UNIVERSITY OF GHANA

SUSTAINABLE WATER UTILISATION IN GHANAIAN BREWERIES: CURRENT PRACTICES AND PROSPECTS

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DECLARATION

I hereby declare that this work is the original work of Richard Rynics Atiegah under the supervision of Prof. D. K Twerefou and Prof. K. Owusu and that it has not been submitted in part or in full to this university or any other university for the award of a degree. I further declare that all references and acknowledgement have been given to the scholarly works used.

I bear the sole responsibility for any shortcomings.

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CERTIFICATION

I hereby certify that this thesis was supervised in accordance with procedures laid down by the University of Ghana.

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DEDICATION

To my family, especially my wife and children

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First, my utmost gratitude goes to God Almighty for giving me life, good health and the opportunity to undertake this study.

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ABSTRACT

Water is extremely essential for all life forms and their very existence. It is a fundamental necessity for livelihoods, economic growth, health and development and environmental sustainability. In the brewery sector, water is the single most important used raw material for production and cleaning purposes, Nonetheless, given the alarming nature of climate change, water pollution, population dynamics and land use evolutions, the brewery industry faces an enormous business risk as the diminishing of freshwater volumes pose a threat to its business continuity. Thus, breweries require a strong commitment to cleaner production processes that hinge on sustainable water management practices for continuous production.

This study investigates the patterns and current trends in sustainable water use, opportunities for optimizing water use and organizational commitment to sustainable water management using survey data from the two main breweries in Ghana for the 2015 to 2018.

Using 48 monthly specific water use data from January 2015 to December, 2018, the specific water usage for both ABL and GGBL are statistically significantly different from the international benchmark value of 6.50hL/hL at the 1% level although, ABL's average water use has a stronger significance or is more sustainable over the study period than GGBl's average water use. Furthermore, the average specific water usage for both ABL and GGBL are compared with the best technology level of 4.00hL/hL and test results reveal that during the period under consideration, ABL's average specific water usage of 4.45hL/hL is statistically significantly different from the best technology level of 4.00hL/hL whiles GGBL's average specific water usage is not statistically significantly different. Thus, considering water use at the best technology level of 4.00 hL/hL, GGBL is more sustainable than ABL.

The study recommends collaborative partnerships between the brewery industry and government agencies that will lead to the development of sustainable water usage index or a local benchmark that factors local challenges and standards for monitoring water usage in the local economy.

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LIST OF ABBREVIATIONS

ABL	Accra Breweries Limited
ABREW	African BREwery Sector Water Saving Initiative
AGI	Association of Ghana Industries
AMA	Accra Metropolitan Assembly
CCSD	Center for Climate Change and Sustainable Development
CPF	Cleaner Production Framework
CSOs	Civil Society Organizations
CSR	Corporate Social Responsibility
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization (of the United Nations)
GGBL	Guinness Ghana Breweries Limited
GSA	Ghana Standards Authority
GWP	Ghana Water Partnership
GWP	Ghana Water Partnership
hL	hectoliter
IPCC	International Panel on Climate Change
IWRM	Integrated Water Resource Management
KPI	Key Performance Indicator
NCPCs	National Cleaner Production Centers
OECD	Organization for Economic Co-operation and Development
SWU	Specific Water Use
SDGs	Sustainable Development Goals

UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USA	United States of America
WMO	World Meteorological Organization
WRC	Water Resources Commissio

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Issues on climate and weather have been critical to the story of human lives. The "International Panel on Climate Change (IPCC)" in 2007 identified that issues like extreme weather events, flood, droughts and tropical storms which are already happening across continents are expected to increase its intensity. The impact of these among others would include decreased yield from rain-fed agriculture, increased food insecurity and malnutrition, increase in arid and semi-arid land, water stress (IPCC, 2001, 2012). Humanity, therefore, face the choice of whether to "seize the opportunities of the transition to a stable climate and a water-secure future, or continue business as usual and face untold risks.

Water is fundamental to many aspects of life, and the surrounding natural environment. It is a fundamental necessity for lives and livelihoods; for economic prosperity, health and development, and environmental sustainability. It is a major natural resource that enables humans to pursue several economic activities: agriculture, domestic and industrial. "It is part of the natural capital base that underpins the production systems that" sustains livelihood (UNDP, 2006). Water is also at the heart of sustainable human development. Yet, its use is often not sustainable. Water, dependent on how it is managed, may become a vessel for social-economic development or a source of conflict between and among communities or states. For example, Iza and Stein (2009, page 17)) suggest that "how a country manages its water resources determines the health of its people, the success of its economy, the sustainability of its natural environment, and its relations with its neighbors". Hence, government play a major role in water resource management.

Governments across the globe have signed several international protocols and agreements and passed significant laws and policies as well as establishing institutions to regulate water resource use. Just like Ghana, water use in most sub-Saharan African countries is governed by both customary rights and formal rights (see UNDP, 2006). In Ghana for example, "the Water Resources Commission (WRC) was established by an Act of Parliament (Act 522 of 1996) with the responsibility of regulating and managing Ghana's water resources and coordinating government policies about them. This law provides that ownership and control of all water resources are vested in the President on behalf of the people, and clearly defines the WRC as the overall body" mandated to manage Ghana's water resources. Beside these formal institutions, other customary arrangements such as taboos and cultural practices have protected water resources over the years (Opoku-Ankomah et al, 2006). However, the social settings of an environment determine which rules and practices can offer the best results.

Beyond the efforts to manage water resources, sustainability concerns have been called to question. Such sustainability concerns are raised both at the domestic and industrial levels. Communities that received free water resource tend to misuse it whilst industries (at various sectors) also demand excessive water and in most times fail to reuse. Duncan (2020) reveals that besides the effects of climate change, one of the major challenges confronting most African countries is the issue of uncontrolled small-scale and illegal mining activities. It is worthy to note that in Ghana, the threat posed by heavy metals polluting water bodies and the deteriorating water quality due to "galamsey" or illegal mining activities has become a major public concern with discussions centered on impending potential freshwater shortage and hence its sustainable use. Sustainable water use basically refers to maintaining a balance between water supply and demand in a manner that does not pose any challenges to society, economic activities, and biodiversity (Gavrilescu et al., 2008). Breweries are a widespread industry in Africa and brewing is intrinsically a water-intensive industry." The brewery industry is known to be one of the most important water consumers (Olajire, 2012), which contributes to conflicts with communities over water supply sources. According to UNEP (2006) most breweries in Ghana, Morocco and Uganda locally compete for water resources with other industrial and urban domestic users. In view of the water shortages already experienced by many cities and planned major expansions of several breweries, this is likely to lead to future conflicts in water allocation. In Ghana, the utility companies cannot meet the water demands of some of the breweries and supplies have to be supplemented with bore water. The effect of this water extraction on other users of groundwater is unknown. Water supply from the municipality is also erratic and the breweries make use of water reservoirs to ensure a steady water supply. This makes it imperative for the brewery industry to adopt sustainable water use. However, the literature on sustainable water resource use in manufacturing industries pays little attention to the brewery sector which is the focus of this study.

1.2 Problem Statement

Since natural resources needed for economic and social development are taken from the environment, which receives as well the resulting pollutants and wastes, a constant reduction of environmental adsorption capacity and a decline of natural resources would help influence the development of the society and ensure ecological equilibrium positively (Gavrilescu et al., 2008). The main cause of environmental damage is unsustainable production and consumption by firms. The concept of sustainable production emerged at the United Nations Conference on Environment and Development in 1992. This was a key component towards sustainable development, which balances three principal requirements: the social, economic and" environmental issues (Bruntlandt, 1987; Krajnc & Glavi, 2003; Harris, 2000).

Achieving sustainable development requires changes in industrial processes, the type and quantity of water used, the treatment of wastewater and the control of emissions. Many of the present industrial systems are not sustainable in the long term because of their excessive demands for non-renewable resources (Gavrilescu et al., 2008). Society needs to rely on sustainable growth rather than destructive consumption. The achievement of such ambitious objectives requires a radical reconsideration of numerous practices of industry such as textile, food, manufacturing, and particularly the brewery. Prior studies on sustainable water use in industries suggest that several manufacturing firms are adopting new ways of incorporating cleaner production approaches in their business operations. For example, Gavrilescu et al. (2008) explore strategies on sustainable water use practices in papermaking in a Romanian mill. According to them, cost reduction is a key concern of every mill, and it is now widely recognized that minimizing water consumption provides significant cost-saving opportunities and can help to improve profitability whilst conserving the natural resource.

Given such large amount of wategr usage in the brewery industry, the United Nations Environment Programme (UNEP) references specific water use (hL water / hL beer) of 6.5hL/hL as an internationally accepted best practice benchmark level whiles 4.0 hL/hL is the best technology level of specific water use practiced in some European and Japanese breweries to enhance water sustaninability (Adewumi, Oyebode, Igbokwe & Aluko, 2011, p.171; UNEP, 2006. p.9). UNEP (2006) through the African BREwery Sector Water Saving Initiative (ABREW) study involving breweries in Ethiopia, Ghana, Morocco and Uganda reports that specific water use varies greatly between breweries in the study countries and ranges from 7.2 hL/hL in Uganda to 22.0 hL/hL in Ethiopia. The UNEP report further claimed that in the case of Ghana, specific water use was between 7.4hL/hL and 9.5hL/hL using 2005 industry data.

When the lens is focused on Africa and particularly Ghana, two main problem areas stand out for research consideration. One, the sustainable water consumption in the brewery industry and two, the threat posed to freshwater bodies by climate change and human activities. On the former, UNEP (2006) through the African BREwery Sector Water Saving Initiative (ABREW) reports that whiles sustainable water use in African breweries ranges from 7.2 hL/hL in Uganda to 22.0 hL/hL in Ethiopia, breweries in Europe and Japan are operating at the best technology level of 4.0 hL/hL. Thus, the specific water use of European and Japanese breweries is more sustainable compared to the international best practice benchmark of 6.5hL/hL whiles water use of African breweries is not sustainable with respect to the international benchmark.

Secondly, freshwater bodies are under a serious threat of drought as a result of climate change and human activities such farming along river banks, lumbering, bush burning and most importantly illegal mining activities. Duncan (2020) points out that a major challenge which has arisen in most African countries is the challenge of uncontrolled small-scale and illegal mining activities. It is worthy to note that in Ghana, the threat posed by heavy metals polluting water bodies and the deteriorating water quality due to "galamsey" or illegal mining activities has become a major public concern. As a result, some water treatment plants in the country are closed down or operated at minimum capacity.

Olu (2015) posits that the beer industry is one of the largest users of pure water. He states that even though water is a key ingredient for the making of beers, large quantities of water are used in the breweries to maintain the cleanliness of the brewing equipment. As a result, the unsustainable utilization of water in the brewery industries may affect the future of brewery industries. Water resource management has been studied in various settings and industries. These studies adopted various theoretical lenses and frameworks in their studies such as the hydro-economic model (Harou et al., 2009), the "Integrated water resource management (IWRM) (Rahaman & Varis, 2005)," adaptive governance theory (Bark et al., 2012), and the cleaner production approach (UNEP, 2007). For example, whilst Rahaman and Varis (2005) analyze the evolution of the integrated water resource management over the past three decades and highlight the prospects of the IWRM in resolving the current water crisis, Harou et al. (2009) use the hydro-economic model to characterize the economic value of water use. Bark et al. (2012) also use the adaptive governance theory to deal with uncertainty and change in water planning and allocation decisions to study: i) decision-making" and policy learning in the contexts of high levels of "uncertainty over the information base and legal and policy arrangements; and ii) institutional arrangements to coordinate decision-making and accountability across multiple decision-making units, values and jurisdictions, to accommodate indigenous water claims in" Australia and the United States of America (USA). However, in Africa and particularly in Ghana, knowledge on the practice in the brewery sector begs for understanding.

In light of the extant studies into water resource management, the literature pays limited attention to sustainable water resource use particularly in the context of developing countries, Africa, and the sub-Saharan. This research contributes to the existing body of knowledge on water resource management by exploring sustainable water use in the Ghanaian brewery industry.

1.3 Research Objectives

This study, in a broader sense, explores sustainable water use among Ghanaian brewery companies. The research sought to ascertain the current patterns and water usage within the Ghana brewing industries for a sustainable water future.

"To achieve this broader objective, the study is guided by the following specific objectives:"

i. To ascertain the current trend of water use among some of Ghana's brewery companies with reference to the United Nations Environment Programme (UNEP) international practice benchmark of 6.5hL/hL and the best technology level of 4.0 hL/hL.

ii. To identify the "needs and opportunities for optimizing water use and wastewater generation from the breweries in Ghana.

iii. To assess the organizations' commitment to sustainable water management practices.

1.4 Research Questions

To achieve the specific objectives above, this study is directed at answering the following research questions:"

i. What is the current trend of water use among Ghana's brewery industry, with reference to the United Nations Environment Programme (UNEP) international practice benchmark of 6.5hL/hL and the best technology level of 4.0 hL/hL?

ii. What are the drivers for optimizing sustainable water use and wastewater generation from the breweries in Ghana?

iii. What informs the organizations' commitment to sustainable water management practices?

