

**SCHOOL OF PUBLIC HEALTH
COLLEGE OF HEALTH SCIENCES**

UNIVERSITY OF GHANA



**THE ASSOCIATION BETWEEN CHLORINE AND CAUSTIC SODA EXPOSURE AND
RESPIRATORY HEALTH AMONG FACTORY WORKERS AT GIHOC DISTILLERIES**

BY

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**THIS DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON
IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF
MSC.IN OCCUPATIONAL MEDICINE DEGREE**



DECEMBER 2023

DECLARATION

I, Nana Amma Owusu-Agyeman, declare that this thesis submitted is my own work and is expressed in my own words. All writers of reference material used for this material have been appropriately cited and a broad list of the reference employed has been admitted. Also, this research was done under supervision.



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DEDICATION

This research is dedicated to God Almighty for providing me with the strength all through the exhaustive times to be able to complete this study successfully. I also dedicate this work to my lovely parents, Mr. and Mrs. Owusu-Agyeman and to my dearest siblings, for their constant encouragement and support.



ACKNOWLEDGEMENT

I am thankful to God Almighty for enabling me to bring this research to a glorious end. I also extend my sincere gratitude to my distinguished supervisor, Dr. Helena Lamptey, for her constant support, patience, guidance and tolerance in seeing me throughout this stage. I would also like to express my sincere appreciation to Dr. John Ako-Mensah for also coaching me when I needed expert advice and finally to the Head of Department, BEOH, Prof. Mawuli Dzodzomenyo for his tremendous support. Many thanks to the management of GIHOC Distilleries Company Limited (GDCL) for their contributions towards my research. To my lovely brother Kwaku Tiboah and all my course mates, especially Abdul-Aziz, I say a big thank you for their sacrifices, unwavering support and contribution towards my wellbeing.



ABSTRACT

Background: Chlorine and caustic soda are widely used in industrial processes and pose potential health risks to factory workers who are frequently exposed to these chemicals. In both humans and animals, poisoning symptoms have been documented and are comparable, including simple respiratory irritation, bronchial spasms, bronchial and alveolar damage, and pulmonary illnesses. In Ghana, disastrous effects and lifelong complications range from respiratory and gastrointestinal burns to death resulting from caustic soda ingestion. This study investigated the association between chlorine exposure, caustic soda and respiratory health among factory workers in Ghana.

Methods: This research was conducted at GIHOC Distilleries Company Limited, located in the North Industrial area, 2 Dadeban Road, in the Greater Accra Region. Quantitative approaches were utilized in an observational cross-sectional study with 134 purposively sampled study participants. A Structured questionnaire, adapted from the OSHA Respiratory Medical Evaluation Questionnaire, was administered. Pulmonary lung function tests were carefully carried out on study participants.

Results: The sex distribution revealed that 44.03% of the study participants were female and 55.97% of the study population were male. The majority (45.52%) of study participants were married. A significant percentage (55.22%) of respondents had a “Very good” knowledge on chemical usage, 12.68% of participants had “Moderate” understanding about chemicals and their usage. Chlorine ($p = 0.002$) and caustic soda ($p = 0.0076$) exposure were significantly associated with respiratory symptoms of cough. However, chlorine and caustic soda exposures had no association ($p > 0.05$) with respiratory symptoms, chest tightness, breathing difficulty, and shortness of breath.

Conclusion: This study highlights the correlation between chlorine and caustic soda exposure in the respiratory health of workers. These findings offer valuable baseline data for ongoing investigations into the adverse health effects experienced by workers at GIHOC distilleries. Therefore, it should be a top priority for production employees at GIHOC distilleries to monitor each other's adherence to safety regulations.



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LIST OF ABBREVIATIONS

AAPCC	-	American Association of Poison Control Centers
ACD	-	Allergic Contact Dermatitis
ACGIH	-	American Conference of Governmental Industrial Hygienists
ALI	-	Acute Lung Injury
ANOVA	-	Analysis of Variance
ARDS	-	Acute Respiratory Distress Syndrome
ATS	-	American Thoracic Society
ATSDR	-	Agency for Toxic Substances and Disease Registry
CDC	-	Center for Disease Control and Prevention
CMAI	-	Cohen-Mansfield Agitation Inventory
DBPs	-	Disinfection By-Products
ERS	-	European Respiratory Society
FEV1	-	Forced Expiratory Volume 1
FVC	-	Forced Vital Capacity
GIHOC	-	Ghana Industrial Holding Corporation
IDC	-	Industrial Development Corporation
IDLH	-	Immediately Dangerous To Life and Health
IVC	-	Inspiratory Vital Capacity
NaOH	-	Sodium Hydroxide
NIOSH	-	National Institute for Occupational Safety and Health
NLCD	-	National Liberation Council Decree

OSHA	-	Occupational Safety and Health Administration
PEF	-	Peak Expiratory Flow
pH	-	Power of Hydrogen
PPEs	-	Personal Protective Equipment's
STEL	-	Short Term Exposure Limit
TLV	-	Threshold Limit Value
TWA	-	Time Weighted Average
UGMC	-	University of Ghana Medical Center
VC	-	Vital Capacity
WHO	-	World Health Organisation



CHAPTER ONE

INTRODUCTION

1.1 Background

Chemicals are indispensable to modern industrial processes, forming the foundation of numerous products and innovations that influence everyday life. They are crucial in producing vital pharmaceuticals, developing sophisticated electronics, and creating durable construction materials. By facilitating greater efficiency, improving product standards, and fostering innovation, chemicals help industries keep pace with the fast-changing global landscape and expand the limits of technological progress (World Economic Forum, 2024). However, the dependence on chemical substances in industrial environments has major consequences for workers, ranging from direct exposure to harmful materials to long-term health concerns. The risks associated with chemical use in these settings are profound and cannot be overlooked. The International Labour Organization (ILO, 2021) also emphasizes that occupational exposure to toxic chemicals can lead to fatal diseases, cancers, and poisonings, all of which are entirely preventable. The extensive use of chemicals in industrial workplaces poses serious risks to workers, exposing them to immediate hazards like burns, inhalation injuries, and chemical poisoning, as well as long-term health issues such as cancer, neurological disorders, and chronic respiratory diseases. Furthermore, the psychological strain of working in dangerous conditions and the potential for workplace accidents emphasize the urgent need for thorough safety training, improved personal protective equipment, ongoing health assessments, and stricter enforcement of safety regulations. Workers face significant health threats from exposure to hazardous substances, particularly in industries where chemicals like chlorine and caustic soda (sodium hydroxide) are commonly used. These chemicals are integral to various industries including textile production,

water treatment, soap manufacturing, and paper processing. However, their beneficial applications are accompanied by potential health hazards, particularly respiratory health.

Chlorine, a greenish-yellow gas with a pungent and irritating odor, is widely used for its disinfectant and bleaching properties. The National Institute for Occupational Safety and Health (NIOSH, 2016) notes that exposure to low levels of chlorine can result in nose, throat, and eye irritation, whereas higher levels may cause coughing, changes in breathing rate, and lung damage. Prolonged exposure has been associated with chronic respiratory diseases such as asthma and bronchitis. In severe cases, the inhalation of concentrated chlorine gas can lead to pulmonary edema and decreased lung function. For instance, one case reported the death of a worker from pulmonary thrombosis six days after inhalation of concentrated chlorine gas (Asano, M. et al, 1999).

Sodium hydroxide, commonly referred to as caustic soda, is a highly alkaline substance widely used in industrial cleaning, soap manufacturing, and chemical production. The Tennessee Department of Health states that at room temperature, it appears as a white, odorless solid and is frequently found in cleaning products and soaps. Contact with caustic soda can lead to serious burns on the skin and eyes, while inhaling its aerosolized form may cause respiratory irritation, persistent coughing, and lung damage (ATSDR, 2007). The Centers for Disease Control and Prevention (CDC) have highlighted that sodium hydroxide is caustic and can react violently with strong acids and water, emphasizing the need for proper handling and storage to prevent accidental exposure. Agency for Toxic Substances and Disease Registry (ATSDR, 2016) posits that the manufacturing industry uses various chemicals, including cleaning agents, such as chlorine

disinfectants, peracetic acid, and caustic soda, which are known to cause skin burns, respiratory irritation, and eye damage.

Exposure to industrial chemicals, such as chlorine and sodium hydroxide (caustic soda), poses significant health risks to factory workers. The National Institute for Occupational Safety and Health (NIOSH) reports that the inhalation of chlorine gas can cause respiratory issues, including coughing and lung damage, as well as irritation of the eyes, nose, and throat.

In recent years, many industries have increasingly relied on chlorine. Chlorine-based compounds rank among the top ten most commonly produced chemicals in the United States and are manufactured under strict regulatory standards. Due to their broad-spectrum disinfectant properties, they have been widely used for both commercial and household purposes for many years (ATSDR, 2016). Extensive research has examined workplace exposure to chlorine gas, emphasizing the serious health risks it poses to workers (Andersson, Holm, & Rönmark, 1999; Smith & Johnson, 2011). Employees may encounter low levels of chlorine during routine operations. However, accidental releases of large amounts of chlorine can lead to significant exposure (ATSDR, 2010; Neghab et al., 2016). The impact of occupational exposure to high concentrations of chlorine gas on respiratory health has been extensively studied (Neghab et al., 2016; Winder, 2001; Leroyer et al., 1998; Ramachandran et al., 1990). Recent research has further highlighted the health risks associated with chlorine exposure in industrial environments. For example, studies have demonstrated the long-term effects of chronic chlorine gas exposure on industrial workers (Fadaei, Sadeghi, & Esfahani, 2021; Jafari & Heydari, 2016). Acute inhalation of chlorine gas can lead to symptoms such as wheezing, coughing, chest tightness, and difficulty breathing, with severe cases potentially resulting in acute lung injury or acute respiratory distress syndrome (Smith & Johnson, 2011; Ali & Hosseini, 2023). Most of the toxicological data on

chlorine available mostly focuses on its effects on the respiratory system (Winder, 2001; Neghab et al., 2016).

