuring that workers have access to health insurance and compensation for work-related injuries. Additionally, policies should require regular health monitoring and workplace safety audits to identify potential risks and address them before they result in harm to employees (Adebayo & Dada., 2021).

Health risk management strategies are essential in cryogenic work environments to protect workers from the adverse effects of exposure to hazardous conditions. Through regular health surveillance, risk reduction strategies, and the enforcement of comprehensive safety policies, both employers and governments can significantly reduce the risks associated with cryogenic work. By focusing on worker health and safety, these measures will not only improve the well-being of cryogenic workers but also contribute to enhanced productivity and a safer working environment.

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, Nigeria. Specifically, the objectives of the study are to:

1. Examine the occupational safety practices among cryogenic workers in Rivers State.
2. Determine health Risk Assessment Indices among Cryogenic workers in Rivers State.

Research Questions

The following research questions are drawn to guide the study:

1. What are the occupational safety practices among Cryogenic workers in Rivers State?
2. What are the health Risk Assessment Indices among Cryogenic 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. 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 Johnson & Umoren (2018). 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. 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

Research Question 1: Occupational Safety Practices Among Cryogenic Workers

Table 1: Frequency Distribution of Occupational Safety Practices among Cryogenic Workers in Rivers State.

Variable	Category	Frequency (n=385)	Percentage (%)
I receive adequate orientation on cryogenic safety before performing any task.	Yes	220	57.1
	Not Sure	40	10.4
	No	125	32.5
Safety protocols for managing cryogenic materials are clearly communicated in my workplace.	Yes	215	55.8
	Not sure	35	9.1
	No	135	35.1
I am provided with appropriate PPE specifically designed for cryogenic operations.	Yes	225	58.4
	Not Sure	30	7.8
	No	130	33.8
The safety equipment available to me is sufficient for protection against cryogenic hazards.	Yes	210	54.5
	Not Sure	40	10.4
	No	135	35.1
Emergency procedures for cryogenic incidents are clearly explained and practiced regularly.	Yes	220	57.1
	Not Sure	35	9.1
	No	130	33.8
Training sessions on proper use and maintenance of cryogenic safety equipment are conducted regularly.	Yes	215	55.8
	Not Sure	40	10.4
	No	130	33.8
I am confident in responding to emergency situations involving cryogenic materials.	Yes	210	54.5
	Not Sure	35	9.1
	No	140	36.4
Safety drills related to cryogenic hazards (e.g., equipment failure, temperature leaks) are held consistently.	Yes	215	55.8
	Not Sure	35	9.1
	No	135	35.1
Management actively promotes and supports a strong safety culture in the workplace.	Yes	220	57.1
	Not Sure	35	9.1
	No	130	33.8
I receive training on environmentally safe disposal methods for cryogenic waste.	Yes	225	58.4
	Not Sure	35	9.1
	No	125	32.5

The results in Table 1 indicate that occupational safety practices among cryogenic workers in Rivers State are moderately observed, with over half of respondents reporting positive engagement with safety measures. Specifically, 57.1% of workers indicated that they receive adequate orientation on cryogenic safety before performing tasks, while 10.4% were unsure and 32.5% reported no such training. Safety protocols for managing cryogenic materials were clearly communicated to 55.8% of workers, with 9.1% unsure and 35.1% disagreeing. Access to appropriate personal protective equipment (PPE) designed