1.5 Significance of the Study

This research contributes to the scanty literature on water resource management in the context of climate change and sustainable development in Ghana, a developing country. Again, the study provides climate change policy directions and contributes to climate change and sustainable development by offering alternative means of addressing water stress. Whilst contributing directly towards attaining the "Sustainable Development Goals (SDGs) 6, 9 and 12 of ensuring availability and sustainable management of water for all, Improving Industry, Innovation and Infrastructure and promoting responsible consumption and production respectively this research also contributes" to laying the initial groundwork for future research on sustainable water resource use in the manufacturing industries in Ghana.

1.6 Scope and Limitation of the Study

"This study does not claim to be exhaustive. It is limited to an inquiry into assessing" sustainable water use among some Ghanaian brewery companies. The study focuses on recent trends in sustainable water use; prospects from optimizing water use and reuse among the brewery industry; and the nature of commitment towards sustainable water management practices by recommending policy directions. In this case, challenges that impede sustainable water use in Ghana and Africa as a whole were sought without throwing into the oblivion factors that may be employed to improve the practice in these regions.

The study uses Ghana's brewery industry as a case study drawing primary data from water resource management institutions, and two (2) main brewery companies: the Accra Breweries Limited (ABL) and the Guinness Ghana Breweries Limited (GGBL). In selecting these organizations, the researcher considered organizations with a key mandate of ensuring that Ghana's natural resources, particularly, water resources are effectively managed. Aside this, the researcher also considered respondents whose activities/responsibilities are consistent with ensuring sustainable water use in the various units of the two brewery companies.

1.7 Chapter Summary and Organization of the Study

This research consists of five (5) "chapters. The first chapter forms the introductory chapter. It comprises the background to the study, statement of the research problem, objectives of the study, research questions, significance of the" study, scope and limitation of the study, and the organization of the study.

Chapter two broadly focuses on a review of relevant literature. Both theoretical and empirical literature relevant to this research were reviewed. The chapter also presents Ghana's policy on water resource management, state of sustainable water management practices and its processes and an outline of some major challenges that hinder efforts to promote sustainable water use in general and also reviews some relevant frameworks and theories that are altered based on the study findings.

The third Chapter provides the methodology adopted for this research. This chapter deals with issues such as the research approa3ewch, research design, study area, sources of data, instrument and data collection tools and data management and analysis as well as ethical considerations, among others.

Chapter four contains a presentation of data analysis and discussion of key research findings. The last chapter summarizes the findings of the research, concludes and makes specific recommendations for practitioners, academia and the general public on the subject investigated.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

While the preceding chapter presents the background and justification for this research, this particular chapter presents a literature review of the study. It discusses the extensive theoretical and empirical literature on key concepts in water resource management in the context of sustainability from different perspectives and on salient issues in order to put this study in a context. The section, foremost, introduces the concept of water resource management and use as the main issue under discussion and further emphasizes its role in the global development agenda.

Situated in the climate change literature, sustainable water use and practices in Ghana is subsequently presented. The chapter also discusses some of the contemporary approaches in adopting sustainable water use and management such as cleaner production and the Integrated Water Resource Management (IWRM). Relevant theoretical frameworks, models and tools proposed by scholars for enhancing effectiveness in the sustainable water use practices towards development and mitigating the negative impacts of climate change are also discussed.

2.1 Water Resources, Climate Change and Water Stress

Rural communities in Africa are home to most of the world's poorest people, who depend greatly on the exploitation of natural resources. Africa has about 59% of its "poor people living in rural areas, depending primarily on agriculture for food and livelihood (Hope, 2009). Water management remains central for the survival of rural people in developing counties, which depends largely on rain-fed agriculture. This is because the water in most of these communities are not processed or treated. Water is a part of the natural capital base that underpins the production systems that sustains livelihood (UNDP, 2006)."

However, recent trends in climate change pose major threats to this natural resource. This has therefore drawn the attention of international development agencies and scholars to study how this situation could be improved (see Grafton et al., 2013; Arnell, 2004). For example, over 2 billion people, representing about a third of the world's population, live in countries experiencing high water stress (UN, 2018) whiles Mekonnen and Hoekstra (2016) asserts that about 4 billion people, representing nearly two-thirds of the world population, experience severe water scarcity during at least one month of the year.

Irrespective of the nature of water source, climate change may affect the resource. For instance, with the existing climate change scenario, by 2030, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people (UNESCO, 2019). In the Antarctica, a large quantity of ice is melting making it unsafe and unsustainable for biodiversity that lives there. Similarly, the dry and sunny Sahara region also experience erratic rainfalls that pose major threats to livelihood and existing water bodies. This also makes monitoring of rainfall patterns difficult (Grafton et al., 2013). Climate change due to an increasing concentration of greenhouse gases is likely to affect the volume and timing of river flows and groundwater recharge, and thus affect the numbers and distribution of people affected by water scarcity (Arnell, 2004).

Estimates of the effect of climate change, however, depend not only on the assumed emissions scenario and climate model used to translate emissions into regional climates but also on the assumed rate of population change." Whilst some scholars blame the depleting water resource on climate changes, others disagree. Those opposing this view (see Seckler et al., 1998, 1999; Alcamo et al., 2000) assert that the depleting water resource is as a result of its use. For instance, Seckler et al. (1999) "assessed future water resource scarcity at the global scale by 2025. They assumed no climate change, and their study concentrated on the development of scenarios for water use – focusing particularly on irrigation use. In their projections of future water resources vis-à-vis water demand, they found that a quarter of the world's population or a third of the population in developing countries live in regions that will experience severe water scarcity within the first quarter of the next century. Furthermore, they found that at a global level, about 23% more water will be required under a scenario of increased irrigation efficiency compared to 56% under the business-as-usual scenario (constant irrigation efficiency).

Without factoring in the effect of climate change, Alcamo et al. (2000) also assessed future water resource scarcity at the global scale based on the assumption that a river basin is under "severe water stress" if its criticality ratio (annual withdrawals over availability) is greater than 0.4. Considering the business-as-usual scenario, Alcamo et al. (2000) uncovered that "water withdrawals in most industrialized countries decline and therefore the pressure put on water resources also declines, while, withdrawals grow in most developing countries and increase the pressure on their water resources". The study claimed that between 1995 and 2025, the areas affected by "severe water stress" expand and intensify, growing globally from 36.4 to 38.6 million km^2 whiles the number of people living in these areas also grows from 2.1 to 4.0 billion. The authors note that in Africa, the increase is especially significant in Southern and Western Africa.

Whichever way the argument is advanced, there is a fact that resources are being depleted and diminishing to a point that the available water supply may not meet both domestic and industrial demands. Hence, the need for adopting practical water resource management strategies (Grafton et al., 2013).

2.2 Water Resource Management

"Water management dates to ancient times when stone rows and ditches were used for irrigation and later aqueducts were built to carry water from the source to points of needs. The purpose of water management" has changed from the past where the focus was placed on getting water for domestic consumption, for hydropower generation and irrigation, to current dispensation where water management is not only for delivering water services, but also to balance the competing interests of stakeholders: individuals domestic needs, industry, agriculture, wildlife, and for recreational purposes (Iza & Stein, 2009). This goes a long way to maintain a good relationship "between all the users who share water resources and develop systems that will accommodate future generations."

Anowie (2012) suggests that effective water resource management that is tailored towards stakeholder participation is a necessary part of the solution to the challenge of managing the resource amid the harsh impact of climate change. Managing water resource has various dimensions: social dimension (equitable use), environmental dimension (sustainable use), political dimension (equal participatory opportunities in decision making), and an economic dimension (efficient use) (see Salame et al., 2009). Hence, the need to weave in various stakeholders representing these interests to be able to address all these four (4) dimensions. Water resource management involves the "manner in which allocative and regulatory politics are exercised in the management of water and other natural resources. This broadly embraces both formal and informal institutions by which authority is exercised (Batcherlor, 2007)."

Water use in most sub-Saharan African countries is governed by customary right and formal right (UNDP, 2006). According to Opoku-Ankomah et al. (2006), many rural communities employ flexible institutional arrangements including the use of taboos and other cultural practices to protect natural resources such as water resource over the years. The socio-cultural settings of an environment determine which rules and practices can provide the best results.

Although these informal institutions have made good efforts in improving water resource management, certain challenges inherent in the cultural relationship weaken compliance and enforcement of these customary laws.

In more recent times, however, new reforms have placed water resources in the hands of the states. The aim is to create a unified and consolidated legal framework for government to allocate water rights with limits of environmental sustainability. This is to ensure that water resources are treated with an integrated fashion (UNDP, 2006). Governments' role in water policy formation and enforcement does not rule out decentralized state-structures, the participation of the poor, nor the local level from making decisions bothering on water resource management (Brauser, 2002). This is the main tenets of Integrated Water Resource Management as espoused by Rahaman and Varis (2005).

2.3 Integrated Water Resource Management

The "Integrated Water Resource Management (IWRM) is the" main approach used to manage water resource, globally. The "Integrated Water Resource Management is defined by Ghana Water Partnership (2000) cited in Rahaman and Varis (2005:15) as "a process, which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". In their paper titled "Integrated water resources management: evolution, prospects and future challenges" which was "published in Sustainability: Science, Practice, & Policy, Rahaman and Varis (2005) emphasized that water should be managed in a basin-wide context, under the principles of good governance and public participation. Since then, this approach has been adopted and recommended by the United Nations for ensuring availability and sustainable management of water for all.

To ensure sustainability and efficient water use in the future, several studies including Mondello (2006) have called for the implementation of IWRM. The Integrated Water Resource Management seeks to reconcile basic human needs, ensure access and equity with economic development not overlooking the integrity of the ecosystem (van der Zaag, 2005). Ahead of the introduction of IWRM concepts, social and economic development and water resource management tended to be fragmented, uncoordinated, top-down approach by sectoral institutions (GWP, 2000). The concept of IWRM has been accompanied by the promotion of the river basin as the logical geographical unit for its practical realization.

In the early 2000s, several countries in Africa incorporated IWRM concept into their formal water governance structures. For example, Ghana has set up a Water Resource Commission with a cross-sectoral mandate. Other policies such as the Ghana Water Act (1998), the South African Water Act (1998), and Mali's 2007 Water Code also adopted an integrated approach to water resource management. Reports by Ghana Water Partnership (GWP) (2000) indicates that Kenya, Malawi, Mali Senegal, and Zambia also completed plans in 2008 whilst Eritrea, Mozambique, Swaziland among others are in the process of developing similar plans to embark on the IWRM approach.

However, the motivation and the rate with which the IWRM was being implemented has begun to reduce, especially in sub-Saharan Africa. Some critics believe that IWRM may work in more formalized water economies in the industrialized countries and not the informal water economies of the Global South. Hence, a renewed and growing call for a new vision of a more refined role for states, and other" players in water resource management in informal sectors in the Global South that allows community-based arrangement to play their full roles (Shah & van Koppen, 2006).

2.4 Sustainable Water Resource Use

Sustainable use of water resource is critical to the survival of human and industrial operations. Gavrilescu et al. (2008) including several other studies have examined sustainable water use in industries. According to them, the manufacturing process is one of the most important water consumers in the world. In the manufacturing sector, water "resources needed for economic and social development are taken from the environment. However, the environment is bombarded with pollutants and waste materials from economic activities and as a result, triggers a constant reduction of environmental adsorption capacity and causes a decline of water resources. Subsequently, the decline in water resources influence the development of society and the ecological equilibrium, thereby making unsustainable production and consumption processes the main cause of environmental damage.

Practices that are consistent with sustainable development appears to be the way forward. Achieving sustainable development requires changes in industrial processes, the type and quantity of water used, the treatment of wastewater, the control of emissions, and the products itself. Many of the present industrial systems are not sustainable in the long term due to excessive demands for natural non-renewable resources. Society needs to rely on sustainable growth approaches rather than destructive consumption. The achievement of such ambitious objectives requires a radical reconsideration of numerous practices of industries.

Within the framework of sustainable development, water and its management play a major role, not only because water is and always has been an essential resource for the existence and evolution of living matter and human activities but also due to its importance for the social and economic development (Teodosiu et al., 2003; Culabra & Purvis, 1999). Sustainable development assumes a continuing equilibrium between ecological, economic, and social development and the fact that any disturbances from this equilibrium lead to environmental damages, economic decline and social unrest" (Gavrilescu et al., 2008). In the context of paper production. Gavrilescu et al. (2008) found three ways through which water resources may be conserved and sustained: i) reducing the outflow of wastewater in papermaking processes; ii) pollution preventive approaches; and iii) adopting integrated processes.

2.4.1 Reducing outflow of wastewater

Reducing effluent in manufacturing processes involves designing a strategy for reuse, generation reuse, and "regeneration recycling of wastewater streams with the aim to minimize water consumption and wastewater discharge. A major challenge is that wastewater discharge from manufacturing facilities often comprises of diverse contaminants such as ions, salts, colouring/bleaching agents, and organics which have severe negative impacts on the ecology. This should be reduced by recycling, reusing and detoxifying towards sustainable water use.

