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Health Risk Assessment as Correlate for Exposure to Occupational Hazards among Cryogenic Workers in Nigeria

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ABSTRACT

This study examined health risk assessment as correlate for occupational hazards among cryogenic workers in Nigeria. This study aimed to identify prevalent hazards, associated health risks and the adequacy of safety practices and healthcare access. A descriptive cross-sectional research design was employed, using a structured questionnaire administered to 385 cryogenic workers selected through stratified random sampling across the area of the study. 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 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 ($r = –.283$, $p < 0.05$). 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.

Introduction

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. Direct contact with these substances cause severe skin and tissue damage due to their ultra-low temperatures and present risks including severe cold burns, frostbite, and asphyxiation due to oxygen displacement (Davis, Lin & Schaefer). 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).

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. 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). 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. 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 (Odeyemi & Adegoke, 2022).

In Rivers State, the rapid expansion of the industrial sector, particularly in oil and gas, has included the use of cryogenic technologies for various applications such as gas liquefaction and storage. However, this growth has often outpaced the development of effective safety measures and regulations. Research indicates that insufficient safety training, inadequate use of personal protective equipment (PPE), and poor enforcement of safety standards are prevalent issues that exacerbate occupational health risks (Ighodaro & Ogie, 2021).

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 (Yoshida & Kobayashi, 2020).

In contrast, in many developing regions, including parts of African and Asia, there are significant challenges in implementing effective safety measures. Research indicates that these regions often face barriers such as inadequate safety regulations, limited resources for safety equipment, and insufficient worker training. For example, in India and Nigeria, the rapid industrial growth, coupled with limited safety infrastructure, has led to increased risks to workers handling cryogenic substances (Ighodaro & Ogie, 2021)

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 (Nduka and Ogoni, 2022). 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 (Eze & Nwankwo, 2021).

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.

1.1 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, 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 (Nwaogazie and Eneh, 2022).

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) (Obi and Eze, 2023). 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 (Ndukwu and Chinedu-Madu, 2024). 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 (Ofor and Samuel, 2022).

1.2 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 (Nguyen, Le, and Tran, 2021).

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 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 McLaughlin, Jones & Roberts (2020) 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 (Ogba, 2020).

1.3 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 (Nwankwo and Brisibe, 2021). 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 (Nwachukwu and Adebayo, 2023).

1.3.1 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 et al., 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 (Nwankwo and Brisibe, 2021).

1.3.2 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 Nwachukwu, Akpuh and Chioma, 2020).

1.3.3 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. 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, (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 (Ogheneovo and Itepu, 2021).

1.3.4 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 (Nwakpa and Amadi, 2023).

1.4 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 (Ogolo and Amadi, 2023).

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. 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.

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

i. Ascertain how occupational hazards relate with Cryogenic workers in Rivers State.
ii. Determine how health outcomes relate to exposure to occupational hazards among Cryogenic workers in Rivers State.

1.6 Research Questions

The following research questions are drawn to guide the study:

i. How does occupational hazards relate with Cryogenic workers in Rivers State?
ii. How does health outcomes relate to exposure to occupational hazards among Cryogenic workers in Rivers State.

2.0 Methodology

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 which 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) earlier. 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 obtained and 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 et al., 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.

3.0 Results

Research Question 1: Occupational hazards Experienced and Cryogenic workers in Rivers State

Table 1: Frequency Distribution of Occupational Hazard among Cryogenic Workers in Rivers State

Variable	Category	Frequency n=385	Percentage (%)
Exposure to low temperatures	Yes Not Sure	220 75	57.1 19.5
	No	90	23.4
Handling cryogenic liquids/gases	Yes Not Sure	210 80	54.5 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 Not Sure	185 90	48.1 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 Not Sure	200 80	51.9 20.8
	No	105	27.3

Table 1 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.

Research Question 2: Health Outcomes related to Exposure to these Occupational Hazards

Table 2: Frequency Distribution of Health Outcomes related to Exposure to Occupational Hazards among Cryogenic Workers (n = 385)

Health Outcomes	Category	Frequency (n=385)	Percentage (%)
Respiratory problems.	Yes	230	59.7
	No	95	24.7
	Not Sure	60	15.6
Skin irritations or Dermatitis.	Yes	220	57.1
	No	95	24.7
	Not Sure	70	18.2
Eye injuries.	Yes	170	44.2
	No	155	40.3
	Not Sure	60	15.6
Headaches or Migraines.	Yes	200	52
	No	120	31.2
	Not Sure	65	16.9
Decline in my hearing ability.	Yes	190	49.4
	No	145	37.7
	Not Sure	50	13
Neurological symptoms.	Yes	200	52
	No	110	28.6
	Not Sure	75	19.5
Fatigue or Weakness.	Yes	220	57.2
	No	105	27.3
	Not Sure	60	15.6
Decrease in my overall health.	Yes	210	54.6
	No	105	27.3
	Not Sure	70	18.2