In both humans and animals, poisoning symptoms have been documented and are comparable, these include simple respiratory irritations, bronchial spasms, bronchial and alveolar damage, and pulmonary illnesses. Chest tightness, respiratory distress, visual disturbances, and loss of vision acuity are the major symptoms (Mehtar et al., 2016; Hasari et al., 2010; Russel et al., 2006). Both acute and long-term exposure to chlorine has been linked to skin reactions like burning and dermatitis (CDC, 1998; Mehtar et al., 2016). Chlorine poisoning primarily affects the lungs, although it can also harm the eyes, skin, and heart. Chlorine exposure causes damage to the respiratory epithelium, which is a frequent clinical symptom brought on by inhaling numerous pulmonary toxicants. This damage is the first harm that develops in the lung because of chlorine exposure. Chlorine is extremely reactive, and the respiratory tract can successfully remove it at lesser quantities (Nadelman and Ultman, 1999; Hoyle and Svendsen, 2016).

Caustic soda, which is present throughout the entire refinery circuit, is a major contributor to chemical splashes (Arax, 2022). It is one of the most widely used industrial chemicals in various sectors, including pulp and paper, alumina, textiles, electroplating, detergents, and wastewater treatment. Additionally, caustic soda plays a crucial role in several applications, such as fuel cell production, food curing, vegetable peeling for canning, manufacturing bleach, drain and oven cleaners, soaps, detergents, and paper products. It is also used in cotton fabric processing, aluminum ore coating, metal pickling, pharmaceuticals like painkillers and anticoagulants, cholesterol-lowering drugs, and water treatment. This study investigated the association between exposure to chlorine and caustic soda and respiratory health outcomes among factory workers in Ghana. By assessing the prevalence of respiratory symptoms, evaluating lung function, and

examining workplace safety practices, the research seeks to provide evidence-based recommendations. The ultimate goal is to inform policymakers and industry stakeholders, facilitating the development and implementation of effective occupational health policies to ensure safer working environments for factory workers in Ghana.

1.2 Problem Statement

Chemicals such as caustic soda and chlorine, which are widely used in manufacturing processes, especially in the refinery and water treatment industries, have become more prevalent in Ghana owing to the country's rapid industrialization. Despite being necessary for manufacturing, these chemicals are dangerous and pose major health hazards to chemicals such as chlorine and caustic soda, which are frequently used in manufacturing processes, especially in the textile, soap, and water treatment industries, and have become more prevalent in Ghana due to the country's rapid industrialization (Botwe et al, 2012). Both caustic soda, a potent alkaline, and chlorine, a highly reactive disinfectant, have been linked to a number of health problems, including those affecting the skin, eyes, and respiratory system (Agency for Toxic Substances and Disease Registry (ATSDR, 2016; Fobil et al., 2020). Chronic exposure to chlorine gas can cause respiratory infections, lung damage, and chronic obstructive pulmonary disease (COPD) (Jafari & Heydari, 2016). Similarly, caustic soda exposure is known to cause severe skin burns, eye damage, and respiratory irritation (Fobil et al., 2020).

In Ghana, there is a significant gap in research examining the extent of exposure to chlorine and caustic soda and their impact on the health of industrial workers. Many workers in factories lack knowledge of the safe usage of chlorine and caustic soda, personal protective equipment, and long-term health risks; therefore, they are often subjected to unsafe working conditions, such as

inadequate ventilation (Fobil et al., 2020). This has resulted in heightened concerns regarding the occupational health of factory workers. Furthermore, the absence of comprehensive studies on the health effects of chlorine and caustic soda exposure in Ghana means that there is limited data to inform safety regulations, making it difficult to implement effective interventions aimed at mitigating the risks associated with exposure to these chemicals. Therefore, understanding health risks and establishing stronger safety protocols are crucial for improving occupational health and worker safety in Ghanaian industries that use chlorine and caustic soda.

1.3 Justification

Over 70% of workers in numerous developing countries are employed in environments that lack adequate safety and health measures, with governments often failing to enforce occupational health and safety regulations (WHO, 2014; Olofinkua, 2015). There is limited research on the impact of workplace hazards on workers' respiratory health, particularly in the growing manufacturing sector, including GIHOC distilleries. Chlorine and caustic soda exposure in brewery industry settings poses significant health risks, particularly to respiratory health, owing to the hazardous nature of substances. These chemicals are widely used in manufacturing and processing industries, where factory workers are frequently exposed to toxic effects. Prolonged or excessive exposure to these substances has been linked to respiratory conditions, such as chronic cough, bronchitis, and other lung diseases, which can significantly impair the quality of life and productivity (Manivannan & Dhanaraj, 2021). Exposure to chlorine and caustic soda in brewery industry settings presents serious health hazards, particularly affecting respiratory health due to the toxic nature of these substances. These chemicals are extensively utilized in manufacturing and processing industries, where workers often face prolonged exposure to their harmful effects. Long-term or excessive contact with these substances has been associated with respiratory issues such

as chronic cough, bronchitis, and other lung diseases, which can greatly impact both quality of life and workplace productivity (Manivannan & Dhanaraj, 2021). Despite this, there is still a significant lack of understanding regarding the extent to which exposure to chlorine and caustic soda affects respiratory health in specific work environments, especially in developing regions where occupational safety measures may be insufficient (Levin, 2006).

Furthermore, while personal protective equipment (PPE) is acknowledged as an essential tool for reducing exposure risks, its use is frequently not consistently followed because of a lack of knowledge, instruction, or enforcement (Etikan, Musa, & Alkassim, 2016). Finding out how common respiratory symptoms are among exposed workers, evaluating the efficacy of current workplace safety protocols, and emphasizing the need for focused interventions are all made possible by this study. The findings will help shape policies targeted at raising occupational health and safety standards, which will lower respiratory health risks and improve workers' well-being by supplying information on the negative health effects of exposure to caustic soda and chlorine as well as the role of working practices. Despite these risks, many industrial environments, especially developing regions, face significant challenges in implementing and evaluating effective protective measures. Investigating the association between chlorine and caustic soda exposure and respiratory health among factory workers is vital to provide evidence-based recommendations for workplace safety standards, enhance the understanding of exposure-response relationships, and contribute to policy development aimed at minimizing occupational health risks. This research not only aims to safeguard the health of factory workers, but also has broader implications for reducing healthcare costs and improving productivity in industrial sectors.

This research aimed to investigate the chemicals and exposure levels associated with respiratory health outcomes among workers in the manufacturing industry.

1.4 Research questions

1. What is the knowledge-level of the factory workers on chemicals (Chlorine and caustic soda) they are exposed to?
2. What is the knowledge-level of the factory workers on personal protective equipment (PPEs) and their usage?
3. What is the association between chlorine and caustic soda exposure and respiratory symptoms among the factory workers at GIHOC distilleries?
4. What is the association between socio-demographic and lifestyle factors on the respiratory health of factory workers at GIHOC distilleries?

1.5 General objective

To determine the association between chlorine and caustic soda exposure on the respiratory health of the factory workers.

1.5.1 Specific objectives

1. To access the knowledge-level of the factory workers at GIHOC distilleries on chemicals (chlorine and caustic soda) they are exposed to.
2. To ascertain the knowledge-level of the factory worker at GIHOC distilleries on Personal Protective Equipment's (PPEs) and their usage.
3. To determine the association between chlorine and caustic soda exposure and the respiratory symptoms of factory workers at GIHOC distilleries.
4. To determine the association between socio-demographic and lifestyle factors on the respiratory health of factory workers at GIHOC distilleries.

1.6 Conceptual framework

This study is based on the Occupational Health Hazards Model, which explores the relationships between occupational hazards, workplace factors, and worker health outcomes. The key components include occupational hazards (chemical substances), workplace factors (ventilation systems, PPE, work practices, training, and education), worker characteristics (age, sex, smoking status and pre-existing medical conditions), and health outcomes (respiratory symptoms and diseases). The relationship among these elements indicates that occupational hazards impact workplace conditions, which subsequently affect worker exposure, heightening the likelihood of respiratory symptoms and diseases, whereas individual worker characteristics determine their susceptibility to chemical exposure.

Chemical exposure and its impact on factory workers' respiratory health is a prevalent yet often overlooked occupational health concern in this region. The specific job roles or tasks assigned to workers can significantly influence their respiratory well-being, particularly when exposure to hazardous chemicals is involved. The duration of exposure is also a crucial factor in assessing respiratory symptoms related to workplace hazards. Prolonged exposure to chemicals such as chlorine and caustic soda increases the likelihood of severe respiratory health issues, posing serious risks to affected workers.

Over time, prolonged exposure to these chemicals due to years of work experience in direct contact may contribute to respiratory health issues, as workers frequently inhale these substances without proper regulation. Additionally, the lack of strict enforcement of personal protective equipment (PPE) policies, combined with job rotation and shift work among those in direct exposure on the production line, can further increase the risk of respiratory health challenges among factory workers. Lifestyle measures ranging from frequent alcohol consumption to various degrees of

smoking by workers are likely candidates for the deterioration of the respiratory health of workers, although the age and gender of these workers also contribute to similar measures. To this end, this study will identify how all these factors independently play a role in the respiratory health of factory workers exposed to chlorine and caustic soda in GIHOC distilleries.