2.4.2 Pollution preventive approaches

In order to determine optimal strategies for water consumption and discharge in processing industries, it is crucial for firms to develop a comprehensive, generic approach to water management and pollution prevention which incorporates economics, reliability and product quality along with maximizing the use of already available process internal resources. In recent times, new methodologies have been developed which are capable of systematically minimizing waste and improving the overall process efficiency. Water conservation and source reduction are interconnected. Source reduction initiatives may result in less wastewater to be treated or disposed resulting in less sourcing, smaller volumes of hazardous wastewaters, and potentially enabling more efficiency.

2.4.3 Adopting integrated processes

According to Gavrilescu et al., (2008), pollution control technology should process waste until it was benign enough for discharge. This is achieved by dilution, destruction, separation, or concentration. Although end-of-pipe recycle/reuse systems provide an attractive approach for wastewater loading minimization, the source reduction perspective involves a greater economic incentive. Industries tend to be reorganized in an integrated process into clusters in which the wastes or by-products of each industrial process are fully matched with other industries' input requirements. They must use processes that deploy materials and energy efficient enough to neutralize contaminants in the waste stream. This approach must incorporate economics, reliability and product quality along with maximizing water use."

Dave and Nalco (2004) argue that global freshwater consumption quadrupled in the last 50 years. In the year "2000, about 5,000 km^3 freshwater was used of which 70% was used by agriculture, 20% by industry, and 10% by domestic uses.

During industrial manufacturing processes, the three major resources are energy, water, and chemical entities, and the undesirable outputs are airborne contaminants, wastewater, and sludge. When the economic intensity of water and energy for different industries is assessed, pulp and paper and petroleum refining are the largest consumers of water and energy in the manufacturing sector (Gavrilescu et al., 2008). What about the situation in the brewery industry? Although studies are limited in the brewery sector, there is the need to encourage a shift towards more "sustainable approaches to water use and management. Consequently, the World Summit on Sustainable Development in 2002, recommend all countries to develop an Integrated Water Resource Management (IWRM) and water efficiency strategy by 2005 to promote health, agriculture, energy and biodiversity. In this particular research, recent patterns and sustainable water use practices among Ghanaian brewery companies are explored.

2.5 The Context of the Brewing Industry

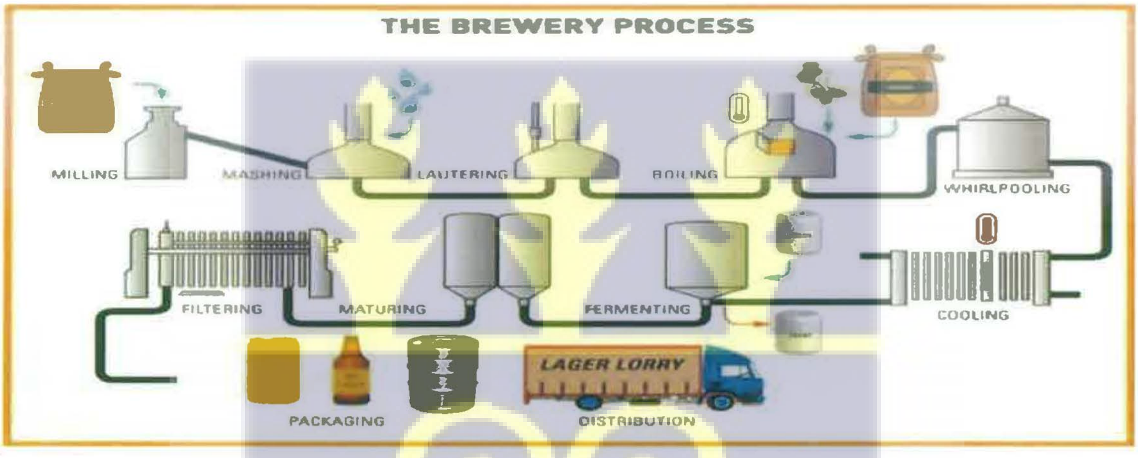
Globally, the brewing industry is one of the largest industrial users of water. Amid the significant technological improvements over the last 20 years, energy consumption, water consumption, wastewater, solid waste and by-products and emissions into the air remain major challenges in the brewing industry (Olajire, 2012). According to the FAO (2003), the brewing sector, among the food industry, holds a strategic economic position with annual world beer production exceeding 1.44 billion hL in 2002, whiles Conway (2019) notes that in 2018, the global beer production amounted to about 1.94 billion hectoliters. Beer is the fifth most consumed beverage in the world besides tea, carbonates, milk and coffee and continues to be a popular drink with an average consumption of 9.6 L/capita by population aged above 15 (OECD, 2005).

Brewing is intrinsically a water intensive industry. The production of beer involves blending extracts of malt, hops and sugar with water, followed by its subsequent fermentation with yeast (see Wainwright, 1998). In the process, large quantities of units after each batch are completed. A large amount of this water is discharged to the drains. The main water use areas of a typical brewery are brewhouse, cellars, packaging and general water use (Olajire, 2012). According to Olajire (2012), water usage attributed to these areas includes any water used in the product, vessel washing, general washing and cleaning – which are of considerable importance both in terms of water intake and effluent produced (see also van der Merwe & Friend, 2002). Given such large amount of wategr usage in the brewery industry, the United Nations Environment Programme (UNEP) references specific water use (hL water / hL beer) of 6.5hL/hL as an internationally accepted best practice benchmark level whiles 4.0 hL/hL is the best technology level of specific water use practiced in some European and Japanese breweries to enhance water sustaninability (Adewumi, Oyebode, Igbokwe & Aluko, 2011, p.171; UNEP, 2006. p.9). UNEP (2006) through the African BREwery Sector Water Saving Initiative (ABREW) study involving breweries in Ethiopia, Ghana, Morocco and Uganda reports that specific water use varies greatly between breweries in the study countries and ranges from 7.2 hL/hL in Uganda to 22.0 hL/hL in Ethiopia. The UNEP report further claimed that in the case of Ghana, specific water use was between 7.4hL/hL and 9.5hL/hL using 2005 industry data

2.5.1 Water Use in the Brewery Process

In order to understand water conservation in the brewery process, it is first important to understand where water is used. Figure 1 depicts the basic brewing process, which uses water at nearly every stage

Figure 2.1: The Beer Brewing Process



Source: http://ibdasiapac.com.au/brewing-and-distilling-process

The first point at which water is used in the beer brewing process is the cleaning process which includes washing the grain, with water, before it is milled. During milling, the malted grain is ground, and then placed in water for hydration. When it has absorbed an appropriate amount of water, it can be milled and turned into a mash. Water, yeast, Mazie grist and sugar are then added to speed the fermentation process. After ketteling, brewing, cooling, and fermentation, it can be watered to the appropriate strength, and placed in kegs or bottles for distribution

(Pitock, 2015). Each of these stages, which require water to be added directly to the mixture for the beverage, require the use of fresh-drinkable water.

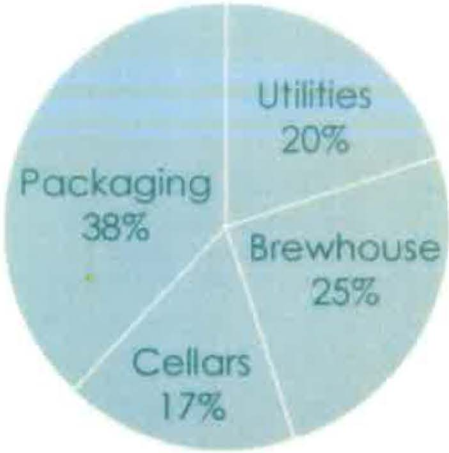
However, these are not the only ways that water is used in the process. Water is needed to cool equipment, is lost to condensation during brewing, is used in the bathrooms of corporate facilities, and more. This water can often be recaptured and reused for other non-food related tasks to decrease emulsion.

More specifically, evidence demonstrates that breweries use various rates of water consumption ranging from four to 11 litres of water, per litre of beer produced. Of the water consumed, two-thirds is directly used in processing, with the remainder used in cleaning and sanitation (Moll, 1991; Perry & De Villers, 2003). Correspondingly, waste is created by both production and sanitation

2.5.2 Trends in the quantity of water utilized in manufacturing of beer

Large quantities of water are often utilized in the production of beer as a result of the batch-type operations employed by breweries to process the raw materials to batch is completed (Van der Merwe and Friend, 2002). The brewing industry has record the final beer product, as well as for washing, cleaning and sterilizing of various units after eased high ratios of water used in beer produced for many years and it can be as high as 10:1 in sites with a large proportion of small pack production, and as low as 5:1 on some traditional brewing sites (Crispin, 1996).

Figure 2.2: Typical brewery water use per area



Water use per department hl water / Total beer

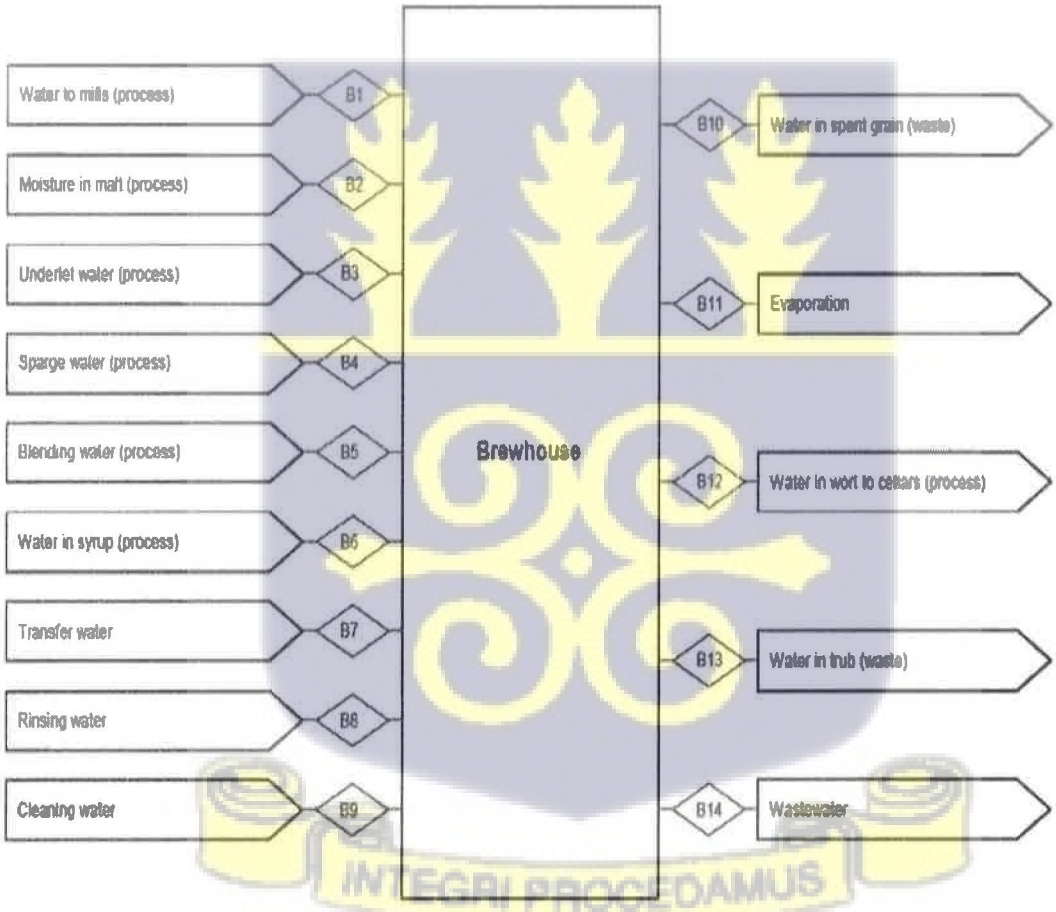
Source: Brewers Association Manual (2013)

The Brewers Research and Education Fund (BREF) (2006) and the European Brewery Convention (EBC) publication (1990), disclosed the usage of water as distributed within a typical brewery in Figure 2.2 where we can express the volume ratio of water consumed per volume of the produced beer or the sold beer which is a function of the technical standard of each unit or department, making up the overall brewery process (Tokos & Glavič, 2007).

Van der Merwe and Friends (2002) had a different record of 1.36 hectolitre of water per hectolitre of beer produced as the overall water balance ratio used at the brewhouse as shown in Figure 1.0 with a breakdown of the consumption of water used by each component of the brewhouse at the brewery. These components consist of the Mills, Mash tun, Lauter tun, Underback, Wort kettle, Whirlpool and relevant storage vessels meant for the addition of hops and syrup. In order to optimize the extraction of soluble substances like starch and protein from the malt, the malted barley, which has water in its composition, is milled and now termed grist.