Table 2 presents the frequency distribution of health outcomes related to exposure to occupational hazards among cryogenic workers in Rivers State. A majority of respondents (59.7%) reported experiencing respiratory problems due to exposure to cryogenic substances, while 24.7% indicated otherwise and 15.6% were not sure. Similarly, 57.1% reported skin irritations or dermatitis from handling cryogenic materials, compared to 24.7% who did not and 18.2% who were uncertain. Eye injuries were acknowledged by 44.2% of workers, while 40.3% disagreed and 15.6% were unsure. In

terms of headaches or migraines linked to hazardous conditions at work, 52% affirmed experiencing them, 31.2% did not, and 16.9% were not sure. Regarding hearing decline from exposure to loud equipment and cryogenic environments, 49.4% reported it, 37.7% disagreed, and 13% were uncertain. Neurological symptoms such as dizziness or confusion were reported by 52% of respondents, while 28.6% disagreed and 19.5% were uncertain. Fatigue or weakness after handling cryogenic substances was experienced by 57.2%, while 27.3% did not report it and 15.6% were unsure. Additionally, 54.6% indicated a decline in overall health since starting work with cryogenic materials, compared to 27.3% who disagreed and 18.2% who were uncertain. Overall, the results highlight a significant prevalence of health challenges among cryogenic workers, emphasizing the occupational risks associated with their work environment.

These findings are further supported by Figure 4.2, which illustrates the spatial distribution of responses on health outcomes related to exposure to occupational hazards among cryogenic workers, showing a consistent pattern of reported respiratory issues, skin irritations, eye injuries, headaches, hearing decline, neurological symptoms, fatigue, and other health impacts across the study population.

4.0 Discussion of Findings

4.1 Identifying occupational hazards experienced by Cryogenic workers in Rivers State

The findings from Table 4.4 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. 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. 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.

4.2 Identifying Health Outcomes related to Exposure to these Occupational Hazards

The results in Table 4.5 show that cryogenic workers in Rivers State experience a wide range of adverse health outcomes linked to occupational exposure. Respiratory problems were the most common (59.7%), followed by skin irritations (57.1%), headaches/migraines (52%), neurological symptoms (52%), and fatigue (57.2%). Nearly half of respondents also reported hearing decline (49.4%) and eye injuries (44.2%), while over half (54.6%) indicated an overall decline in health since starting cryogenic work. Furthermore, 50.7% of workers reported requiring medical treatment for work-related conditions. These findings highlight that prolonged exposure to cryogenic hazards has both acute and chronic effects, affecting multiple organ systems and contributing to significant occupational health burdens. These results are consistent with recent studies in Nigeria, which have documented similar health risks among industrial and petrochemical workers. For instance, Onwuka, Ogwu & Eze, (2022) reported that exposure to industrial chemicals in Port Harcourt significantly increased cases of respiratory complications and skin disorders among workers. Similarly, Okoro & Nwankwo (2023) found that industrial workers exposed to cryogenic and petrochemical substances frequently experienced headaches, eye problems, and neurological disorders, particularly due to inadequate PPE and prolonged exposure. Aigbiremolen, Okojie & Ede (2021) also emphasized that fatigue and chronic health decline are prevalent among workers in high-risk industries due to cumulative exposure to toxic substances and poor occupational health surveillance. The alignment between these studies and the present findings suggests that cryogenic workers face occupational health risks similar to those reported in broader industrial settings in Nigeria.

These findings align with recent Nigerian studies that show how occupational hazards in industrial sectors contribute to multiple health problems. For instance, Aigbiremolen et al., (2021) reported high rates of respiratory illnesses, skin irritations, and fatigue among petrochemical workers in Edo State due to prolonged chemical exposure. Similarly, Ezenwa and Nwachukwu (2023) found that Nigerian oil and gas workers often reported headaches, neurological symptoms, and declining general health linked to hazardous exposures. Such evidence suggests that cryogenic workers in Rivers State face a comparable health burden due to the hazardous nature of their work environment.

The implications for this study are significant, as they underscore the urgent need for better occupational health policies and workplace interventions in cryogenic industries. The prevalence of respiratory and neurological symptoms indicates that cryogenic exposure has both short- and long-term effects, which may reduce workers' productivity and increase medical costs. Additionally, the finding that more than half of the respondents required medical treatment for work-related conditions suggests gaps in preventive measures and inadequate safety culture within these workplaces. Without targeted interventions, workers risk long-term chronic illnesses, which could place additional pressure on the healthcare system in Rivers State.

In conclusion, the study establishes a clear link between exposure to occupational hazards and adverse health outcomes among cryogenic workers. These findings are in line with broader Nigerian literature on occupational health risks, reinforcing that industrial workers across the Niger Delta are particularly vulnerable due to insufficient safety practices, weak regulatory oversight, and limited access to occupational healthcare services. Addressing these gaps through stricter enforcement of safety standards, mandatory health monitoring, and improved workplace safety culture will be critical in mitigating the identified health risks and improving the overall well-being of cryogenic workers.

5.0 Conclusion

Based on the findings of the study, the researcher concludes that:

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.

Health Outcomes Related to Exposure to Occupational Hazards

1. Workers reported respiratory problems (59.7%), skin irritations (57.1%), headaches (52%), neurological symptoms (52%), fatigue (57.2%), and overall health decline (54.6%).
2. Chi-square tests confirmed significant associations between high exposure levels and adverse health outcomes across multiple organ systems.
3. Hypothesis Two (H_{02}) is rejected, demonstrating that occupational hazards significantly impact workers' health, emphasizing the need for targeted interventions.

6.0 Recommendations

Based on the conclusion, the researcher made the following recommendations

1. 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.
2. Employers must guarantee regular provision of appropriate PPE such as insulated gloves, protective clothing, and face shields and enforce their mandatory use through supervision. This will directly address skin injuries, respiratory problems, and other immediate health risks identified in the study.

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