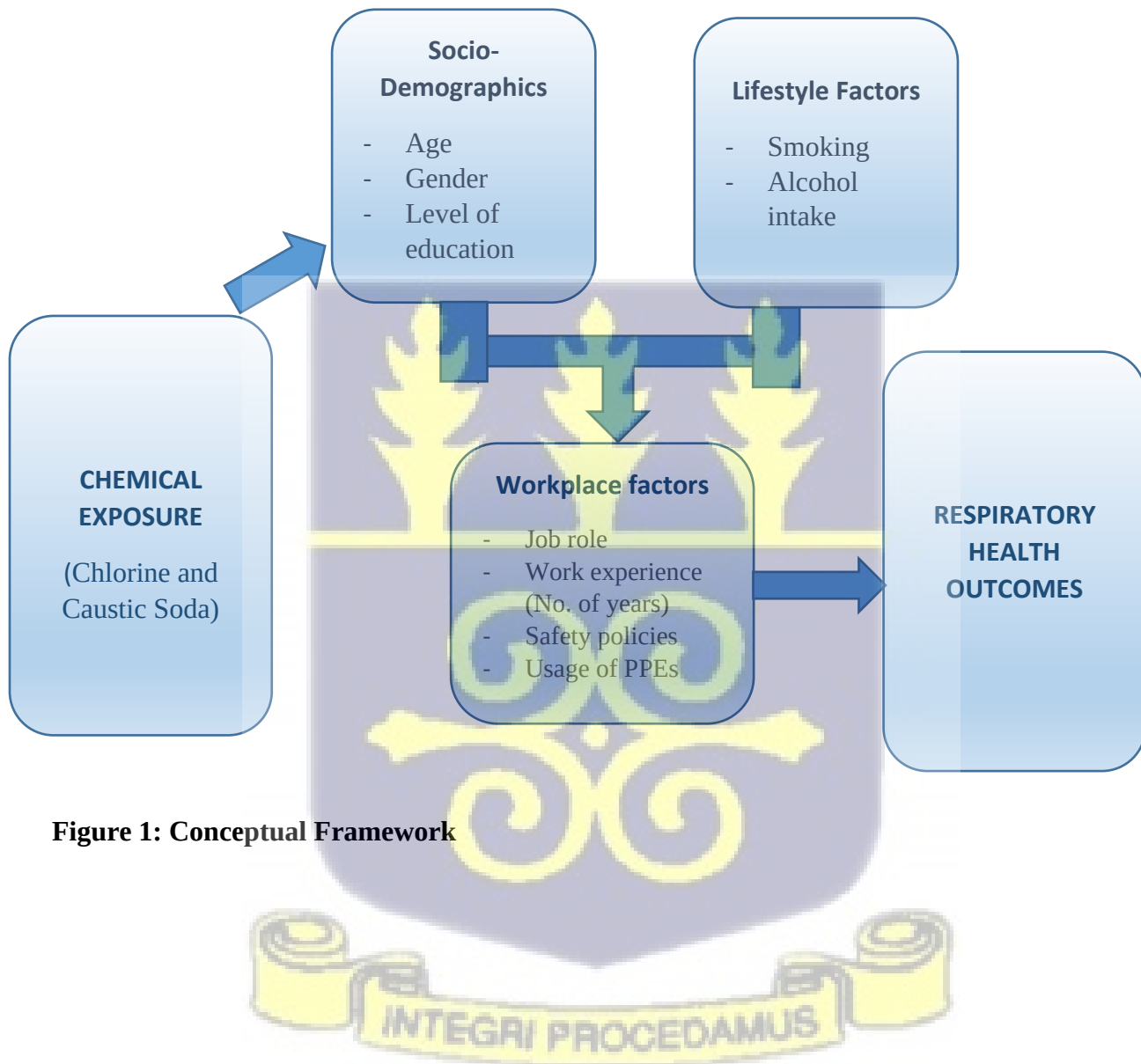


Figure 1: Conceptual Framework

CHAPTER TWO

LITERATURE REVIEW

2.1 Common Chemical Irritants

Acute inhalation toxicity is typically caused by chemicals that act as irritants in occupational and environmental settings. Below is a summary of the traits, consequences, and sources of the most prevalent chemical irritants.

2.1.1 Chlorine

According to the Encyclopedia Britannica (2023), chlorine gas is a greenish-yellow gas that is diatomic at room temperature and is a member of the halogen group in the periodic table. It is a strong oxidizing agent and extremely reactive. The electrolysis of sodium chloride brine is the main industrial process used to manufacture chlorine. It is widely used to produce a variety of chemicals, including as polyvinyl chloride (PVC) and other organic compounds, as well as to purify and bleach water. Table salts (sodium chloride) and other chloride compounds are widespread in nature, but chlorine is rarely discovered in its elemental form due to its strong reactivity. Chlorine gas exposure can be dangerous since it can irritate the respiratory tract and have other negative health effects. According to epidemiological research, chlorinated drinking water increases the risk of developing bladder, colon, and rectal cancers (Diana et al., 2019; Evlampidou et al., 2020; Villanueva et al., 2017). The most frequent route of chlorine assimilation by humans, as reported by the American Association of Poison Control Centre (AAPCC) and the National Poison Data System (NPDS), was ingestion (83%); other options included inhalation, cutaneous absorption, rectal absorption, and ocular absorption. Vomiting (49.1%), nausea (28.3%), abdominal discomfort (22.6%), and diarrhea (20.8%) were the most frequently reported side effects. Most exposure to chlorine resulted in acute toxicity (84.9%), as most effects occurred

immediately or ≤ 24 h of exposure (75.5%). The Centres for Disease Control and Prevention (CDC) states that chlorine gas, even at low concentrations, can irritate the eyes, skin, and respiratory tract. Chlorine poses significant health risks when inhaled, particularly for workers in environments with inadequate safety protocols. Research has highlighted the acute and chronic health impacts of chlorine gas exposure, emphasizing its severe effects on the respiratory system.

Risks of Exposure to Chlorine

Exposure to chlorine gas can cause immediate and severe respiratory symptoms. According to the Centers for Disease Control and Prevention (CDC), chlorine inhalation can cause coughing, chest tightness, and shortness of breath, which may progress to pulmonary edema in severe cases (CDC, n.d.). White and Martin (2010) further underscored that acute exposure to chlorine may result in airway inflammation and hyper-responsiveness, contributing to conditions such as reactive airway dysfunction syndrome (RADS). These findings highlight the urgent need for rapid medical interventions following exposure.

2.1.3 Chronic Health Risks of Exposure to Chlorine

Chronic inhalation exposure to low chlorine gas levels can have long-term effects on respiratory health. Hoyle (2016) reported persistent airway obstruction and chronic bronchitis in individuals exposed to chlorine for extended periods. In addition, repeated exposure may cause a decline in pulmonary function, making individuals more susceptible to respiratory infections and other health complications.

2.2 Caustic Soda

Caustic soda, or sodium hydroxide (NaOH), is a highly corrosive substance widely used in industries such as manufacturing, chemical processing, and cleaning. While its inhalation is less

common than skin or eye contact, exposure to airborne particles or mist of caustic soda can pose significant health risks, especially to workers in industrial environments.

2.2.1 Acute Health Risks

Inhalation of caustic soda particles or aerosols can cause severe irritation to the respiratory tract. The CDC identifies symptoms such as coughing, nasal irritation, and throat discomfort as common acute effects. In high concentrations, exposure can lead to respiratory distress or chemical pneumonitis, a potentially life-threatening condition requiring immediate medical intervention.

2.2.2 Chronic Health Risks

Prolonged exposure to airborne sodium hydroxide, even at low concentrations, can lead to persistent respiratory problems. Research by Broughton et al. (2021) indicates that workers frequently exposed to caustic soda may develop chronic bronchitis, airway inflammation, and reduced lung function. Additionally, repeated exposure can aggravate existing respiratory conditions such as asthma. Studies emphasize the severe health risks associated with inhaling caustic soda, highlighting the need for strict safety measures and preventive strategies in industrial settings. Implementing effective interventions can help minimize both immediate and long-term health effects, ensuring worker safety.

Short-term exposure to high concentrations of sodium hydroxide can cause acute irritation and burns to the skin, eyes, nose, throat, and lungs. Inhaling high doses of the substance can result in irreversible obstructive lung disease and laryngeal edema. Ingesting sodium hydroxide may initially cause abdominal pain and vomiting, with severe complications such as shock and gastrointestinal perforation developing hours later. Conversely, exposure to dilute solutions (4% or less) may not cause immediate irritation, with symptoms potentially appearing hours after skin contact. Eye exposure initially causes a burning sensation and may lead to long-term damage, with

the full extent of the injury sometimes taking up to 72 hours to assess (Salocks & Kaley, 2003; ATSDR, 2000).

Children who accidentally ingest sodium hydroxide may suffer from severe necrosis, esophageal stricture, or even death. Skin contact can lead to dermatitis, hair loss, and necrosis, depending on individual sensitivity to caustic substances (Ahmadi & Seyedin, 2019). Exposure to 0.5 mg/m^3 can cause mild to moderate respiratory discomfort, while inhaling sodium hydroxide mist or dust may result in nasal and airway irritation. Early signs of poisoning include nose and throat irritation, indicating airborne sodium hydroxide levels have reached hazardous concentrations (Salocks & Kaley, 2003).

Inhalation Exposure Standards of Sodium hydroxide

Occupational Exposure Limits (NIOSH, 1997; ACGIH, 1994)

1. Ceiling Limit (C): 2 mg/m^3 (never to be exceeded).
2. There is no recognized short-term exposure limit (STEL or ST).
3. 2 mg/m^3 for the 8-hour Time Weighted Average (TWA).
4. The 10-hour Time Weighted Average (TWA) has not yet been determined.
5. IDLH (10 mg/m^3): Immediately Dangerous to Life & Health

2.3 Effects of chemicals on Respiratory health of humans

Every year, chronic respiratory diseases claim the lives of approximately 4 million people worldwide (FIRS, 2014). The respiratory system is vulnerable to various hazards, including allergens, toxins, tobacco smoke, airborne pollutants in gaseous or particulate form, and numerous chemicals such as pesticides (Crinnion, 2012; Mamane et al., 2014). Research on the effects of occupational pesticide exposure on respiratory health by Ye et al. (2013) found that individuals exposed to pesticides in the workplace often experience reduced lung function. Strong evidence

links occupational pesticide exposure to asthma, particularly among agricultural workers. There are also indications of an association between pesticide exposure in the workplace and conditions such as chronic bronchitis and COPD. However, findings on the link between occupational pesticide exposure and lung cancer remain inconclusive. Additionally, human activities like using e-cigarettes have been shown to negatively affect lung health. Studies suggest that exposure to e-cigarettes can disrupt pulmonary homeostasis, leading to impaired gas exchange, reduced lung function, heightened airway inflammation and oxidative stress, weakened immunity, and an increased risk of respiratory infections (Miyashita & Foley, 2020). In developed countries such as the United States and across Europe, demographic and workforce studies indicate a rising prevalence of asthma-like symptoms among professional cleaners (De Matteis et al., 2020; Takeda et al., 2009; Maestrelli et al., 2009)

2.3.1 Workplace Factors and Vulnerable Populations

Poor ventilation, lack of proper personal protective equipment (PPE), and limited knowledge about chemical handling contribute to a higher risk of exposure in industrial environments. The Health Protection Agency (2007) reports that individuals in such settings show increased sensitivity to chlorine and caustic soda, potentially worsening pre-existing health conditions. Workers with respiratory illnesses or those who smoke are especially at risk, as their already weakened respiratory systems make them more susceptible to the harmful effects of these chemicals (Broughton et al., 2021).