Furthermore, water is mixed with the grist (after exiting the milling chamber), before being transferred to the Mash tun for conversion to a fermentable extract and later moved to Lauter tun which has water in its content already (a process described as Underletting) while in the Later tun, a process known as Sparging gulps 41,760 hl of water. Thereafter, while in a vessel called Underback which accommodates the extracted mash liquor temporarily, some quantity of blending water is added to the Wort. An amount of water is then used to transfer between the vessels the resultant product derived from the wort kettle and during Clean-in-place (CIP) cycle (Van der Merwe and Friends, 2002).

Figure 2.3: Overall water balance for the brewhouse



Source: Van der Merwe and Friends (2002)

Tokos & Glavič (2007) had a similar discovery in his research as recorded by Brewers Research and Education Fund, BREF (2006), revealing the water usage in litres per litre of beer produced at the department from the Brewhouse to wort cooling and Clean-in-place (CIP) systems to be within the range of 1.3 – 2.36 (L/L) (Tokos & Glavič, 2007).

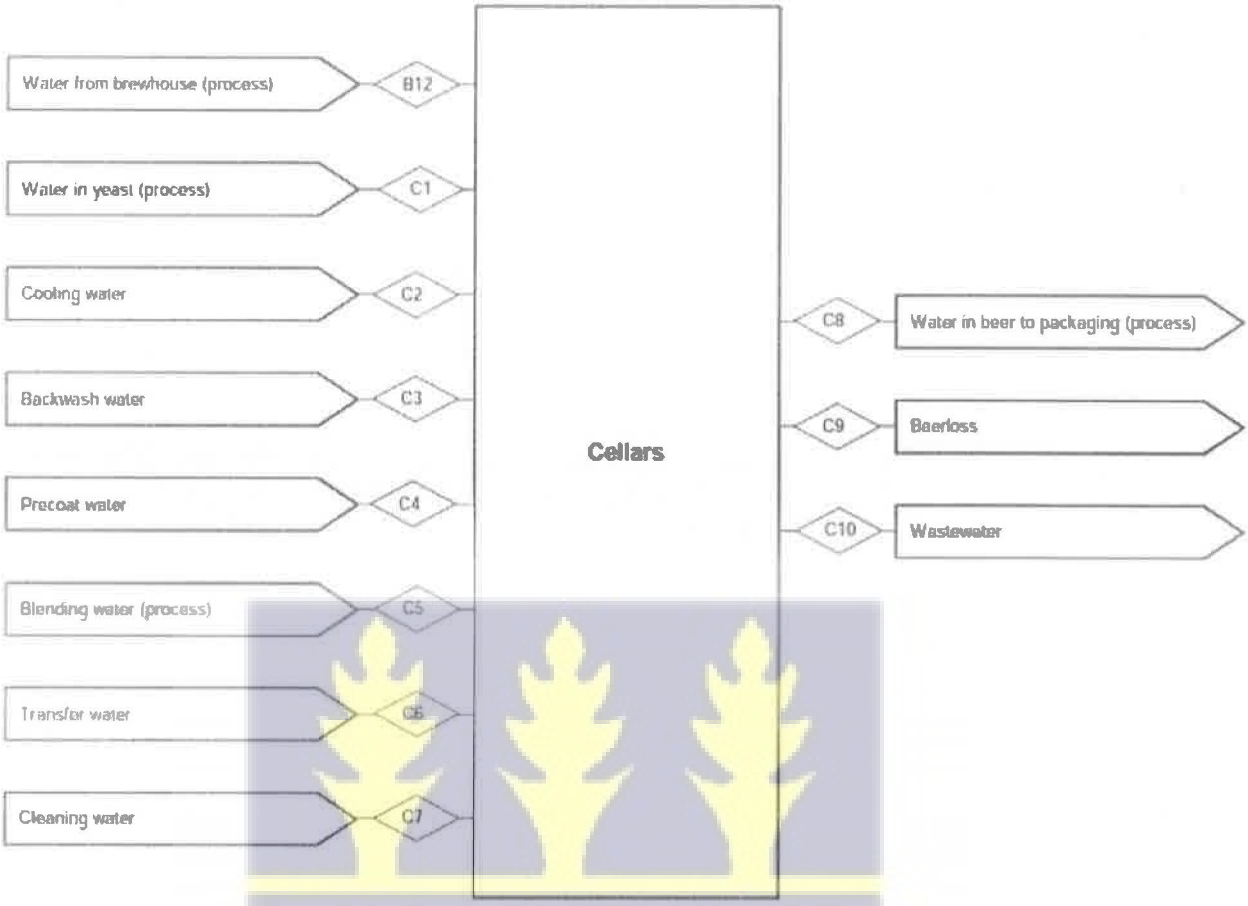
2.5.3 Water usage in the cellar

The cellar is a component of operations during the brewing process which is a continuation of the process accomplished at the Brewhouse. In this department, fermentation and yeast handling with CIP, maturation with CIP, and thirdly, filtration and bright beer tanks (BBT) with CIP experienced water usage ratios per litre of beer produced within the range of 0.32 – 0.53 (L/L), 0.24 – 0.67 (L/L) and 0.31 – 1.09 (L/L) respectively as revealed by the BREF (2006) and Tokos & Glavič (2007).

After wort cooling, yeast pitching is the next operation in the cellar where water is added to the wort while fermentation follows and at the end of fermentation, a product termed green beer is derived and sent to the storage vessels for maturation via the racking process (which involves centrifugal separation, chilling and carbonation steps). This process prompts an addition of cooling water transferred through the shell of the centrifuge and discharged to the drains in order to avoid the damage of the centrifuge (Van der Merwe and Friends, 2002).

Water is also used during the pre-coating process and backwashing and a quantity of de-aerated carbonate water is also added to correct the alcoholic content of the high-gravity beer which is later stored in bright beer tanks (BBT) till when it will be packed into containers for distribution and consumption. For cleaning the vessels and transferring between the vessels a quantity of 38,010 hl and 14,912 hl of water is utilized respectively and at the end of the cellar operations, 0. 89 hl water/ hl packed beer was used (Van der Merwe and Friends, 2002).

Figure 2.4: Overall water balance for the Cellar



Source: Van der Merwe and Friends (2002)

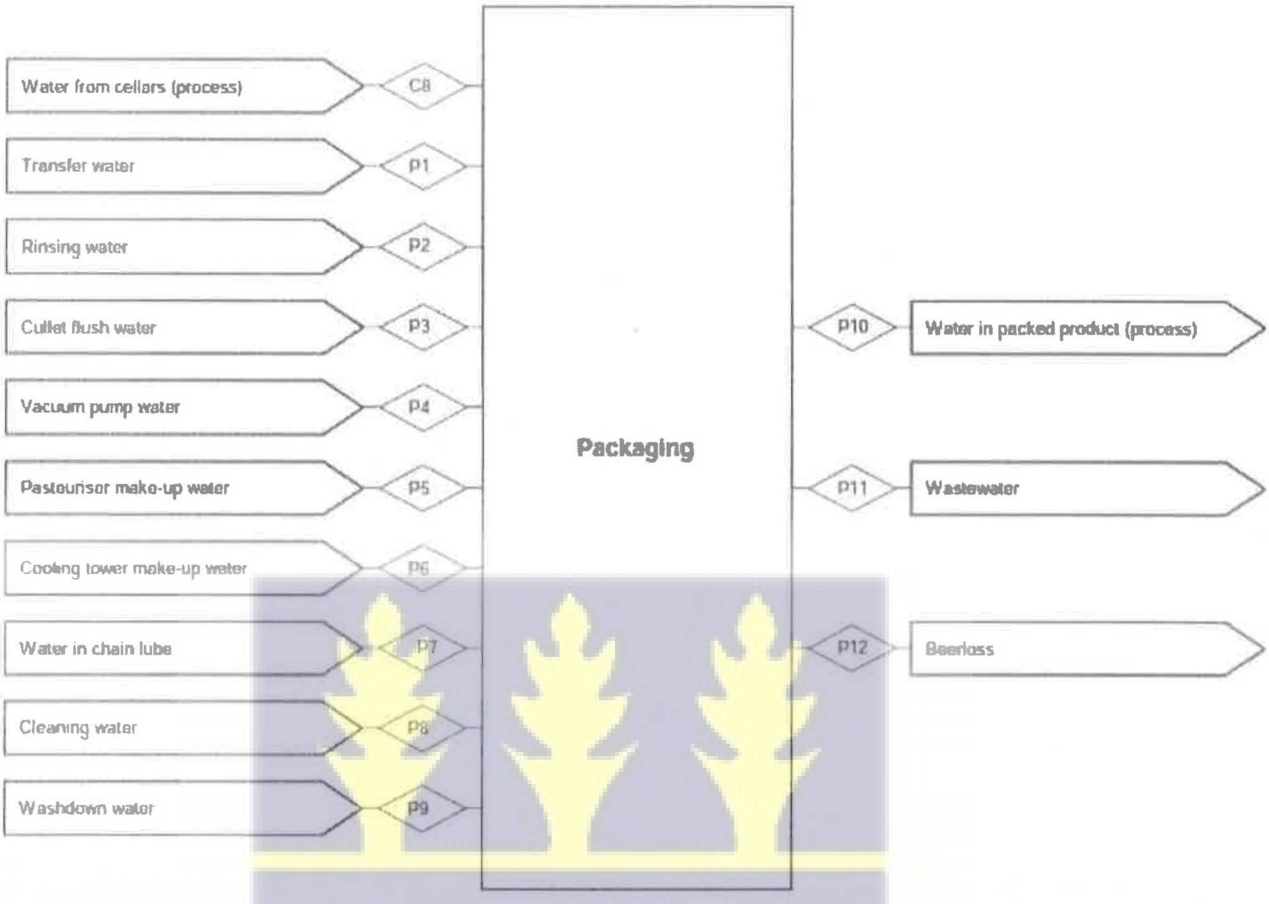
The German brewery industry reported that the process steps of wort cooling, fermentation cellar and yeast treatment, filter and pressure tank room and finally, storage cellar recorded water consumption per sold beer, as stated in the figure above, of 0.0 within a range of 0.0 – 2.4 (m3/m3), 0.6 with a range of 0.5 – 0.8 (m3/m3), 0.3 with a range of 0.1 – 0.5 (m3/m3) and 0.5 within a range of 0.3 – 0.6 (m3/m3) respectively (World Bank, 1998). This shows from the compared research works that a reduction in water usage during cellar operation was experienced per volume of beer produced or sold by the breweries.

2.5.4. Water usage during packaging

In 1998, the World Bank "Pollution prevention and abatement" handbook revealed that during the packaging operations, bottling consumes 1.1 cubic meters of water per cubic meter of beer sold while barrel filling used 0.1 (m^3/m^3).

In Van der Merwe and Friends (2002) research work, it was discovered that the packaging operations consume an overall of 153,290 hl water to pack 104,016 hl of beer with a water ratio at the packaging section as 1.47 (hl/hl). The sections of these operations that consumed water include; water used by the vacuum pump, the amount used to flush broken glass or cullet from the filler, to make-up the levels within the pasteurizer and to the cooling towers, the quantity utilized in washing and rinsing containers and crates and in transferring the beer to the filler up to the water used for wash down of equipment used in production as disclosed in figure 6 below (Van der Merwe and Friends, 2002).

Figure 4.0: Overall water balance for the packaging section



Source: Van der Merwe and Friends, (2002).

According to the Brewery Research and Education Fund (2006), Bottle washing and keg washing utilized a range of 0.59 – 1.63 (L/L) and 0.13 – 0.61 (L/L) respectively, as per water usage in packaging the beer produced (Tokos & Glavič, 2007) which is a remarkable improvement in conserving water during brewing process.

2.5.5. *General Water usage*

The quantity of water used for wash down and other losses are considered as part of general water. General water is an additional water for production with a total of 104,413 hl used to supply 10.702 hl water to the brewhouse, 6,250 hl to the cellars and 26,250 hl to the packaging section with 40,476 hl evaporated at the engine room and boiler house as well as 20,735 hl discharged to the drain which eventually resulted into 1.00 (hl/hl) water used in these operations for beer production (Van der Merwe and Friends, 2002).

The water consumption reported for the German Brewing Industry revealed the general water usage and their ranges per cubic meter of beer sold (m3/m3) to include; 1.5 (1.0 – 3.0) for wastewater from cleaning of vehicles, sanitary use etc., 0.2 (0.1 – 0.3) for steam boiler and 0.3 (0.1 – 0.5) for air compressor (World Bank, 1998).

The reviewed research works have unleashed that, quite a number of factors could influence water usage in beer production and consequently profit in the production of beer.

2.6 A Brief History of Breweries in Ghana

2.6.1 Guinness Ghana Brewery Limited

Guinness Ghana has three sites, namely Achimota, in Accra, Ahensan and Kaase in Kumasi. Guinness Ghana Breweries Limited (GGBL) emerged out of a merger of Guinness Ghana Limited (GGL) and Ghana Breweries Limited (GBL). To understand the history of GGBL it is necessary to provide separate information on GGBL and GBL before 2004, the year in which the merger process commenced.