for cryogenic operations was affirmed by 58.4% of respondents, 7.8% were not sure, and 33.8% reported insufficient PPE. Slightly lower proportions reported that available safety equipment was sufficient to protect against cryogenic hazards (54.5% yes, 10.4% not sure, 35.1% no). Emergency procedures were clearly explained and practiced regularly according to 57.1% of workers, with 9.1% unsure and 33.8% reporting otherwise. Regular training on the use and maintenance of cryogenic safety equipment was confirmed by 55.8% of respondents, with 10.4% unsure and 33.8% not receiving training. Confidence in handling cryogenic-related emergencies was expressed by 54.5%, while 9.1% were unsure and 36.4% lacked confidence. Safety drills were regularly conducted according to 55.8% of respondents, with 9.1% unsure and 35.1% reporting irregular drills. Management's commitment to maintaining a strong safety culture was acknowledged by 57.1%, with 9.1% unsure and 33.8% perceiving inadequate support. Finally, training on environmentally safe disposal of cryogenic waste was reported by 58.4% of workers, 9.1% were unsure, and 32.5% did not receive such training. Overall, these findings suggest that while a majority of cryogenic workers engage in safety practices, there remain notable gaps in training, equipment adequacy, emergency preparedness, and management support that could impact effective occupational hazard mitigation.

Table 2: Health Risk Assessment Indices

SN	Variable	Exposure Level (Weighted Score)	HQ (Exposure / AEL)	Risk Characterization
1	Exposure to low temperatures	1.34	1.34	Unacceptable risk
2	Handling cryogenic liquids/gases	1.3	1.3	Unacceptable risk
3	Knowledge of AEL	1.23	1.23	Unacceptable risk
4	Awareness of exposure duration	1.19	1.19	Unacceptable risk
5	Use of protective measures	1.09	1.09	Unacceptable risk
6	Experienced symptoms	1.1	1.1	Unacceptable risk
7	Workplace ODH monitoring	0.97	0.97	Acceptable risk
8	Follow exposure procedures	1.09	1.09	Unacceptable risk
9	Undergone medical checkup	0.84	0.84	Acceptable risk

10	Confidence in monitoring & emergency	1.25	1.25	Unacceptable risk

Table 2 presents the Health Risk Assessment (HRA) indices for cryogenic workers in Rivers State, showing both exposure levels and hazard quotients (HQ) for ten key variables. Exposure to low temperatures recorded a weighted score of 1.34 and an HQ of 1.34, indicating unacceptable risk, while handling cryogenic liquids and gases had a weighted score of 1.30 and an HQ of 1.30, also representing unacceptable risk. Knowledge of acceptable exposure limits (AEL) scored 1.23 (HQ = 1.23) and awareness of exposure duration scored 1.19 (HQ = 1.19), both classified as unacceptable risk. Use of protective measures had a score of 1.09 (HQ = 1.09) and experienced symptoms scored 1.10 (HQ = 1.10), similarly indicating unacceptable risk. Workplace oxygen deficiency hazard (ODH) monitoring recorded a lower score of 0.97 (HQ = 0.97), reflecting an acceptable risk, while following exposure procedures scored 1.09 (HQ = 1.09) and confidence in monitoring and emergency systems scored 1.25 (HQ = 1.25), both falling under unacceptable risk. Finally, having undergone a medical checkup scored 0.84 (HQ = 0.84), indicating acceptable risk. Overall, the results suggest that while workers show moderate awareness of certain hazards, the majority of variables demonstrate exposure levels above the acceptable limit, highlighting the need for improved preventive measures and safety practices in the workplace.

Discussion of Findings

Level of Safety Practices in Place for Cryogenic Workers

The findings from Table 1 indicate that occupational safety practices among cryogenic workers in Rivers State are moderately observed, with just over half of respondents reporting engagement with key safety measures. The fact that 57.1% of workers reported receiving adequate orientation on cryogenic safety before performing tasks highlights some level of institutional preparedness; however, the significant proportion of workers who were unsure (10.4%) or did not receive training (32.5%) suggests gaps in pre-employment or on going safety education. This is consistent with recent studies in high-risk industrial environments, which indicate that insufficient orientation and safety training contribute to increased workplace accidents and hazard exposure (Amodu, Ibrahim & Salihu, 2023).