2.3.2 Preventive Measures and Safety Protocols

Personal protective equipment (PPE) plays a crucial role in protecting workers in high-risk industries, particularly those handling hazardous substances like chlorine and sodium hydroxide. It provides essential defense against immediate dangers such as respiratory distress, chemical

burns, and eye irritation while also reducing the risk of long-term health complications, including chronic respiratory diseases (Centre for Disease Control and Prevention [CDC], n.d.). PPE compliance is not only necessary for worker safety but also helps businesses adhere to occupational health regulations, minimizing legal and financial liabilities (Occupational Safety and Health Administration [OSHA], 2023). Additionally, PPE contributes to a safer work environment by boosting worker confidence and providing critical protection for individuals who are more sensitive to chemical exposure (Hoyle, 2016).

The correct use and upkeep of PPE are vital for maintaining workplace health and safety. Implementing comprehensive safety protocols is essential to minimizing health hazards related to chlorine inhalation. Key preventive measures include efficient ventilation systems, consistent use of PPE, and routine air quality monitoring in industrial settings (White & Martin, 2010). Moreover, worker education and training programs can significantly lower the risk of exposure-related health issues.

Research consistently links chlorine inhalation to both short- and long-term respiratory health problems. These findings emphasize the need for stringent safety regulations in workplaces where chlorine is present, as well as ongoing research to develop effective strategies for preventing and managing exposure-related conditions.

2.4 Spirometry

Spirometry is a widely used diagnostic tool in clinical settings to identify restrictive, obstructive, or mixed ventilatory impairments. It is essential for diagnosing and managing respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD). This method is non-invasive, highly reproducible, and sensitive to early lung function changes, making it a reliable and objective assessment technique. With the availability of portable spirometers, testing

can be conducted in various settings by individuals with proper training. Spirometry is utilized to detect lung diseases, assess the extent of lung damage, monitor the effects of occupational and environmental exposures, and evaluate the effectiveness of treatments (Moore, 2012).

Spirometry assessment

Spirometry assessments have been widely utilised in various industries and establishments. When evaluating asymptomatic individuals for airflow limitation, spirometry is not advised. There was insufficient evidence to support the use of spirometry to screen for airflow limitation in people without respiratory symptoms, including smokers with defined levels of tobacco smoking. Spirometry should be performed to diagnose airflow limitation in patients with respiratory symptoms, as suggested in the most recent joint American College of Physicians/American College of Chest Physicians American Thoracic Society/European Respiratory Society (ATS/ERS) clinical guidelines. Additionally, it is not advised to employ inhaled treatments in asymptomatic people with or without spirometry evidence of airflow restriction. The available data also does not point to a substantial advantage for symptomatic patients' therapy planning or disease status monitoring following the start of treatment from routine spirometry (Qaseem et al., 2007; Qaseem et al., 2011; Bin-Miad Liang, 2012). Certain occupations involve consistent exposure to airborne pollutants such as dust, chemical agents, exhaust fumes, fuels, particulate matter (PM), and vapors from paint, solvents, and welding materials. Industries such as welding, painting, manufacturing, and automobile repair are particularly affected. Extensive research has shown that prolonged exposure to these substances contributes to a decline in lung function. A cross-sectional study involving workers in small-scale industries who met similar anthropometric and demographic criteria found that chest tightness and wheezing were the most frequently reported respiratory symptoms, occurring in 22.7% of exposed workers compared to 10% of unexposed individuals.

The study indicated that occupational exposure occurred frequently in 22.7% of cases, occasionally in 68.2%, and never in 9.1%. However, the use of respiratory protection, such as masks, was reported to be minimal. In terms of overall respiratory health, 54.5% of exposed workers rated their health as excellent compared to 73.4% of the unexposed group, while 27.3% and 23.3% rated their health as good, and 18.2% and 3.3% as average, respectively. The mean lung function parameters among exposed workers, including Forced Expiratory Volume in 1 second (FEV1) (3.12 vs. 3.50), Forced Vital Capacity (FVC) (4.12 vs. 4.43), FEV1/FVC ratio (79.60 vs. 80.79), and Peak Expiratory Flow (PEF) (414.77 vs. 523.16), were all lower compared to the control group, suggesting varying levels of respiratory impairment (Ahmad & Balkhyour, 2020).

Similarly, a study conducted by Anyfantis et al. (2017) on workers in the cotton industry reported comparable findings. Chest tightness and wheezing were the most prevalent respiratory symptoms, with 22.7% of exposed individuals and 10% of unexposed individuals affected. Occupational exposure was observed frequently in 22.7% of cases, occasionally in 68.2%, and never in 9.1%, while the use of respiratory protection remained limited. The exposed group's overall respiratory health ratings were lower than those of the unexposed group, with a significant decline in lung function parameters, reinforcing the link between occupational exposure and respiratory health deterioration.

There are some checklists of factors that participants should avoid prior to spirometry assessment as described by Moore (2012).

Table 1: A table showing activities and duration within which spirometry can be carried out as part of the checklists for the procedure.

Activity	Length of time to stop before spirometry
Drinking alcohol	4 hours
Eating a large meal	2 hours
Vigorous exercise	30 minutes
Smoking	>1 hour
Medication use	Document treatment and when last used

Prior to the commencement of testing as described by Garbe (2021).

- I. Explain the test to the study participant
- II. Loosen any tight clothing
- III. Measure weight and height without shoes
- IV. Instruct and enthusiastically demonstrate the test to the subject
- V. Demonstrate correct posture
- VI. Show how the mouthpiece is inserted into the mouth, not like a trumpet

Table 2: A table showing the American Thoracic Society (ATS)/European Respiratory Society (ERS) acceptability and repeatability quality criteria of spirometry testing.

ACCEPTABILITY
Free from artifacts
Cough
Glottis closure
Early termination
Submaximal effort
Leaks
Obstructed mouthpieces
Expiratory time ≥ 6 s
REPEATABILITY
Three appropriate test, at the very least, should be acquired.
The two greatest FVCs ought to be separated by no more than .15 L
Within .15 L of one another should be the two greatest FEV1.

(Miller et al., 2005; Haynes, 2018).

2.4.2 Patient positioning

- I. Sit upright
- II. Feet flat on floor with legs uncrossed
- III. Loosen tight-fitting clothing
- IV. Use a chair with arms

2.4.3 Infection control

Between each participant, hands must be washed and sanitised. All participants should utilize bacterial-viral filters, and after the conclusion of testing, the patient should discard the filters. Mouth pieces used should be sterilised and used each per participant. If an infectious patient needs to be tested, this should be done at the end of the session, and the equipment should be disassembled, cleaned, and parts replaced as described by Moore (2012).

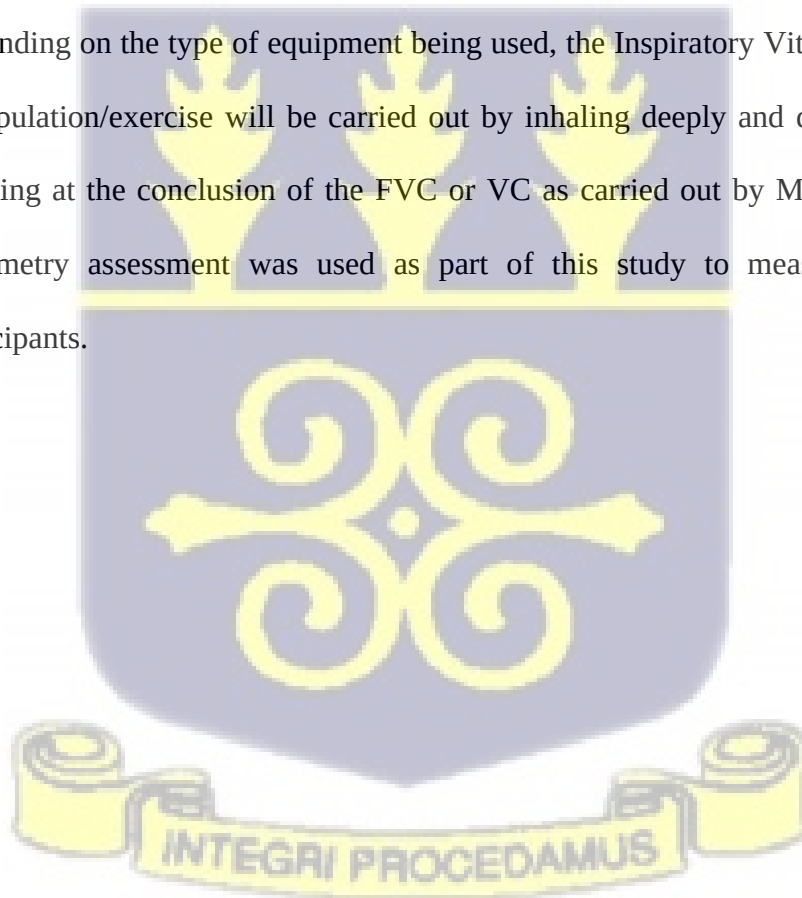
2.4.4 Spirometer calibration

Spirometers should have their device calibration confirmed daily using a 3 L calibration syringe, according to the 2005 American Thoracic Society/European Respiratory Society (ATS/ERS) spirometry guidelines. Recorded values for slow, middle, and fast flows should range from 2.9 L to 3.1 L, or 3 L $\pm$ 3.5%. A spirometer from some manufacturers will indicate that it "doesn't require calibration." Since the device is calibrated when it is built, it would be more correct to say that many of these spirometers "cannot be calibrated," although this calibration should still be checked every day and anytime a flow sensor is changed (Haynes, 2018).

2.4.5 Spirometry technique/procedure

- I. Tidal (normal) breaths can be taken initially, then a deep breath can be taken in while still using the mouthpiece, then another quick, full inspiration can be performed after the forced expiration.

- II. Another option is to take a deep breath in, close your mouth tightly around the mouthpiece, and then fully exhale.
- III. For the Forced Vital Capacity (FVC) and Forced Expiration Volume (FEV1) measurements, the patient inhales deeply and fully before exhaling quickly and forcefully until no more air is left.
- IV. The FEV1 and FVC manipulation yield the Peak Expiratory Flow (PEF).
- V. The participant must inhale as deeply as fully as they can, then blow continuously for as long as they can until no more air is there so as to obtain the Vital Capacity (VC). Because of the limited flow, VC requires nose clips because air can seep out.
- VI. Depending on the type of equipment being used, the Inspiratory Vital Capacity (IVC) manipulation/exercise will be carried out by inhaling deeply and quickly after fully exhaling at the conclusion of the FVC or VC as carried out by Moore (2012). This spirometry assessment was used as part of this study to measure the in-study participants.