Guinness Ghana Limited was incorporated as a private company in 1960 and was listed on the Ghana Stock Exchange in 1990. Upon incorporation, Guinness Ghana Limited had the mandate to manage the importation and marketing of Guinness Foreign Extra Stout in Ghana. The shareholders were Guinness Overseas Limited (67.5%) and Atalantaf, a Bermudan Company (32.5%). In 1971, a brewery was designed and constructed in Kaasi, Kumasi. Beer production commenced on November 11, 1971 with an installed capacity of 100,000 hectolitres.

By 1977, the brewery was producing at maximum capacity. In 1976 Government of Ghana by an Investment Policy Decree acquired 40% of the shareholding in the Company. Other shareholders were Guinness Overseas Limited (28.68%), Atalantaf Limited (16.32%), Individuals (12.72%), Institutions (1.18%) and Employees (1.10%). The shareholding structure changed again when the Government of Ghana divested its holding in the 1990s.

In May 1995, Guinness Ghana invested 18 billion cedis to expand its packaging capacity and commissioned a 40 billion cedis fully automated brewhouse facility using state of the art brewing and process control technology in July 1999. This process allows product testing at every stage of the brewing process, thus delivering world-class purity and excellence throughout. In November 2003, Guinness Ghana commissioned a second state of the art packaging line at a cost of 165 billion cedis.

Guinness Ghana initially produced Foreign Extra Stout only. In 1989 it introduced Malta Guinness, a non-alcoholic beverage that was later produced in other markets in Africa. By the close of 2003 the Company had a range of products covering stout beer, malt drinks and ―ready-to-drink‖ market. In 2003 financial year Guinness Ghana produced 576,000 hectoliters of its products. As at 31 December 2003, the Company had a volume share of 31.3% of the combined beer and ―ready-to-drink‖ market and 72.7% of the malt drinks market (as per AC Nielson data)

As at 30th October 2009, the range of Guinness Ghana Brand products covering: Mini Star, Gordon Spark, Star Large, Malta Guinness Quench, Amstel Malta, Malta Guinness can, Malta Guinness, Malta Guinness Quench can, Gulder Large, Heineken can/bottle, Guinness FES, Star Draft 30L Keg, Smirnoff Ice, Guinness FES can, Alvaro and Smirnoff /J& B /Gordon's data). Guinness Ghana Breweries Limited becoming a total beverage business by bringing the Diageo

Spirit Brands into the GGBL portfolio. These branded products that is being imported and sold on behalf of other companies are Johnny Walker (Red or Black), Baileys/J&B.

2.6.2 Ghana Breweries Limited (GBL)

Ghana Breweries Limited was incorporated on 30th April, 1992 under its previous name, ABC Brewery Limited. On 26th October 1994, it acquired the assets of Achimota Brewery Company Limited, a state-owned enterprise operating at Achimota, Accra. In October 1997, Heineken International acquired 90% of the outstanding ordinary shares of ABC Brewery Limited and subsequently renamed the company Ghana Breweries Limited. Ghana Breweries than merged with Kumasi Brewery Limited, a brewing company established in May 1959, with effect from 1st January 1998. Before this merger, Heineken and its wholly-owned subsidiary, Limba Ghana Limited, held 50.26% of the issued shares of Kumasi Brewery Limited. In June 2003, Ghana Breweries underwent a capital restructuring exercise. Consequently, the stated capital of the Company increased from 74.4 billion cedis to 144 billion cedis. Heineken Ghanaian Holdings held 75.59% while institutional and individual investors held 24.41% of the Company's shares.

Ghana Breweries' range of product covered beer (lager), malt drinks and soft drinks. As at 31st December 2003, had a volume share of 39.5% of the combined beer and ready -to-drink-market and 23.3% of malt drinks marker (according to AC Nielson data).

In 2004 Guinness Ghana Limited and Ghana Breweries Limited began a merger process. Up to 2007, the two companies transacted business together as two separate legal entities under the new name: Guinness Ghana Breweries Limited. The merger process ended when Guinness Ghana Breweries Limited acquired all the assets of Ghana Breweries Limited in 2008.

2.6.3 Accra Brewery Limited (ABL)

Accra Brewery Limited is a Ghana-based company primarily engaged in the beverage industry. Its main activity is the manufacture and distribution of beer, sparkling soft drinks and non-alcoholic malt beverages. The Company's portfolio of product includes Stone Strong Lager, Castle Milk Stout, Club Beer, Castle Beer, Club Shandy and among others. The Company's ultimate holding company is Anheuser-Busch (AB) InBev (ABInBev) after it acquired SABMiller Plc.

Starting in the early 1930s, Overseas Breweries Ltd., a Swiss company, purchased a piece of land overlooking Agbogbloshie in Accra for the construction of a brewery. The Nathan Institute of Zurich, Switzerland, was contracted to see to the general supervision of all construction works, installation of plant and machinery, and brewery technology. The building contract, meanwhile, was awarded to Turner & Schilling, a local firm who, with the assistance of over 500 workers, completed all the buildings for the official opening. The Governor of the Gold Coast, Sir Shenton Thomas, inaugurated the Brewery, setting it up as the country's first non-traditional manufacturing company. In the first year of operation, a quantity of 24,411 cases, or 8,878hl of beer and 2,076 dozen of soda and mineral water were sold. This was just enough to break even: for 1933/34, the books showed a moderate profit. The following year, sales made was 54,102 cases of beer, also equal to 19,500hl and 6,795 dozen soda and mineral waters which meant that we produced nearly at as full as the installed capacity for the whole year which was about 20,00hl. From 1935 onwards, the Board was able to repay its capital debts and declare a modest dividend of 7% of the equity capital.

The company's ownership was revised in 1975 following the passage of an Investment Law. Consequently, Overseas Breweries Ltd. acquired 45% shares, the government of Ghana bought 40% shares, and the remaining 15% shares were floated to the Ghanaian public. In view of this new arrangement, Sekar Limited was brought in as Technical Management, formally heralding the new and current identity as Accra Brewery Limited (ABL).

In 1997, SABMiller PLC {then South African Breweries (SAB)} acquired controlling shares of ABL through its acquisition of Overseas Breweries Ltd. The acquisition and subsequent infusion of capital and expertise propelled the brewery into the new millennium. Product range expanded with the introduction of Castle Milk Stout, and very recently, Beta Malt, unto the Ghanaian market. Capping this era is the million-expansion project that has resulted in the construction and installation of three new packaging lines; warehouse with hardstand and loading area; electricity substation; two additional power generators; ten new beer tanks; two additional water storage tanks; a water treatment plant; sidewalks for location road; and a new entrance with gatehouse and offices. The expansion was necessary and urgent as a result of the increasing need to meet consumer demands. In October, 2016, ABL became a member of the Anheuser-Busch (AB) InBev family after it acquired SABMiller Plc.

2.7 Theoretical Framework

In this section, the theoretical foundation of this research is discussed. Here, the researcher reviews several relevant theories that have been applied to sustainability and water resource management studies and how they may apply to the objective of this research.

A review of prior literature suggests that water resource management has been studied in various settings and industries ranging from agricultural, food and beverage, and paper manufacturing, among others.

2.7.1 The Cleaner Production Framework (CPF)

For the purposes of this study, the Cleaner Production Framework (CPF) by the United Nations Environment Programme (UNEP) (2007) is used as the analytical lens. According to UNEP (2007) Cleaner Production is "the continuous application of an integrated, preventive strategy applied to processes, products and services in pursuit of economic, social, health, safety and environmental benefits". In other words, cleaner production can also be said to be the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to human health and the environment. As an approach to improving industrial processes towards sustainability and efficiency, the CPF is a framework that hinges on a "prevention is better than cure" strategy. For production processes, cleaner production includes conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes before they leave a process. For products, the strategy focuses on reducing impacts throughout the life-cycle of the product, from raw material extraction to ultimate disposal.

Adoption of cleaner production principles reduces waste and this, in turn, results in lower environmental impact and occupational risks. Cleaner production also reduces the cost of wastewater disposal by reducing the volume and strength of effluents that need to be treated. Cleaner production framework therefore holds significant promise in the preliminary stage of designing treatment works.

One of the major proponents of this framework, Silva et al. (2013) in their paper published in Journal of Cleaner Production, posits that although the CPF is hailed for the several economic, environmental and social benefits, its implementation is a challenge. The authors therefore propose a new Clean Production methodology that is enhanced by a systematic integration of quality tools that helps to overcome the aforementioned problems. According to Silva et al.

(2013), the use of these tools can enhance nearly all steps of a Clean Production approach including the planning stage, which is crucial for the success of a Clean Production program.

According to UNEP (2007), cleaner production can be achieved in a number of different ways. The three most important are:

1. Changing attitudes
2. Applying know-how
3. Improving technology

It is important to stress that cleaner production is not simply a question of changing technology: changing attitudes means finding a new approach to the relationship between industry and the environment. Simply re-thinking an industrial process or a product in terms of cleaner production may produce the required results without introducing new technology.

It is also important to stress that the preferred cleaner production option will always be reduction of waste at source. Breweries are characterized by significant resource consumption, but very limited utilization of environmentally hazardous components. Cleaner production in breweries therefore focuses on minimization of resource consumption, process efficiency, and, to a smaller degree, product substitution. A brewery's resource consumption is influenced by actions in three different functional areas, as shown in Table 1.1 below.

Table 2.1: Areas in which resource consumption may be reduced

Process	**Ancillary operations**	**Management**
Production methods	Operations	Target-setting
Operations	Individual system design	monitoring
System design	Maintenance	control
Maintenance	Training	responsibility allocation
Training		Training

In general, breweries with a relative high unit resource consumption can immediately achieve a substantial reduction by addressing management issues and small changes in ancillary operations and process systems. Breweries with relatively low consumption need to begin by focusing on all three functional groups in detail.

Upgrading a brewery, in order to reduce resource consumption, requires actions in three areas:

1. Training
2. Engineering
3. Plant equipment

It should be stressed that taking action in one of these areas without complementary actions in the other two may greatly reduce their effectiveness. On the other hand, there is a large potential for synergies through combining actions in these areas. There are a number of technologies available to reduce resource consumption and emissions within breweries. In addition, there are management options that should be considered. Activities with respect to cleaner technology and environmental management need to be coordinated. The construction of a new brewery, or major refurbishment of an existing one, offer possibilities for reducing consumption of resources in a cost-effective manner. In an existing brewery, increasing efficiency requires a concerted effort from all departments.

Cleaner production is an approach to improving industrial process efficiency. Adoption of cleaner production principles reduces waste and this in turn results in lower environmental impact and occupational risks. Cleaner production also reduces the cost of wastewater disposal by reducing the volume and strength of effluents that need to be treated. Cleaner production is thus a useful preliminary stage to designing treatment works.

2.8 Empirical Review

Water management is expected to take a more pronounced role amongst the metrics for sustainability (Refalo & Zammit, 2013). Assessing the role of water in manufacturing, Dupont & Renzetti (2001) adopts a Capital, Labour, Energy and Materials (KLEM) model of the sector's technology on two facets of water use which includes: intake and recirculation. The authors pooled three annual cross-sectional surveys on plant-level water use together with census data to estimate an extended model for the Canadian manufacturing sector over the period 1981–1991. Inference drawn from statistical tests supports denoting water intake as a variable input. It was found that water intake is a substitute for water recirculation, energy, labour and capital and thus, the relationship between water intake and recirculation is stronger when water intake is process-related rather than related to cooling and steam production. Dupont & Renzetti (2001) further added that Technological change has been biased in the direction of increased water intake and decreased water recirculation.

Taking into account sustainable water management in the brick-manufacturing industry, an intensive water-consuming industry that requires a sustainable and integrated water management strategy to reduce reliance on freshwater consumption, Skouteris, Ouki, Foo, Saroj, Altini, Melidis ... & O'Dell (2018) developed a rigorous analytical tool based on water footprint principles and water pinch analysis techniques that can be used to manage and optimize water consumption. Quantifying the water consumption footprint (the sum of blue and green water footprints) and the theoretical water pollution footprint (grey water footprint) by performing thorough water audits, the total water consumption footprint of a brick is determined as 2.02 L, of which blue water is identified as 1.71 L (84.8%) and green water as 0.31 L (15.2%). The theoretical grey water footprint of a brick was found to be 1.3 L, a value that would have been higher if in-situ wastewater treatment had not been operated before effluent discharge. To reduce the water footprint of a brick, Skouteris et al. (2018) applied water pinch analysis techniques for the brick-manufacturing processes. Further exploring two water recovery schemes, (direct re-use/recycle and water regeneration), calculations indicate that direct re-use/recycle scheme reduces with the standard water consumption footprint reduced only by 15.6% whiles water regeneration scheme, on the other hand, improved the current value by 56.4%. The analysis clearly shows that the water consumption footprint of a brick is improved when the brick-manufacturing industry operates sustainable water management strategies.