Emergency preparedness also showed moderate compliance, with 57.1% affirming that emergency procedures are clearly explained and practiced, and 55.8% confirming regular safety drills. While these figures suggest some institutional emphasis on emergency readiness, a sizeable minority of workers were unsure or reported irregular drills. These findings reflect patterns observed in other cryogenic and LNG operations, where infrequent drills and inconsistent practice reduce both worker confidence and actual emergency response effectiveness. (Ezenwa & Amadi, 2024; IGU, 2023). Confidence in handling cryogenic-related emergencies was slightly lower (54.5%), reinforcing the notion that training and drill frequency directly influence worker self-efficacy in high-risk environments.

Overall, these findings suggest that while a majority of cryogenic workers engage in essential safety practices, significant gaps remain in training coverage, PPE adequacy, emergency preparedness, and management commitment. Addressing these gaps through enhanced training programs, regular drills, sufficient protective equipment, and stronger management oversight is essential to mitigate occupational hazards and improve workplace safety in cryogenic operations (AIHA, 2022; IGU, 2023).

Investigating the Health Risk Assessment Indices Among Cryogenic Workers in Rivers State

The Health Risk Assessment results in Table 2 indicated that cryogenic workers in Rivers State are exposed to elevated risks in most areas, with hazard quotients above 1.0 for eight of the ten assessed variables. Notably, exposure to low temperatures (HQ = 1.34), handling cryogenic liquids or gases (HQ = 1.30), and confidence in monitoring and emergency systems (HQ = 1.25) represent unacceptable risk levels. Only workplace oxygen deficiency hazard monitoring (HQ = 0.97) and undergoing medical checkups (HQ = 0.84) fall within the acceptable risk range. These findings are consistent with

occupational health patterns observed in other Nigerian industrial sectors. For example, Okeke (2020) reported that factory workers in Nnewi, Anambra State, experienced high workplace hazard exposure despite being aware of safety risks, highlighting the gap between hazard awareness and protective actions.

Overall, these findings underscore the need for robust occupational health strategies, including consistent hazard assessment, strict enforcement of personal protective equipment usage, improved monitoring systems, mandatory medical surveillance, and targeted training on cryogenic hazards. Such measures are critical to bridging the gap between awareness and actual protective behavior and to mitigating health risks among cryogenic workers in Rivers State (Osagiede, 2023).

The findings from the health risk assessment show that although a majority of cryogenic workers in Rivers State are aware of the potential hazards associated with cryogenic substances, a substantial proportion still lack adequate training, medical surveillance and confidence in the safety systems available in their workplaces. This pattern reflects broader occupational safety concerns reported in Nigerian industrial environments, where awareness of hazards often coexists with gaps in training, risk assessment and enforcement of safety regulations.

CONCLUSION

In the level of Safety Practices in Place**,** moderate compliance with safety practices: 57.1% received safety orientation, 55.8% reported clear protocols, 58.4% had access to PPE, and 55.8–57.1% participated in drills and emergency preparedness. Significant gaps exist in training coverage, PPE adequacy, emergency preparedness, and management engagement. Improvements in training programs, PPE provision, emergency drills, and management commitment are critical to enhancing workplace safety. Hazard quotients exceeded acceptable levels for most variables, including low temperatures (HQ = 1.34) and handling cryogenic liquids/gases (HQ = 1.30). Only oxygen deficiency monitoring (HQ = 0.97) and medical checkups (HQ = 0.84) were within safe limits. Findings emphasize the need for consistent hazard monitoring, PPE use, targeted training, and medical surveillance to reduce health risks.

RECOMMENDATIONS

1. Industries should establish on-site occupational health units, conduct regular medical screenings, and collaborate with local hospitals for specialized care. This will ensure early detection and treatment of both acute and chronic conditions associated with cryogenic exposure.
2. Employers should integrate safety into organizational culture by encouraging incident reporting, conducting regular emergency drills, and involving workers in safety decision-making. This will improve readiness for hazards such as gas leaks, explosions, or burns, thereby minimizing their impact.

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