CHAPTER THREE

METHODS

3.1. Study Area

The study was conducted at GIHOC Distilleries Company Limited located at the North Industrial area, 2 Dadeban road, in Greater Accra Region with GPS address **GA-73-4519**.

West Africa's first contemporary distillery was founded by GIHOC Distilleries Company Limited. It was founded in 1958 as the State Distilleries Corporation for the production of alcoholic drinks by the pre-independence Industrial Development Corporation (IDC). But in 1968, it was made a division of the Ghana Industrial Holding Corporation (GIHOC), as defined by NLCD 207.



Figure 2: GIHOC Distilleries Company Limited

Source: www.googleearth

3.2. Target population

The study population consisted of factory workers within GIHOC distilleries limited with emphasis on Production staff, Quality Assurance staff and technical staff on the production line.

3.3 Variables of interest

3.3.1 Dependent variables

Respiratory Health: Respiratory symptoms and investigation into the Lung function Test of participants was measured, for Normal spirometry test ($>70\%$ FEV1/FVC, $>80\%$ FEV1 and FVC) and abnormal spirometry test ($<70\%$ FEV1/FVC, $<80\%$ FEV1 and FVC) were considered.

3.3.2 Independent variables

- Social and demographic factors: marital status, age, gender, and level of education
- Lifestyle factors
- Chemical exposures

3.4 Study design

This study used an observational cross-sectional study design to examine the relationship between chemical exposure and respiratory health among workers at GIHOC Distilleries at a specific point in time. According to Setia (2016), cross-sectional surveys are particularly effective in identifying associations between exposure to hazardous substances, such as chlorine and caustic soda, and the prevalence of respiratory conditions. This design was chosen due to its cost-effectiveness and practicality, as it provides a snapshot of the current situation without requiring extended follow-up (Wang & Cheng, 2020).

The approach enabled the collection of both quantitative data, including air quality measurements and spirometry results, and qualitative data obtained through worker interviews and

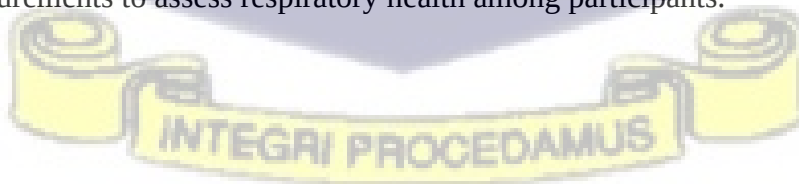
questionnaires. By integrating these data sources, the study offered a comprehensive perspective on the impact of chemical exposure on respiratory health (Creswell & Poth, 2018). The findings are crucial for enhancing workplace safety protocols and informing policy measures aimed at mitigating respiratory risks associated with chemical exposure. Consequently, the study primarily adopted a quantitative research approach.

3.5 Sampling technique

A purposive sampling method was used to select factory workers from the production line at GIHOC Distilleries, focusing on individuals with known exposure to chemicals. This sampling approach is particularly beneficial for exploratory research or studies targeting specific high-risk subgroups. Purposive sampling is frequently employed due to its strategic selection of participants who are most relevant to the study's objectives. Its adaptability allows researchers to concentrate on specific groups, such as high-risk workers or those using protective equipment, facilitating a detailed examination of key factors (Palinkas et al., 2015).

In contrast, administrative workers were recruited randomly to serve as the reference group. A simple random sampling technique was applied at this stage to ensure that each administrative worker had an equal probability of being selected. This method helps minimize selection bias and improves the representativeness of the sample (Taherdoost, 2016).

Data collection involved administering an interviewer-administered questionnaire and conducting spirometry measurements to assess respiratory health among participants.



3.6 Selection criteria

3.6.1 Inclusion criteria

Study participants were recruited having satisfied the following:

- I. Workers that were part of the production staff and are within the production line.
- II. Workers who have worked in the production line for more than a year.
- III. Duration of exposure 8 hours a day for more than 1 year.
- IV. Workers within the Administrative unit were considered as a reference group.

3.6.2 Exclusion criteria

Study participants were excluded from the study under the following considerations:

- I. Workers within the company with known chronic respiratory diseases.
- II. New employees in the company who have spent less than a year.

3.7 Sample size

Using Yamane (1973), the sample size for this study will be determined to be

$$n = \frac{N}{1 + Ne^2}$$

Where n = sample size

N = population size

e = error (0.05) reliability level of 95%

But N = 140 (Total number of workers in the target population obtained from the Human Resource Department)

$$e = 0.05$$

Therefore, $n = 140$

$$\frac{1}{1 + 140 (0.05)^2}$$

$$n = 140$$

$$1.35$$

$$n = 103.7$$

$$n = 104$$

$$10\% \text{ non-response rate} = 10 \times 104$$

$$\frac{100}{100}$$

$$= 10.4$$

$$= 10$$

Therefore, total sample size = $104 + 10$

$$n = 114$$

Twenty (20) administrative workers were randomly sampled to serve as a reference group.

Therefore, total sample size for this study was One hundred and thirty-four (134).

3.8 Data collection

Quantitative data was derived through structured and self-administered questionnaires together with mean values that was obtained from pulmonary spirometry assessment using the Spirometer.

Firstly, baseline information such as a list of workers directly exposed to the chemicals of interest was obtained from the various departments involved. Information on respiratory symptoms, including current cough, phlegm production, cough with phlegm, wheezing, shortness of breath, and chest tightness was collected by using a standardized respiratory questionnaire translated and modified from the American Thoracic Society's (ATS) respiratory questionnaire. Data collection

was based on this structured questionnaire and spirometric pulmonary functions tests (PFTs). The questionnaire also included information on individual and working characteristics (age, gender, work experience, marital status, and educational level, smoking habits (as cigarettes/day). The pulmonary function tests for both groups were performed by the same technician in all departments as carried out by Mozaffari et al., (2023).

3.9 Data processing and analysis

The data entry accuracy was checked using a Microsoft Excel spreadsheet before being sent to STATA version 17 for analysis. The data sheet was cleaned by cross-checking to find any problems before analysis started and any error were fixed by referring to the relevant questionnaire. Additionally, variables were categorized as necessary. The data were descriptively presented. The categorical data were compared with the Chi-square test. i.e., the comparison of respiratory health symptoms across demographics. The independent student's t-test and one-way ANOVA were used to compare the mean score between two or more groups. Pearson correlation was used to estimate the relationship between the lifestyle factors and respiratory health outcomes, after adjusting for potential confounding variables. A significance level of $p < 0.05$ value was adjusted in all analyses. Simple linear, multiple, and logistic regressions were carried out to determine the strength and direction between variables.

3.10 Ethical consideration

This study was conducted in accordance with the principles of the Declaration of Helsinki and ethical approvals were obtained from the University of Ghana Medical Centre's ethical review board (**UGMC-IRB/MSRC/048/2023**) as well as the Ethical Review Board of Noguchi Memorial Institute of Medical Research (**FWA 00001824/IRB 00001276**). Participants' confidentiality was maintained throughout the study, and all data were de-identified.

CHAPTER FOUR

RESULTS

4.1 Introduction

In the following section, the findings of this investigation were summarized. Tables and graphs were used to describe the findings of an investigation into the determination of the association between chlorine and Caustic soda exposure on the respiratory health of the factory workers at GIHOC distilleries.

4.2 Socio-Demographics of Study Participants

Table 1 provides a summary of the socio-demographic characteristics of the 134 people who participated in the research study that was carried out at GIHOC distilleries, an Alcohol manufacturing company in Ghana. These data offer a comprehensive view of the distribution of participants across a variety of important factors.

From the demographic data, the ages of the participants were widely distributed, with the majority lying within the age group of 23-33, accounting for 44.03% of the total study population. In contrast, the 56-66 age group make up 9.70% of the total study population with age groups 34-44, 45-55 accounting for 22.39% and 23.88% of the population, respectively.

The gender distribution revealed that females made up 44.03% of the study participants while 55.97% of the study population were males. The majority (45.52%) of study participants are married, 6.72% divorced, 2.24% separated. Singles comprise 41.0% of participants with participants cohabiting consisting of 4.48%. It is clearly shown that majority of the study participants had formal education with 38.46% university graduates, 15.38% technical school

graduates, 40.77% had secondary education, 1.54% primary education and 3.85% with no formal education.

The departmental distribution shows 46.27% production unit workers, 11.94% technical unit, 7.46% blending unit, 4.48% Administration workers, 4.48% Human Resource (Clinic workers), 4.48% Transport unit workers and others representing 20.90%.

Table 3: Socio-Demographic Characteristics of Study Participants

	Frequency	Percentage
Age		
23-33	59	44.03
34-44	30	22.39
45-55	32	23.88
56-66	13	9.70
Sex		
Female	59	44.03
Male	75	55.97
Marital Status		
Married	61	45.52
Single	55	41.04
Separated	3	2.24
Cohabiting	6	4.48
Divorced	9	6.72
Education		
None	5	3.85
Primary	2	1.54
Secondary	53	40.77
Technical	20	15.38
University	50	38.46
Departments		
Production	62	46.27
Technical	16	11.94
Blending	10	7.46
Administration (Cleaners)	6	4.48

Human Resource (Clinic)	6	4.48
Transport	6	4.48
Others	28	20.90
Total	134	100.00

4.3 Knowledge of Study Participants on Chemicals (Chlorine and Caustic Soda)

This study examined participants' knowledge on chemicals (chlorine and caustic soda) in their line of duty. Table 2 provides a detailed picture of participants' knowledge and awareness of chemicals.

Most individuals had an appreciable Chemical knowledge. A significant percentage of 55.22% respondents had a “Very good” knowledge on chemical usage, 12.68% of participants had "Moderate" understanding about Chemicals and its usage. About 15.67% of individuals were rated “Good” in their knowledge on Chemicals and their usage. 16.42% of respondents are unaware about Chemicals and their usage, suggesting that this group may need targeted education and awareness.

Table 4: Knowledge and awareness of Chemical (Chlorine and Caustic soda) exposure

	Frequency	Percentage
Knowledge on chemicals		
Very good	74	55.22
Good	21	15.67
Moderate	17	12.68
No knowledge	22	16.42
Total	134	100.00

At significance level $\alpha = 0.05$, there is no association ($p\text{-value} = 0.82$) between Number of Years at GIHOC and the knowledge and awareness of Chemical exposure. Preliminary investigation into the level of education on the Knowledge and awareness of chemical usage revealed that there is no association ($p\text{-value} = 0.15$) between educational level and the knowledge and awareness of

chemical exposure among study participants. However, frequency of chemical usage significantly ($p = 0.0139$) influenced the participants knowledge and awareness on chemical usage among study participants.