Industrial water is used for a variety of purposes as one of the most important inputs in the production process. Estimating the economic value of water in the Korean manufacturing industry by employing the concept of the value of the marginal product (VMP), Ku & Yoo, (2012) used data on 53,912 factories surveyed in 2003 and consider two types of production functions: the Cobb-Douglas and trans-log functions. The authors found that the industry-wide output elasticity and VMP of industrial water were estimated to be 0.0104 and USD 1.05 per m3, respectively. The estimated VMP ranged from USD 0.39 per m3 for the precision instrument sector to USD 12.51 per m3 for the transportation equipment sector, indicating that the VMP varies across sectors. The results have important implications for various areas of industrial water management. Any cost-benefit analysis of new projects providing industrial water requires information on the economic value of industrial water. Moreover, such information is required for determining how scarce water resources could be distributed to various sectors.

Assessing life cycle and management of water use in selected breweries in Nigeria, Joshua & Kehinde, (2014) using a combination of purposive and random sampling techniques and a questionnaire as a research instrument. Using Ibadan brewery and Ilesha brewery as a case study, the authors find that the two breweries are still far from the accepted international best practice benchmark level of 6.5 hl/hl, let alone the best technology level of 4 hl/hl. Whiles Ibadan brewery is having 10.22 hl of water per beer, Ilesha brewery is having 8.75 hl of water per beer. Joshua & Kehinde, (2014, page 191) concluded that "the efficiency levels of the two breweries can at best be described as medium, with rather wide variations between countries and breweries". Even though the two breweries are not meeting up to the standard, it can be said that the efficiency of water use at Ilesha brewery is better than that of Ibadan brewery. Thus, the financial implication of water loss can be minimized if the management method is improved for maximum effectiveness and optimal benefit.

Although the Food and beverage industry is one of the major contributors to the growth of all economies and constitutes the largest manufacturing sector in terms of turnover, value-added, and employment in the European Union, the sector has been associated with various environmental issues including high levels of water consumption and wastewater production. In a literature review of water usage and wastewater management in the food and beverage industry, Valta, Kosanovic, Malamis, Moustakas & Loizidou, (2015) investigated management practices among slaughterhouses, potato processing, olive oil production, cheese production, and beer manufacturing, the authors concluded that between these different sectors, water consumption and wastewater generation vary greatly with wastewater pollution load depending on the type of product being processed, the process and the equipment used, and the common characteristic being the strong organic content. Valta, Kosanovic, Malamis, Moustakas & Loizidou, (2015) pointed out that the predominant treatment methods found in the recent literature are biological with special attention to the application of the anaerobic digestion process.

Considering water resources management in the soft drink industry-water use and wastewater generation, Ait Hsine, Benhammou & Pons (2005) using data from a two (2) year survey (2001 and 2002) in Morocco investigated the state of consumption and fresh water-use and the generation of the effluent in a carbonated soft drink industry plant. Comparing to the 1994 benchmark when water use in the food and drink industry was approximately 24 million m^3 per year including 14 % of drinking water, the study identified potential opportunities for reducing freshwater intake and minimizing wastewater production by focusing on the possibility of sustainable water management: reuse, recycling and treatment.

2.9 Chapter Summary and Research Gap

The review above clearly indicates a growing attention for sustainable approaches to water resource management in the rise of harsh climatic impacts in both domestic and industrial activities globally. It was established that besides agricultural, the manufacturing industry consumes large qualities of total water resource supply annually. Notwithstanding the copious studies on the field of water resource management and sustainable water use, there appears to be limited knowledge on sustainable water use strategies adopted in the brewery sector. In the midst of these numerous research gaps identified, this particular research aims at assessing the current trend of water use, drivers for optimizing water use and wastewater generation, and organizational commitment towards sustainable water management practices in the Ghanaian brewery industry.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This "chapter presents the methodology used to collect and analyze data for the study. The chapter is composed of the research approach, design, study population, sample size and the sampling technique. It also includes data sources and research instruments" used. Further in this chapter are data gathering procedures, data analysis technique, limitations and ethical considerations.

3.1 Research Approach

This study adopts a mixed-method approach to addressing the research questions stated in the earlier chapter. Thus, "both quantitative and qualitative research approaches are adopted. In the case of a quantitative approach, the study uses statistical measures to gather data and address the research questions. This type of approach has the strength of presenting an objective outcome or results. A qualitative research approach is also used to address the research problem and arrive at its findings and conclusions. Qualitative methods are often linked with an assessment of the social dimensions of this nature. According to Kothari (2004), qualitative methods help the researcher to portray how people feel as well as their motives and desire for a phenomenon. Hence, the strength of both the quantitative and qualitative approaches are used to explore the sustainable water use practices in the brewery industry of Ghana.

3.2 Research Design

This research adopts a cross-sectional study design to provide answers to the three questions: i) what is the current trend of water use among Ghana's brewery industry with reference to International Benchmarks of 6.5hL/hL and best technology levels of 4.0hL/hL? ii) what are the drivers for optimizing sustainable water use and wastewater generation from the breweries in Ghana? and iii) what informs the organization's commitment towards sustainable water management practices?

A cross-sectional design, whilst gathering data once within the limited time frame, also allows for a fair representation of responses from the study population (Creswell, 2003). Hence, the study selects brewery companies in Ghana to represent both the Ghanaian brewery industry and the respective institutions mandated with the responsibility of managing Ghana's water resource and brewery operations in Ghana.

3.3 Target Population

A population refers to all people or items with the characteristics that the researcher wishes to study. According to Boateng (2014), it is the entire aggregation of entities which the research seeks to understand or predict a social phenomenon. This is the unit to which the research would like to generalize its results.

For this study, the target population is the entire brewery industry in Ghana and regulators such as the Environmental Protection Agency (EPA) and Ghana Standards Authority (GSA), among others. There are currently two (2) brewery companies (these companies do not include distilleries) in Ghana. These are Accra Brewery Limited (ABL) and Guinness Ghana Brewery Limited (GGBL). The current study examines sustainable water management practices among these two (2) large breweries in the industry.

3.4 Sampling Technique

The study solely uses a purposive sampling method which is a non-probability sampling technique to identify respondents. Saunder (2011) postulate that a purposive sampling technique allows a researcher to use his or her own judgments to select cases which best answer the research questions and meet the research objectives. Therefore, this study samples official from the two main brewery companies whose activities are consistent with sustainability and water resource management. In addition to these, other public sector agencies that regulate this sector towards ensuring availability and sustainable water resource are also selected. Some of these include the Environmental Protection Agency (EPA) and Water Resources Commission (WRC)).

3.5 Sample Size

Considering the beverage and brewery industries in Ghana, the two (2) brewery organizations were chosen from which twenty (20) principal officers were asked to take part in the survey. We also invited two respondents from the state regulatory agencies to take part in the survey. Table 3.1 provides summary information of the institutions which took part in the survey.

Table 3.1: A Summary of Companies/Agencies Used

Sampled Institutions	Strategic goals in sustainable water management	Respondents
Accra Breweries Limited (ABL)	Organization's Environmental Policy, Sustainability and water-saving programs (Our ultimate goal is to ensure water access and	Fluids and Energy Manager

	quality for both our communities and our breweries)	
Guinness Ghana Breweries Limited (GGBL)	Organization's Environmental Policy, Sustainability and water saving programs (Water Blueprint defines their strategic approach to water stewardship)	Utilities Manager
Environmental Protection Agency (EPA)	1. Under the Environmental Assessment Regulations (1999), any activity that is likely to adversely impact on a water body has to go through an EIA process for an environmental permit before the project can commence. 2. Monthly/ quarterly environmental quality monitoring returns to EPA Annual environmental reports to the EPA (which includes monthly water consumption and water-saving practices thus organization commitment towards sustainable use of resources)	Program Officer and Principle Program Officer
Water Resources Commission (WRC)	Act 522 of the Water Resources Commission Act addresses water resource management issues. Part 3 of the Act provides for the acquisition and use of water resources. Section 13 of the Act prohibits the use of water resources without authority from the Water Resources Commission.	Water resource commission official

	1. Water Use Regulations Legislative Instrument (L.I.) 1692 (2001), 2. Water Sector Strategic Development Plan (WSSDP) sets out Ghana's commitment to and provides the framework for achieving the vision in respect of water, which is "sustainable water and basic sanitation for all by 2025." 3. National Water Policy	

Specifically, we interviewed ten (10) officers from Accra Breweries Limited (ABL) and Ten (10) officers from Guinness Ghana Breweries Limited (GGBL) chosen using purposive sampling, with two (2) others from Environmental Protection Agency (EPA) and Water Resources Commission (WRC). These respondents were selected based on the consistency of their operations with sustainability and water resource management in general.

3.6 Research Limitations

In carrying out this study, the researcher encountered many glitches in the course of the study. For example, financial challenges posed a major challenge in the course of data collection for this research. Also, the study participants were reluctant to provide responses to seemingly sensitive issues. In addressing this, interview questions were carefully framed during data collection.

The time factor also presented a great challenge to the research as the study was exploratory. However, the researcher developed a strategic and flexible schedule to attend to interviewees whenever possible. Amid these enormous limitations, however, the researcher employed all necessary means to ensure that findings of this study are valid and reliable.

3.7 Sources of Data

Both primary and secondary data were collected. The main primary data for the study were the responses from the 22 people interviewed. However, to enhance data validity and reliability, primary data are complemented with secondary data for triangulation. The secondary data on the other hand included existing data relevant to the topic under study (e.g., amount of water consumed, the volume of beer produced and specific water use by each brewery house) According to Hanson-Thompson (2007), secondary sources have the advantages of providing bases for comparison and providing a useful background for identifying key questions and issues needed to be addressed by primary research.

These secondary data comprise internal publications such as reports and evaluation documents on water resource management, policy documents, and external documents, including evaluation reports. Also, the study resorts to other secondary data found from journal articles from credible databases on sustainability and water resource use and management to support primary data from the field.

3.8 Data Collection

This study uses an interview guide to collect data from respondents. Whilst the interview guide helps to conduct interviews which is a common method of gathering data in qualitative research, secondary data in quantitative form is also sourced from both companies to allow for some statistical analysis. This type of interview guide allows comparability of results while leaving room for respondents to provide personal explanations of the topics under study (Yin, 2003). This is necessary when an understanding is being sought into the meaning of concepts and can bring out a true descriptive view of situations (Hansen-Thompson, 2007). Interview guides are structured into five main sections: biodata of respondent; awareness of sustainable water use; current sustainable water use strategies; drivers for optimizing sustainable water use and reuse; and organizational commitment towards sustainable water management. These themes reflect the specific objectives of the study.

3.9 Data Collection Procedure

Data collection was undertaken in three stages. This process began with a pilot stage. Initial responses from the pilot were discussed with the supervisor and other colleagues for their inputs in the structuring of the main interview guide. The piloting helped by ensuring that questions posed stimulate relevant responses suitable to the research objectives. Also, it informed a further reading of particular reports, from which extra information was essential for the robustness of this study. A second stage consists of the comprehensive data collection exercise where twenty- two (22) in-depth interviews (lasting between 25 minutes to an hour) were conducted. The sampling method used for this is the purposive sampling method. Participants interviewed at this stage are experts in the field who can provide useful information on the research topic. These participants include; equipment operators, utility managers, packaging supervisors, team supervisors, brewhouse supervisor etc.

The study combined both face-to-face and phone interviews. With the face-to-face interviews, data were collected directly from the source without any flaws as the researcher had the opportunity to raise issues that the interviewer had not thought of (Bailey, 1983). Thus, whilst face to face interviews which allowed probing and spontaneity was used in the first and second stages of data collection, telephone interviews were employed to gather additional primary data to consolidate findings due to its flexibility. Based on the outcome of the information obtained and subsequent analyses, secondary data was collected in the third stage of the study to consolidate the emerging findings.

3.10 Data Analysis

A thematic content analysis approach was used to analyze the data. Qualitative data from the in-depth interviews were foremost transcribed from audio recordings into words and were subsequently edited to detect and eliminate typographical errors. The transcribed data were further coded into themes under the three fundamental objectives in addition to an awareness assessment of the sustainable water use concept among respondents.

Findings from qualitative analyses were triangulated with the quantitative data. The quantitative data which include amount of water consumed, volume of beer produced and specific water use were analyzed with the STATA 15. Descriptive statistics were generated to describe the data and means test were conducted to find out which brewery company engaged in a more sustainable production.

3.11 Ethical Considerations

To demonstrate ethical responsibility, this research was conducted within the norms of ethical rights in both literature and empirical study. Bless and Higson-Smith (2000) argue (cited in Walters, 2009, p.17) that the general aspect of the ethical rights of a participant is the right to privacy, voluntary participation, anonymity, and confidentiality.

The researcher sought permission to collect data from the selected brewery companies with an introductory letter from the Center for Climate Change and Sustainable Development (CCSD). The researcher further ensured that the participants took part in the study voluntarily. Thus, they were informed that they were at liberty to withdraw at any stage of the interview process.

In addition, participants were informed that the results would be used for research purposes only. Respondents were also made to withhold their names to ensure anonymity in the responses provided. High degree of confidentiality was observed during and after the data collection.