Awareness of Exposure	Education level					
	No formal Education	Primary	Secondary	Technical	University	Vocational
No	1	0	6	2	12	1
Yes	2	2	47	19	38	0

Pearson's Chi-squared test

data: D1

X-squared = 12.004, df = 8, p-value = 0.151

Awareness of Exposure	Duration at Work		
	1-2 Years	3-4 Years	More than 4 Years
No	5	4	13
Yes	21	17	74

Pearson's Chi-squared test

data: D1

X-squared = 0.39375, df = 2, p-value = 0.8213

Awareness of Exposure	Chlorine Frequency		
	Not Often	Once a while	Very Often
No	3	5	2
Yes	13	29	46

Pearson's Chi-squared test

data: D1

X-squared = 19.186, df = 8, p-value = 0.0139

Awareness of Exposure	Soda Usage Frequency		
	Not Often	Once a While	Very Often
No	3	5	1
Yes	20	23	34

Pearson's Chi-squared test

data: D1

X-squared = 15.187, df = 9, p-value = 0.08593

Table 5: Responses on effects of over exposure of chemicals on respiratory health

Awareness of Over exposure	
NO	YES
22	112
16.42%	83.58%

83.58% of the respondents are aware of the effects of the over exposure of chlorine and caustic soda on their respiratory health while 16.42% are not aware of the consequences of over exposure of these chemicals on their respiratory health.

4.4 Knowledge of factory workers on Personal Protective Equipment (PPE) and their usage

Table 6: Knowledge on PPE and its usage

	Frequency	Percentage
Knowledge on PPE usage		
Knowledgeable	82	61.65
No knowledge	51	38.35
Total	134	100.00

The participants demonstrated varying levels of knowledge regarding Personal Protective Equipment (PPE) and proper usage. A significant proportion (61.65 %) exhibited a satisfactory understanding of PPE and its applications in the workplace. However, 38.35% of the respondents displayed a lack of knowledge on the appropriate use of PPE, highlighting the need for targeted educational interventions to address knowledge gaps and improve PPE usage practices among this population.

4.5 Association between Chlorine and Caustic Soda exposure on respiratory symptoms of factory workers at GIHOC distilleries

The associations between respiratory symptoms reported by the participants and different chemicals are presented in Table 5. The chi-square test was utilised to analyse the associations, with a predetermined level of statistical significance at $p < 0.05$.

Table 7: Association between Chlorine and Caustic Soda exposure on respiratory symptoms of factory workers

	Chest tightness	Breathing difficulty	Shortness of breath	Cough
Chlorine Exposure				
Percentage	50.52	43.16	35.48	22.45
Chi2	2.4587	5.2570	4.9523	16.9380
P-value	0.4828	0.1539	0.1750	0.0002
Caustic soda exposure				
Percentage	51.16	41.86	30.23	76.74
Chi2	2.5130	6.0910	6.3180	9.7601
P-value	0.4911	0.1069	0.1101	0.0076

It is worth noting that Chlorine ($p = 0.002$) and Caustic soda ($p = 0.0076$) exposures were significantly associated with respiratory symptom Cough. On the other hand, chlorine and caustic soda exposures had no association ($p > 0.05$) with respiratory symptoms; chest tightness, breathing difficulty and shortness of breath.



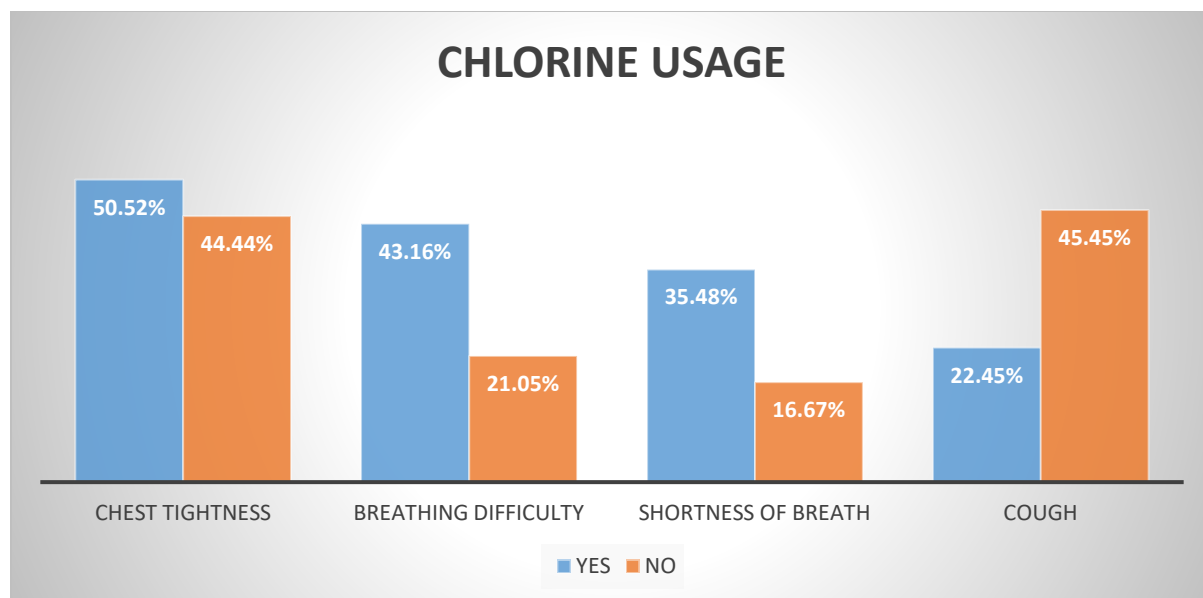


Figure 3: Bar graph of chlorine usage on respiratory symptoms

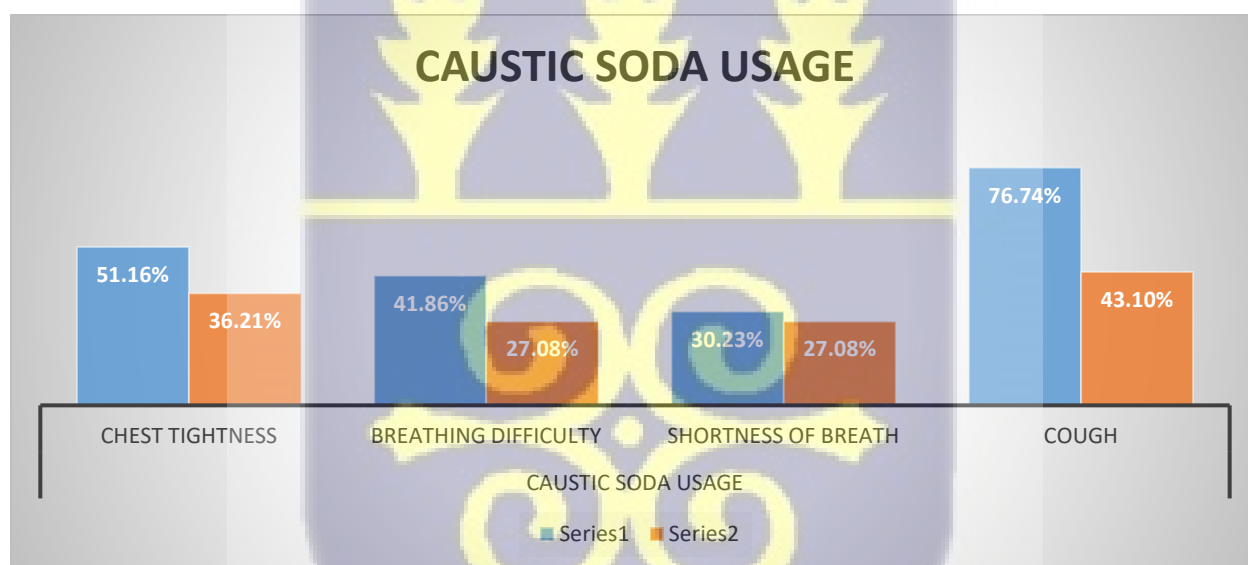


Figure 4: Bar graph of caustic soda usage on respiratory symptoms

The consistent usage of these chemicals among factory workers had a representation of 88.24% cough respiratory symptom, 49.51% chest tightness, 34.41% breathing difficulty and 30.84% shortness of breath. The chi-square test was further utilised to analyse the association between the frequency of chemical usage and the respiratory symptoms with a predetermined level of statistical

significance at $p < 0.05$. Cough was significantly ($p = 0.0222$) associated with high frequency of chemical usage whereas shortness of breath, difficulty in breathing, chest tightness were not significantly ($p > 0.05$) associated to frequent chemical usage as shown in table 6 below.

Table 8: Frequency of chemicals (chlorine and caustic soda) usage on respiratory symptoms

	Chest tightness	Breathing difficulty	Shortness of breath	Cough
Frequent chemical usage				
Percentage	49.51	34.41	30.84	88.24
Chi2	21.549	28.510	33.086	29.262
P-value	0.6062	0.2391	0.1023	0.0222

4.6 Association between socio-demographics on respiratory health of factory workers at GIHOC distilleries

Respiratory health was determined by carrying out a lung function test using the spirometer. The lung function of individuals is measured by the FEV1(L) and FVC(L). The average of FEV1(L) is **80.84** with a minimum of 42.00 and maximum of 155.00. The average of FVC(L) is **86.69** with a minimum of 47.00 and a maximum 151.00.

Table 9: Spirometry results of study participants

Mild Obstruction	Moderate Obstruction	Moderate Restriction	Normal Spirometry	Obstruction with possible Restriction	Severe Restriction	Mild Restriction	Moderate Obstruction	Moderate severe restriction
3	1	25	61	3	3	26	2	10
2.24%	0.75%	18.66%	45.52%	2.24%	2.24%	19.40%	1.49%	7.46%

The results clearly shows that **45.52%** of the respondents have normal spirometry that is a normal lung function while **54.48%** have lung function problems in various forms. 2.24% of them had Mild obstruction, Moderate obstruction is 0.75% ,18.66% had moderate restriction, 2.24% also

accounted for Obstruction with possible restriction and the same percentage for severe restriction (2.24%). 19.40% have mild restrictions, 1.49% have moderate obstruction and 7.46% accounted for moderate severe restrictions.