3.12 Chapter Summary

In summary, this chapter discussed the methodology of this research in details. It outlined issues of research approach, design, study population, sample size and the sampling technique. It also elaborates on data sources, and data collection procedures."

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

The general objective of this study is to explore sustainable water use by ascertaining the current patterns and trends of water usage within the Ghanaian brewing industry for a sustainable water future. With respect to this overarching objective, we provide a detailed account of the results and discussions using thematic content analysis and statistical tests in this chapter. The chapter presents descriptive statistics of variables, graphical analyses of trends and means tests to answer the research questions.

4.1 Descriptive Analysis, Trend Analysis and Means test

This section provides a statistical summary of ABL and GGBL's water consumption and production levels, trend analysis, and various combinations of means test on the specific water usage (SWU).

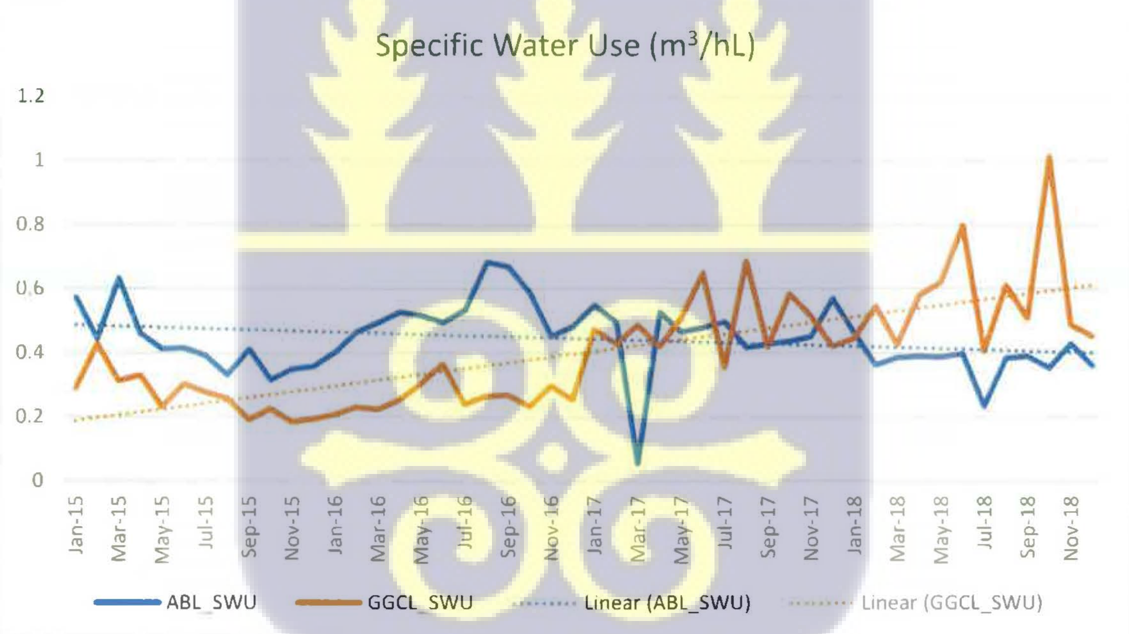
Table 4.1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
ABL Water Consumption (m^3/month)	48	40055.97	11035.85	4907	59286
ABL Production (HL/month)	48	92667.52	26814.28	50398.1	179000
GGBL Water Consumption (m^3/month)	48	13867.71	4733.135	6679	23895
GGBL Production (HL/month)	48	37112.54	10348.8	18209	59560

Source: Author's compilation from industry data

From Table 4.1, **Obs.** represents the total number of observations recorded per variable. This consists of 48 months of data. **Std. Dev** represents the standard deviation or spread associated with the means or average values of the variables. The average water consumption of ABL stands at about 40,056 m^3/month with a variation of 11,035.85 m^3/month whiles GGBL's average water consumption is approximately13,868 m^3/month, which is associated with a monthly spread of 4,733m^3. Minimum (Min), as well as maximum (Max) observations, are also indicated with ABL production records ranging from 50,398 HL to 179,000 HL compared to GGBL's production ranging from 18,209 HL to 59,560 HL hence conforming to the relatively higher water consumption of ABL.

Figure 4.1: Overall Trend of Specific Water Use (SWU) (2015-2018)

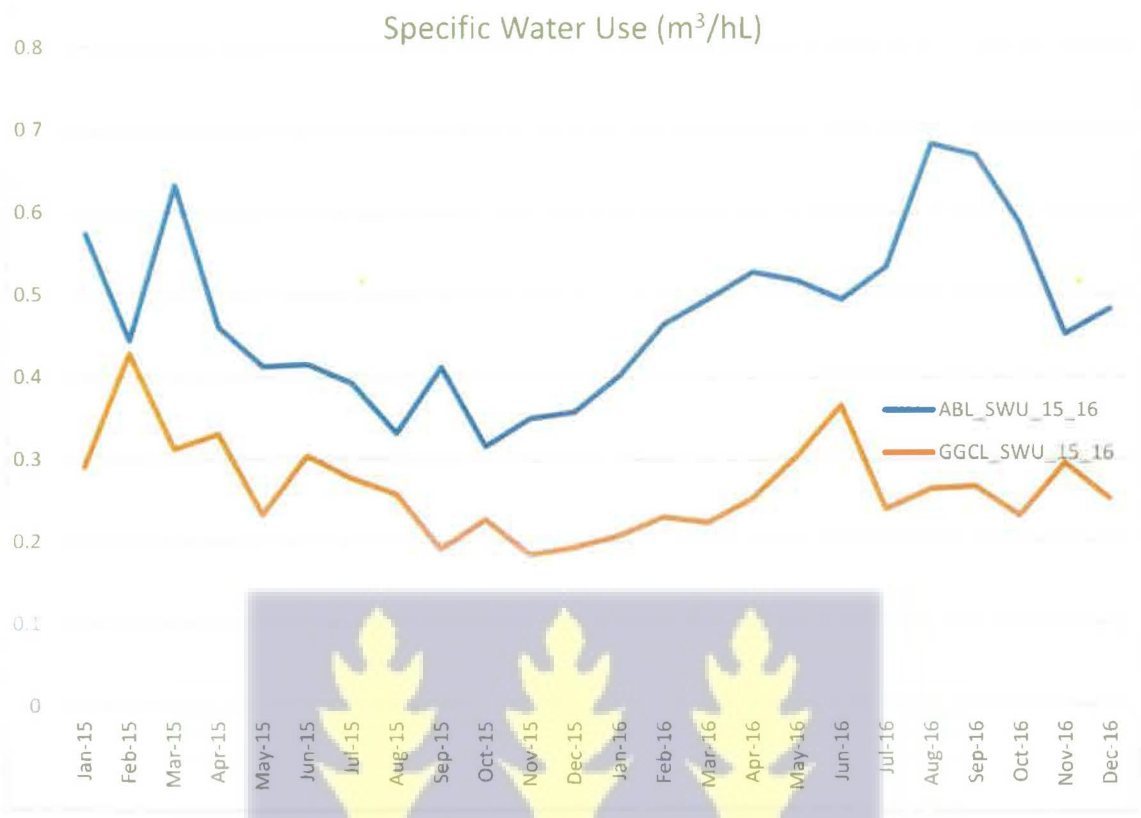


Source: Author's compilation from industry data

Fitting a trendline to the SWU series of both companies from 2015 to 2018, there has been a general upward and downward trend in the specific water use of GGBL and ABL respectively. With a SWU value of approximately 0.29 m^3/hL in January, 2015, GGBL records the lowest value (0.184m^3/hL) ever for the period under study in November, 2015 making its water use more sustainable compared to ABL's 0.35m^3/hL in the same month. From 0.184m^3/hL in November 2015, GGBL's SWU has undergone a gradual increase to almost a double in June, 2016, bringing its SWU to 0.366m^3/hL. Within the study period, ABL recorded its all-time highest SWU of 0.684_m^3/hL in August 2016 and the lowest of 0.055m^3/hL in March 2017, whiles GGBL's peak SWU value was 1.01m^3/hL in October 2018.

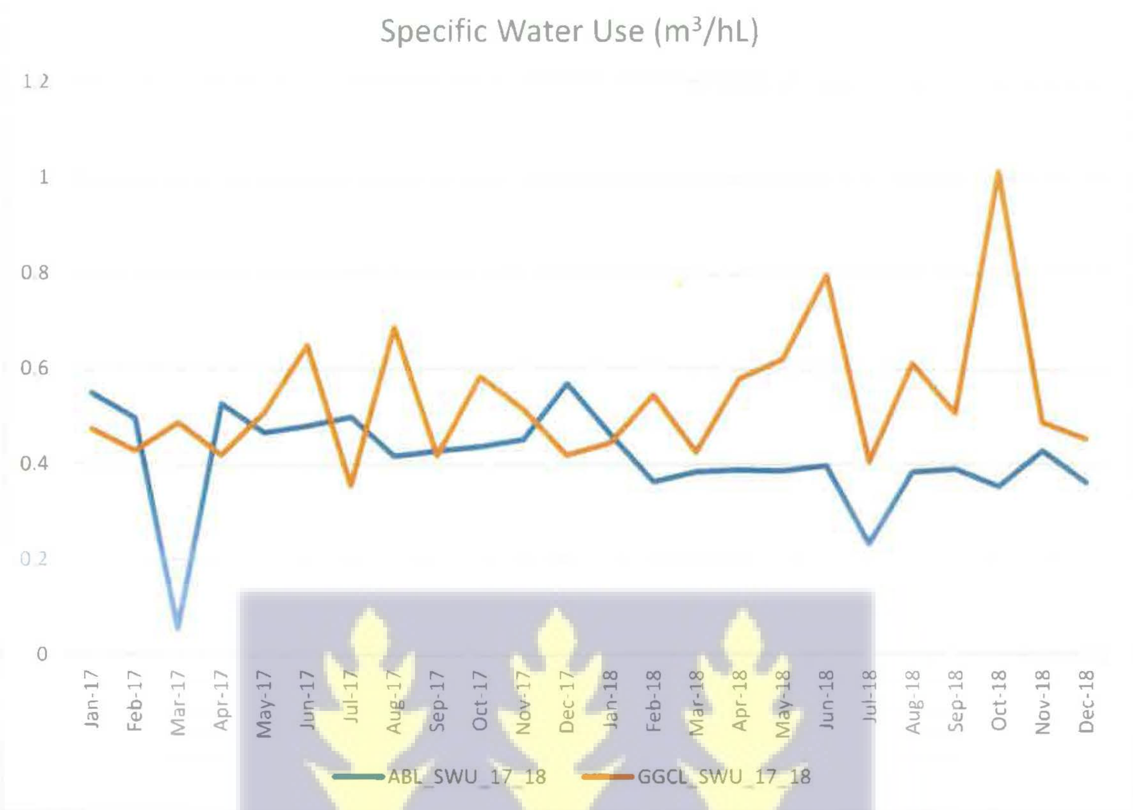
In order to compare and contrast differences and fine details between the SWU of both ABL and GGBL, we further divide the 48 months data into two samples of 24 months each, i.e. from January, 2015 to December, 2016 as one sample and from January, 2017 to December, 2018 as the second sample. This split is motivated by the seemingly stable nature of the trend from January 2015 to December 2016 and the erratic nature of the trend from January 2017 to December, 2018. Figures 4.2 and 4.3 show a graphical representation of the trends in specific water use by both companies.

Figure 4.2: Trend of Specific Water Use (2015-2016)



***Source:* Author's compilation from industry data**

Figure 4.3: Trend of Specific Water Use (2017-2018)



Source: Author's compilation from industry data

Table 4.2: Means test for Specific Water Use

	Obs	ABL Mean (m^3/hL)	GGBL Mean (m^3/hL)	Diff	Std. Err	t-value	p-value
ABL-GGBL (2015-2018)	48	0.445	0.4005	0.44045	0.033	1.35	0.1835
ABL-GGBL (2015-2016)	24	0.476	0.2655	0.21014	0.021	9.95	0.0000
ABL-GGBL (2017-2018)	24	0.4135	0.5355	-0.12205	0.0395	-3.1	0.0050
ABL (2015/2016-2017/2018)	24	0.476	0.4135	0.06243	0.0365	1.70	0.1025
GGBL (2015/2016-2017/2018)	24	0.266	0.5355	-0.26974	0.031	-8.65	0.0000

Source: Author's compilation from industry data

Note: 1 m^3 = 10 hL

From the first row of Table 4.2, of the 48 monthly observations recorded from 2015 to 2018 on the specific water use variable, ABL recorded a mean SWU of 0.445m^3 (equivalent to 4.45hL) which implies that on the average, for every 1.00hL (or 0.10m^3) of beer produced per month, 0.445m^3 of water is used, whiles GGBL recorded a mean SWU of about 0.40m^3/hL. Thus, for every 0.40m^3 of water used, 1.00hL of beer is produced per month. Even though these figures imply that GGBL uses water more sustainably relative to ABL's specific water usage, considering the p-value of 0.1835 for the independent t-test reveals that there is no statistically significant difference in the specific water use of the two companies at the 5% level of significance.