Table 10: Comparing the means of FEV1L and FVCL across the various departments

	FEV1L	FVCL
Production	78.53	77.53
Blending	89.3	85.2
Quality Assurance	86.2	88
Technical	88.12	82.88

The average of the FEV1L and FVCL were all normal except for those in the production unit which falls below. There is however a strong degree of association between FEV1L and FVCL with correlation measurement of +0.87. That is both of them move together in the same direction as shown in the figure below.

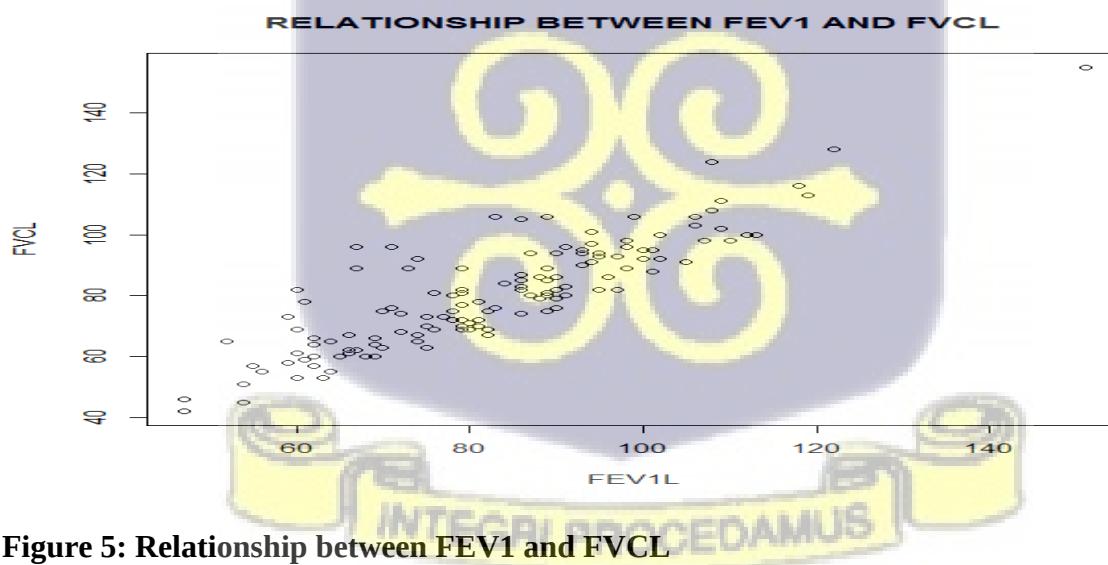


Figure 5: Relationship between FEV1 and FVCL

The Kruskal Wallis test will be used to test the significance of the differences in the averages of FEV1L and FVCL

H0: There are no differences between the averages of FEV1(L) among the various departments.

HA: There are differences between the averages of FEV1(L) among the various departments

Significance level, $\alpha=0.05$

p-value = 0.5432

Since the p-value $> \alpha=0.05$, we reject the null hypothesis and conclude that there are differences between the averages of FEV1(L) among the various departments.

H0 : There are no differences between the averages of FVCL among the various departments.

HA: There are differences between the averages of FVCL among the various departments

Significance level, $\alpha=0.05$

p-value = 0.5379

Since the p-value $> \alpha=0.05$, we reject the null hypothesis and conclude that there are differences between the averages of FVCL among the various departments.

Table 11: Comparison of the averages of FEV1L and FVCL those use PPE always and those who never use PPE

Always Use PPE		Never Use PPE	
FEV1	FVCL	FEV1	FVCL
81.08	80	59.8	64.6

Those who never use PPE are found to be at more risk than those who always wear it.

Using Welch Two Sample t-test to compare the averages of FEV1L of those who always wear PPE and those who never wear, the difference in average is statistically significant ($p=0.005829$).

In same vein, comparing the averages of FVCL of those who always wear PPE and those who never wear, there is a statistical difference ($p=0.04174$) in their average means. Therefore, the use of PPE has a significant role in the reduction of respiratory health risks of workers.

4.6.1 Multiple linear regression of demographic variables on respiratory health parameters

Table 12: Multiple regression table of demographic variables on respiratory health (FEV1 and FVC)

	FEV1	P-value	FVC	P-value
Age	0.4238	0.0430	0.394	0.0527
Department (Years)	-0.5604	0.0605	-0.337	0.2426
Bmi	-0.5764	0.1005	-0.5352	0.1167

It can be observed that, an increase in the number of years a participant spends in the department by a year reduces FEV1L by 0.5604. Also, an increase in Age by a year increases FEV1L by 0.428. Furthermore, it is reported that an increase in the BMI by a unit reduces FEV1L of study participants by 0.5764.

It can be observed also that, an increase in the department years by a year reduces FVCL by 0.3372. Also, an increase in Age by a year increases FVCL by 0.3944. Furthermore, it is reported that an increase in the BMI by a unit reduces FVCL of study participants by 0.5352.

CHAPTER FIVE

DISCUSSION

The study revealed that a significant majority (83.58%) of participants were aware of the impact of chemical overexposure on respiratory health, likely due to their frequent use of these chemicals. Over half of the participants (61.65%) also demonstrated knowledge about the use of Personal Protective Equipment (PPE) in the workplace. However, the duration of exposure or length of service did not show a significant association with the respiratory symptoms reported. Notably, the high prevalence of respiratory symptoms, particularly cough, was significantly associated with frequent usage of chemicals like chlorine and caustic soda ($p = 0.022$).

The sex distribution among factory workers at GIHOC distilleries was male dominated, 75 (55.97%) similar to a study conducted by Salami, (Salami et al., 2017) among industrial workers where male dominance was observed to be 53.12%. Schachter et al., (2009) in a meta-analysis where workers employed in organic dust industries were predominantly male (54.2%) was further reported. A similar study was carried out in Australia where participants in the Alumina refinery industry were shown to be male dominating (68%) as reported by (Fritschi et al., 2001). Among asphalt workers in Oslo and Norway, male dominance was as well exhibited (Randem et al., 2004). Industrial workers in Catalina Spain were not left out in a finding reported by Jaen et al., (2006) where study participants were male dominant. Majority of the study participants fell within the age bracket of 23-33.

The variation in participants' knowledge levels on Chemicals (Chlorine and Caustic Soda) and their usage can be attributed to multiple reasons, which demonstrate the complex nature of public awareness efforts and the spread of information coupled with inadequacy in targeted education

and training among factory workers. Majority of study participants (55.22%) displayed very good knowledge in exposure to chemicals and their usage. This could be attributed to reduced in-house trainings and education programs on chemical usage and safety among workers at GIHOC distilleries. From this study, 83.58% of study participants further responded affirmatively to knowledge on over exposure of chemicals on the respiratory health of persons which could be due to their exposure to frequent usage of these chemicals and the duration of stay at their areas of work. This is in line with the findings from a study among particleboard workers in Ethiopia which revealed that knowledge on chemicals is high among permanent workers with longer duration of work experience at the workplace (Asgedom et al.,2019). With reference to knowledge on the usage of Personal Protective Equipment (PPE) at the workplace, more than half (61.65%) of study participants demonstrated knowledge on PPE usage which was a product of the availability and supply of PPE by management as in the case reported by Asgedom et al., (2019) coupled with the provision of training on their usage. However, in another study, there was a 100% knowledge among study participants on PPE usage which is relatively higher than findings in this study (Sah et al., 2015).

The study revealed that generally all study participants reported at least one of the respiratory symptoms, which is comparable to a study conducted by De Matheis et al., (2020) among workers exposed to cleaning products. Hence, these products include dangerous qualities that could have an impact on your health through several underlying mechanisms (De Matteis et al., 2020; Minov et al., 2010). This sharp contrast could be attributed to inadequacy in supply of appropriate protective gears, non-compliance to safety rules and supervision hindrances. Chest tightness (50.52%) and breathing difficulty (43.16%) were the most prevalent issues among participants who were exposed to chlorine, with shortness of breath (35.48%) and cough (22.45%) being less

common among participants exposed to chlorine. However, study participants who were exposed to Caustic soda reported prevalence in respiratory symptoms such as Cough (76.74%) and Chest tightness (51.16%) together with Breathing difficulty (41.86%) and Shortness of breath (30.23%) being less prevalent.

The high percentage of respiratory symptoms reported in this study could be because of the frequency of usage of chlorine and caustic soda which significantly ($p=0.022$) was associated with respiratory symptom cough among study participants. Similar studies were carried out by Mashallah et al., (Mashallah et al., 2006) with a 75% response on respiratory cough. Despite the fact that 61.65% of participants used personal protective equipment, the high frequency of respiratory symptoms raises the possibility that there are additional factors at play, such as worker compliance with using the equipment (Nwibo et al., 2012). Duration of exposure (Length of service) however did not significantly associate with respiratory symptoms reported by study participants which agrees with findings from another study (Parker et al., 2006). This contradicts with findings by Anyfantis et al., (2017) who reported 9% respiratory symptom cough in the wood industry in addition to chronic sputum production (8.6%) and wheezing (5.9%) indicating potential variations between production facilities in various nations.

In this study, (45.52% of participants had normal lung function ($FEV1/FVC >80$) with 54.48% showing lung function problems in various forms. This is comparable to studies conducted by Badirdast et al., (2017) where 52% of exposed workers in the wood dust manufacturing industry in Golestan Province showed normal respiratory functions (Badirdast et al., 2017). The lung function for all workers were normal except for workers in the Production unit. It was observed that there was a significant association ($p=0.04174$) in the reduction of FEV1 and FVC values between workers who use PPEs and those who do not. Hence, negligence in the usage of

appropriate PPE and strict enforcement on the part of supervisors might have played a role in pinning production workers to the wall.



CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The purpose of this study was to assess whether manufacturing workers at GIHOC Distilleries had respiratory health issues related to exposure to chlorine and caustic soda.

The study participants were predominantly males compared to females and majority of them had formal education. Approximately half of them (55.22%) had very good knowledge on chemicals and their usage with 16.42% of respondents unaware of chemical usage. The knowledge on PPE usage was significantly higher (61.5%) among the study participants with the remaining 38.35% exhibiting no knowledge. The prominent respiratory symptoms experienced were chest tightness, difficulty in breathing, shortness of breath and cough out of which chlorine and caustic soda were significantly associated with cough among study participants. The frequency of usage of these chemicals was significantly associated with the respiratory symptoms exhibited by study participants. In addition, 45.52% of study participants showed normal spirometry results with normal lung function while 54.48% showed various forms of lung function problems especially among the production department. A significant statistical difference existed however between workers who made use of PPE and those who never use PPE as the usage of PPE had a role in the reduction of respiratory health risks of workers.

6.2 Study Limitations

This study was however met with some challenges notable among which include.

Proper health records of the participants were not assessed, hence one cannot tell if there were underlying conditions prior to the study.

Other factors that are associated with lung problems such as smoking, BMI, allergic reactions could be confounding factors.

6.3 Recommendations

The following suggestions are offered to stakeholders to consider and put into practise based on the findings from this study. The data generated would help to inform occupational health policy in such industries.

1. Even though the company's employees are subjected to a yearly periodic medical checkup, weekly or monthly monitoring of workers' respiratory ailments is necessary to support public health advocacy.
2. To effectively manage the organization's health and safety systems, management should implement a thorough Occupational Health and Safety management programme that includes frequent in-service trainings, effective awareness-raising, and strict adherence to all safety regulations.
3. It should be the top priority for production employees to monitor each other's adherence to safety regulations.



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APPENDIX A: PARTICIPANT INFORMATION SHEET

Title of Research: The Association between chemical exposure and respiratory health among factory workers at Gihoc distilleries.

Principal Investigator: Nana Amma Owusu-Agyeman

Address: Department of Biological, Environmental and Occupational Health-School of Public Health, University of Ghana-Legon.

General Information about Research

Chlorine exposures in the manufacturing and processing of various products, including plastics, rubber, metals, papers, pharmaceuticals, pesticides, cosmetics, disinfectants, batteries, antifreeze, and adhesives, can happen during the production, storage, and transportation of the substance. Employees may be exposed to low quantities of chlorine under regular operational settings. The emission of a significant amount of chlorine during an accident, however, can also result in high-level exposures. The consequences of occupational exposure to high quantities of chlorine gas on the respiratory system have been researched. The most common routes that people are exposed to toxic substances are through inhalation, direct skin or eye contact, and/or ingestion. The latter of which is more frequently associated with fatalities. A variety of respiratory tract illnesses, including tracheitis, bronchiolitis, and pulmonary edema, can result from chemicals being directly absorbed into the lungs. With this in mind, we will determine the association of chemical exposure and respiratory health among factory workers at Gihoc distilleries. This study is expected to last for two weeks, within which we will use participants will be answering structured questionnaire questions between fifteen to twenty minutes at one time point. Participant smoking and drinking habits will be sort for as well as health conditions of participants. With the aid of the mouthpiece

of a Spirometer, participants will be required to take in deep breaths and out so as to monitor lung function of participants.

Eligibility of study participants

Must be part of the production staff that are within the production line.

Must have worked in the production line for more than a year.

Must have a duration of exposure 8 hours a day for more than 1 year.

Possible Risks and Discomforts

There may be anticipated risks associated to this study within the stipulated time which include slight discomfort in inserting the mouthpiece during spirometry. Also, a brief distortion in breathing frequency may be experienced during spirometry.

Possible Benefits

There may be no direct benefits to you as an individual, however, the study will be of more relevance for policy directives on chemical usage in industry.

Confidentiality

For the purpose of this study, participant confidentiality is key and hence as a researcher, i will like to state unreservedly that, information obtained about you will be secured to the best of my ability by deidentifying responses with unique codes. For possible review and publication purposes as well, you will not be named in any reports.

Compensation

Study participants will receive a token of appreciation (in the form of GHC20 Call credit) after participation.

Voluntary Participation and Right to Leave the Research

This study involves a **voluntary** participation throughout the study as the researcher encourages. However, study participants might be excused at any point of the study without coercion when they deem it fit to.

Contacts for Additional Information

For further clarity and consultation with regards to this study, participants are encouraged to reach out to the under listed persons.

Nana Amma Owusu-Agyeman (School of Public Health)

Phone: 0240417874

Dr. Helena Lamptey (Senior Research Fellow, Noguchi Memorial Institute of Medical Research)

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Dr. John Arko-Mensah (Senior Lecturer, University of Ghana)

Phone: 0548923559

UGMC IRB Administrator

Phone: 0596993830



APPENDIX B: PARTICIPANT CONSENT FORM

The above document describing the benefits, risks and procedures for the research title **(Association of chemical exposure and respiratory health among factory workers at Gihoc distilleries)** has been read and explained to me. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree to participate as a volunteer.

Date

Name and signature or mark of volunteer

If volunteers cannot read the form themselves, a witness must sign here:

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered, and the volunteer has agreed to take part in the research.

Date

Name and signature of witness

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

Date

Name Signature of Person Who Obtained Consent

APPENDIX C: RESEARCH QUESTIONNAIRE

Section 1: Socio-demographic factors

1. Participants ID number.....
2. Kindly indicate your age
3. Please what is your gender? ☐ Male ☐ Female
4. What is your current marital status? ☐ Single/Never Married ☐ Married
☐ Divorced/Separated ☐ Cohabiting ☐ Widowed
5. What is your highest level of education?
☐ No formal education ☐ Primary ☐ Secondary (JHS/SHS)
☐ Vocational/Technical School ☐ University

Section 2: Occupational History

6. Which of the following department do you currently work in?
☐ H.R ☐ Administration and Legal ☐ Production ☐ Blending
☐ Quality Assurance ☐ Procurement ☐ Warehouse and Transport
☐ Internal Audit ☐ Security ☐ Sales
7. How long have you worked in this department?
☐ 1 -2years ☐ 2-3 years ☐ more than 3 years
8. How long do you spend in a day working in the department stated in 6 above?
☐ Less than 6 hours ☐ 8 hours ☐ 10 hours ☐ 12 hours
☐ More than 12 hours

Section 3: Knowledge on chemical exposure and Personal Protective equipment use

9. Does your work directly or indirectly involve chlorine usage?
☐ Yes ☐ No

10. How often do you use it?

☐ Not often ☐ Very often ☐ Once in a while

11. Are you directly or indirectly exposed to caustic soda?

☐ Yes ☐ No

12. How often do you use it?

☐ Not often ☐ Very often ☐ Once in a while

13. Are you aware of the effects of over exposure to these chemicals on your respiratory health?

☐ Yes ☐ No

14. Which other chemicals are you exposed to in your line of duty at work?

.....

15. Do you make use of Personal protective equipment like the respiratory protector when working?

☐ Yes ☐ No

16. How often do you use any personal protective equipment at work?

☐ Always ☐ Never ☐ Sometimes

17. Does the company provide you with any Personal Protective Equipment such as a respiratory protector?

☐ Yes ☐ No

18. Have you been trained on the use of Personal Protective Equipment?

Section 4: Self-reported health status in relation to occupation

19. In general, how would you rate your health today?

☐ Excellent ☐ Very good ☐ Good ☐ Fair ☐ Poor

20. Have you been diagnosed with any respiratory condition?

☐ Yes ☐ No

a. If yes, what condition?

21. Do you have any health condition (illness) you're aware of?

☐ Yes ☐ No

a. Kindly indicate the medical condition(s).....

b. Is the condition made worse by the work you do?

☐ Yes ☐ No

22. Do you experience any of the symptoms below? Please tick as appropriate

Symptoms	Always	Sometimes	Never	I don't know
Chest tightness				
Difficulty in breathing				
Shortness of breath				
Cough				

23. Do these symptoms stop or reduce in frequency when you're away from work?

☐ Yes ☐ No

Section 5: Life style factors

24. Do you smoke?

☐ Yes ☐ No

25. For how long have you being smoking?

☐ 1 – 5 years ☐ 6 – 10 years ☐ > 10 years

26. How many sticks do you smoke per day?

☐ < 5 sticks ☐ Between 5 – 10 sticks ☐ > 10 sticks

27. Do you consume alcoholic drinks?

☐ Yes ☐ No

28. For how long have you been consuming alcoholic drinks?

☐ 1 – 5 years ☐ 6 – 10 years ☐ > 10 years

29. How much of alcohol do you consume per day?

☐ < 5 tots ☐ Between 5 – 10 tots ☐ > 10 tots

30. Is there any other activity of yours that has the tendency to impact your respiratory health?

Please state

We are most grateful for your participation in this study. It will go a long way to assess chemical exposures on your respiratory health so as to offer the recommended safety practices.

Height (cm): Weight (kg):

Spirometry results

FEV1:

FVC:.....

.....

Overall results:



APPENDIX D: ETHICAL APPROVAL LETTER FROM UGMC



8th August 2023

Nana Amma Owusu-Agyeman
University of Ghana, School of Public Health - Department of Biological, Environmental and Occupational Health.
Address: P.O.BOX 14966
Adum-Kumasi
Phone: 0240417874
naowusu-agyeman@stug.edu.gh

Protocol Title: "THE ASSOCIATION BETWEEN CHEMICAL EXPOSURE AND RESPIRATORY HEALTH AMONG FACTORY WORKERS AT GIHOC DISTILLERIES."

Protocol #: UGMC-IRB/MSRC/048/2023

Funding Source: Self-financing
Review Date: July 12th, 2023
Effective Date: August 7th, 2023
Expiration Date: September 31st, 2024
Review Type: Expedited
Review Action: Approved

Dear Nana Amma,

Decision on your Protocol Review

On July 12th, 2023, after a review of your Protocol, the University of Ghana Medical Centre Institutional Review Board (UGMC-IRB) granted **Approval** for the above-referenced submission. Please note that the approval for this protocol will lapse on September 31st, 2024, and requires you to submit progress and final report to the UGMC-IRB.

This approval includes the following:

1. **Proposal**
2. **Work Plan**
3. **Budget**
4. **Data collection tool**

The UGMC-IRB requires you to conduct the study in accordance with the protocol and its appendices as submitted for approval and to comply with all its requirements, subject to ethical and safety considerations, including complying with ICH Good Clinical Practice.

Please contact the UGMC-IRB Administrator via **Tel: +233-(302)-550843-5 Ext.16207** or **Email: msrc@ugmc.ug.edu.gh** if you have any questions.

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Instagram: University of Ghana Medical Centre
Website: www.ugmedicalcentre.org

Sincerely,



Dr. Maurice Ankrah,
Chair, UGCM-IRB.