Additionally, in the second row, we compare the specific water use of ABL and GGBL in the 2015-2016 production years. With an average SWU of 0.476m^3/hL and 0.2655m^3/hL for ABL and GGBL respectively, the independent t-test yields a statistically significant difference between their uses of water relative to production, with GGBL's water use being more sustainable. This significant difference could be due to GGBL's Water Blueprint and its stakeholder engagements on sustainable water use awareness programs focused on achieving annual progress towards their 2020 targets of 50% reduction in water usage.

Comparing ABL and GGBL's operations over a period of 24 months (2017- 2018), we find that with an average of about 0.414m^3/hL of ABL's water use as opposed to GGBL's average of about 0.536m^3/hL, a statistically significant difference is seen in the specific water use of ABL. Interestingly, whereas GGBL's specific water use is more sustainable in production years 2015-2016, this progress in itself has not been sustained. Thus, in the 2017-2018 production years, ABL's specific water use becomes more sustainable even though the degree of this sustainability of relative lower when compared to GGBL's sustainability in the previous years.

Furthermore, the fourth row of Table 4.2 compares the specific water use of ABL during two 2-year periods, i.e., from 2015 and 2016 to 2017 and 2018. For the production years 2015 and 2016 put together, we find that the average SWU is 0.476m^3/hL whiles 2017 and 2018 reports an approximate average of 0.4135m^3/hL. It is worthy to note that despite the approximate

0.06243 difference in specific water use between the two 2-year periods of ABL's operation, this difference is not significant at the 5% level of statistical significance as the p-value of the t-test equals 0.1025. For the difference in specific water use between the two 2-year periods of ABL's operation to be significant at the 5% level, we expect the p-value of the t-test to be greater than 1% but less or equal to 5%.

Considering the sustainable water use of GGBL during the periods 2015 to 2016 and 2017 to 2018, we find that there is a statistically significant difference of approximately -0.27 between the average SWU of 0.266 in 2015 and 2016, and the average SWU of 0.536 in 2017 and 2018. This further confirms the finding that GGBL practiced more sustainable water use in production year 2015 to 2016 than 2017 to 2018.

4.2 Benchmarking

In this subsection, we discuss whether or not water use of each brewery company is sustainable. The average specific water usage for both ABL and GGBL are compared with the international best practice benchmark of 6.5 hL/hL using a one-sample t test. The test finds that from January 2015 to December, 2018, the specific water usage for both ABL and GGBL are statistically significantly different from the benchmark value at the 1% level although, GGBL's average water use has a stronger significance or is more sustainable over the study period than ABl's average water use. Test results are provided in Table 4.2 below.

Table 4.2: Specific Water Use (International best practice benchmark of 6.50 hL/hL)

	Obs.	Mean (hL/hL)	St Err	t value	p value	Sustainable
ABL	48	4.45	0.15	-13.281	0.000	Yes
GGBL	48	4.01	0.25	-9.883	0.000	Yes

Furthermore, the average specific water usage for both ABL and GGBL are compared with the best technology level of 4.00hL/hL as is the case in some European and Japanese breweries. Test results reveal that during the period under consideration, ABL's average specific water usage of 4.45hL/hL is statistically significantly different from the best technology level of 4.00hL/hL whiles GGBL's average specific water usage is not statistically significantly different. Thus, considering water use at the best technology level of 4.00 hL/hL, GGBL is more sustainable than that of ABL at the best technology level. Table 4.3 provides the test results.

Table 4.3: Specific Water Use (Best technology level of 4.00 hL/hL)

	Obs.	Mean (hL/hL)	St Err	t value	p value	Sustainable
ABL	48	4.45	0.15	2.879	0.006	No
GGBL	48	4.01	0.25	0.019	0.985	Yes

4.3 Thematic Content Analysis

In order to respond to the second and third objectives, responses from interviews and questionnaire were structured into three main thematic areas such as: Awareness of sustainable water use; Current sustainable water use commitments and strategies; and Drivers for optimizing sustainable water use and reuse.

From the responses, we gleaned those employees in various functional departments in both companies are aware of and understand the need for sustainable water use as "the practice of using water wisely to reduce water wastage in our organization" or "the day-to-day activities and processes to reduce water consumption and wastage in our brewery in order to stay in business continuously".

At GGBL, an interviewee notes that "our Water Blueprint helps us create a more efficient business and support our ambition to be one of the most trusted and respected consumer Products Company in the world and we remain focused on achieving annual progress towards our 2020 targets of 50% reduction in water usage"

Moreover, both companies also recognize the water crisis affecting communities, cities and companies around the world and unanimously agree that failure to adopt sustainable solutions to reduce, recycle and reuse of water resources have a ginormous potential for stakeholder conflicts which put their business operations at an immeasurable risk.

As part of measures towards sustainable water management, staff of both companies appreciate the fact that water is their most valuable and most important raw material for the production of beer and as such realize the need to use it sustainably to ensure future productions. Staff of these companies understand that without adequate water to sustain production, they run the risk of staying out of business. Another need for sustainable water usage is to keep down the high industrial cost of water for production which has profit maximization implications for both companies.

Furthermore, brewery companies implement sustainable practices by reducing the amount of water used and quantity of effluent discharge into water bodies in order to protect the business environment under the three (3) pillars of sustainability which are social, environmental and economic sustainability; informally referred to as people, planet and profits.

In addition, both ABL and GGBL practice sustainable water management due to regulatory requirement from external stakeholders. For example, the Environmental Protection Agency (EPA) encourages sustainable water usage and cleaner production through reducing, recycling and reusing as conditions for granting and renewing permits.

As a way of organizational commitment towards sustainable water management practices, both ABL and GGBL show commitment in terms of innovative chemical processes during production, equipment and monitoring, performance indicators, staffing and training on the need and advantage for water management also through Corporate Social Responsibility (CSR)

Both companies have an automated metering system in place for all processes involving water lines and the usage of press taps and hand-sensitive taps in washrooms as part of capital investments to ensure all water consumptions are monitored, accounted for and misuse identified. Daily automatic records and staff inspections of water pipes and lines by a multi-disciplinary team looking out for water leakages and any other potential water and energy wastage in the organization.

As part of the Cleaner Production Framework, both breweries are strongly committed to water reuse: There are four stages in the bottle washing process- pre-rinse, caustic washing, final pre-rinse and final rinse. The final pre-rinse water is reused at the first bottle pre-rinse stage to save water which is free of any trace of caustic and also using water after effluent treatment for gardening and cleaning of external drainage. Common innovative strategies both companies practice include the reuse of pasteurizer water. In this case, after pasteurization, the water is sent to a receiving tank where it is air-cooled and sent back to the pasteurizer depending on the quantity of water lost in the process, less water is added to make up the difference instead of using entirely freshwater. Additionally, the usage of caustic blast which reduces the amount of water use during Wort line cleaning and filter backwash water reuse to clean for the floors and toilets are among some common sustainable water management practices.

Commitment to sustainable water management is also exhibited by organizing water-saving workshops and forums to educate workers on the importance of water-saving and its implications for the future of their business. As part of these workshops are meetings and plenary sections to create awareness on emerging freshwater scarcity, global water challenges and conflicts and offer opportunities to discuss the team and departmental-level water consumption and sustainability KPIs that will enhance productivity and maximize profitability. These trainings build the requisite capacity and mindset for staff at both management and non-management levels to take ownership of water-saving opportunities at their various departments.

The brewery industry also shows its commitment to sustainable water management through its CSR undertakings. For example, in 2017, GGBL was adjudged and awarded the CSR Company of the Year at the Seventh (7^{th}) CSR Excellence Awards in Accra by recognizing its unrelenting role in committing to building thriving communities in Ghana through the company's impactful "Water of Life" (WOL) program whiles ABL was adjudged AGI Award for Best Practices in Sustainable Manufacturing in 2013.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

4.0 Introduction

This chapter has three sections. The first section summarizes the key findings with respect to the research objectives. Conclusions are drawn for each objective in the second section whiles recommendations for policy and future research directions are provided in the last section.

5.1 Summary of findings

The objective of the study is analyses the current trend of water use among the two main breweries in Ghana, identify the needs and opportunities for optimizing water use and wastewater generation and to assess the organizations' commitment to sustainable water management practices.

We observe that over the study period the specific water usage for both ABL and GGBL are statistically significantly different from the international benchmark value (6.5hL/hL) at the 1% level although, GGBL's average water use has a stronger significance or is more sustainable over the study period than ABI's average water use. Furthermore, the study finds that, for water use at the best technology level of 4.00 hL/hL, GGBL is still more sustainable than that of ABL at the best technology level.

Comparing ABL and GGBL to themselves during the two sample periods, we find that despite a considerable reduction in ABL's specific water use which implies that ABL has been practicing sustainable water use in recent years, the reduction is not statistically significant.

Nevertheless, the on the contrary, GGBL has been less sustainable in its specific water use in the last two years than in the first two years and the difference is statistically significant.

We construct a content analysis of research instruments under three thematic areas namely: Awareness of sustainable water use; Current sustainable water use commitments and strategies; and Drivers for optimizing sustainable water use and reuse.

In view of these themes, we conclude that employees at the breweries are fully aware of freshwater crisis around the world and understand the need for its sustainable use given that it is the most important and largely used raw material.

With regard to organizational commitment to sustainable water management practices, research instruments reveal that both ABL and GGBL show their allegiance to sustainable water practices by adopting cleaner production systems, innovative chemical processes and techniques during production, installation of equipment that enhance monitoring and evaluation, the design of key performance indicators, staffing and capacity building on the need and advantage for supportive water management and also through their corporate social responsibility and community outreach undertakings.

Responses from both companies also indicate that various training, capacity building, weekly and monthly monitoring and evaluation programmes are organized to sensitize employees about sustainable water use in order to reduce total production cost and maximize profit and protect the environment by reducing and treating the quantity of effluent discharge into water bodies to mitigate the risk impact on aquatic life.

In terms of drivers for optimizing sustainable water use and reuse, responses solicited confirm that water cost minimization and profit maximization objectives, regulatory requirements for permits, business continuity and environmental sustainability are considered by both breweries.

It is interesting to note that even though a commitment to sustainable water use appears to be similar among the brewery companies under review, SWU values differ significantly in certain periods. These differences could be attributed to contrast in production capacities (as evident in Table 4.1) and economies of scale, institutional age and experience, dissimilarity in human resource capital, equipment and operational differences, and revenue gaps among other factors.

5.2 Recommendations

Given that ABL and GGBL have their individual KPIs, there must exist collaborative partnerships between the brewery industry and government agencies like Ghana Water Company, Water Resources Commission, Environmental Protection Agency's unit for Cleaner Production, Ghana Standards Authority and other agencies to share ideas and technical knowledge for the design, implementation and periodic review of sustainable water usage index, standards, benchmarks and threshold values for water sustainability scores by factoring in the demand and supply of beer products and freshwater availability to ensure a more efficient oversight, monitoring and evaluation of sustainable water use.

In order to maintain the momentum and at best improve on the current sustainable water management practices, there is the need for an industry-wide government-supported incentive-mechanism scheme to motivate sustainable water use in the brewery industry. This may come in the form of reducing tariffs on imported metering equipment, other industrial equipment and their spare parts which relate to sustainable water management.

Last but not least, there is the need for a renewed commitment of brewery companies to incorporate sustainable water management as part of their core values. To sustain this commitment, governments should, at least, demand and publish information on water abstraction released by companies in the interests of more transparent management of water resources. Governments would also benefit from making industrial issues a more prominent part of their national water policies, including targets for water use efficiency by key sectors such as breweries. Greater use could be made of financial instruments such as water abstraction and discharge fees, with more realistic fee scales to influence industrial water management and to recover government costs in administrating the legislation. By linking the performance of the brewery sector to national water plans, governments would encourage breweries to compare their performance and pursue water saving goals established under these plans.

5.3 Limitations and suggestions for further Studies

While some important conclusions are drawn from this study, it is clear that there is still a shortage of adequate data for more detailed decision-making both at national and at plant levels in the two breweries studied. For various reasons, many of the measurements needed for a fuller sustainability analysis of cleaner production potential are not being undertaken at present. At the national level, industrial water use as a proportion of total water is not usually calculated. While volume and quality of wastewater discharge is more commonly measured, its impact on ambient water quality is rarely documented.

Even with the limited data, we can conclude that individual plants have a variety of technology options for improving water efficiency especially, in the washing and bottling plants, but also in cooling, and through water re-use and yeast recovery. Some of these require additional investments, but they will also allow an increased output. Improvements in housekeeping and operation can realize some significant water saving without any major investments. There appear to be further opportunities for recycling used waters of various types in the plant, and for outside users if the chemical composition can be controlled. Unfortunately, lack of effective flow monitoring in brewery plants currently prevents plant managers from being able to study all these options in a clear-cut way.

Given that the required data becomes available, future research may consider optimization of water use subjected to correlation and regression analyses with focus on the drivers for optimizing sustainable water use and wastewater generation in the brewery industry of Ghana.

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