Appraisal of Water Resources for Effective and Sustainable Management

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The Volta Lake, Ghana

By

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This book is dedicated to my wife, Mrs. Bridget Akosua Tay, and my children, Mirabel Yayra Tay, Jerry Jefferson Selasi Korbla Tay, and Donald Kwame Senyo Tay for their continued support for my pursuit of success in my career.

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FOREWORD

Information on the overall status, trophic status, and primary productivity of lakes is an important component of the efficient and sustainable management of lakes within the framework of the socio-economic development of a country. Reliable data on transboundary water resources transcending riparian countries for joint management are a key factor now and in the future within the context of managing the resource to satisfy the changing demand placed upon it without system degradation. The desire for water quality data is ever increasing and there is indeed a considerable demand for data, not only on the overall status of lakes to provide adequate knowledge of their uses but also on their trophic status and primary productivity to provide managers of lakes with knowledge as to whether to design monitoring schemes to protect or recover a lake. This information aids the detection of early warning signals of a dysfunctional ecological framework of aquatic ecosystems and the subsequent design of the most appropriate monitoring schemes for efficient and sustainable management of these resources. As a transboundary river basin, it is important that (1) the availability of water quality data through the provision of equipment and preparation of a dedicated water quality database is improved, (2) capacity is built to undertake multi-criteria decision analysis for investment planning and prioritization and, (3) policies and institutions that govern water quality management in the Volta River Basin are harmonized.

As part of the Government of Ghana's program to reform the country's aquaculture and fisheries sector to increase domestic fish production, achieve the global mean and attract investment into the sector, zonation of the Volta Lake was commissioned in 2015 to delineate areas on the Volta Lake that are suitable for cage aquaculture. Water and sediment quality featured and were assessed within this framework.

This book presents a narrative of the overall status of the Volta Lake in Ghana as well as its trophic status and primary productivity. It is anticipated that the information provided in this book will be of definitive use to water managers in all riparian countries of the transboundary Volta River Basin for efficient and sustainable management.

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CHAPTER 1

INTRODUCTION

Although freshwater is a renewable natural resource, it is finite and vulnerable (Loucks and Beek 2017, V). Owing to its vulnerability, freshwater scarcity is increasingly becoming a global threat to the survival of many, and may remain a threat for decades to come due to the widespread pollution of surface water resources, including lakes. According to Søndergaard (2007, 1), paleolimnological investigations have documented the biological development of lakes through human activities and changed land-use patterns in lake catchments with considerable changes in the environmental state. This potential threat may be partially caused by the increasing demand for freshwater by the rapidly growing populations, the uneven spatial distribution of rainfall, and the natural variability or unpredictability in the timing and amounts of rainfall, which are exacerbated by climate change. Besides, freshwater scarcity may be caused by a long history of poor management practices. Typically, humans simultaneously use the same limited water resources for multiple purposes without considering the cumulative impact on these water resources. Subsequently, pollution of surface water resources has become a major environmental phenomenon due to the increasing rates at which their pollution occurs globally. This environmental problem requires continuous appraisal and monitoring at all scales toward ecosystem sustainability. For instance, the Global Oceanic Environmental Survey posits that water pollution is one of the major environmental problems that potentially presents an existential threat to life on Earth in the next decades (Tay 2021, 1). It is estimated that 1.8 million deaths occurred globally in 2015 due to water pollution (Tay 2021, 1). A further threat is the possibility of increased pollution in the general water situation due largely to global changes (Loucks and Beek 2017, V). This further threat is not only due to climatic change but other global drivers of change including population growth, urbanization as a result of rural-urban migration, and changes in land-use patterns which have the potential to pose unprecedented global challenges (Loucks and Beek 2017, V). Fundamentally, within the context of global water pollution, chemical pollution is key, as domestic and agricultural discharges are linked to changes in water chemistry, resulting in ecosystem dysfunction (Tay 2021, 1). Chemical parameters are thus, potential indicators of pollution in aquatic ecosystems (Tay 2021, 1). However, water quality monitoring programs are invariably bedeviled with cautiously generated water quality data that are difficult to implicitly interpret (Herojeet *et al*. 2016, 39; Tay 2021, 1). Oftentimes, it is difficult for water managers to conduct meaningful assessments of the enormous water quality data generated by monitoring programs (Tirkey *et al.* 2015, 15). Nonetheless, water resources are expected to be managed efficiently and sustainably, ensuring that these resources meet the demands and expectations of current and future generations (Loucks and Beek 2017, VI; Tay 2021, 1). However, managing these resources rarely includes considerations for protecting the underlying biophysical processes, which are critical for sustaining the water resources and their associated ecosystems, especially in developing countries. This has provoked many philosophical slogans/statements on saving water today for the future. Some of these slogans include:

- *Water is critical for sustainable development, including environmental integrity and the alleviation of poverty and hunger, and is indispensable for human health and well-being.*
  —United Nations

- *If there is ever going to be a 3rd World War then it's almost at our door steps and its going to be about water, to curb this we need to take action now.*
  —Kofi Annan

- *Water, water, everywhere, nor any drop to drink.*
  —Samuel Taylor Coleridge

- *By means of water, we give life to everything.*
  —Koran

- *The wars of the twenty-first century will be fought over water.*
  —Ismail Serageldin

- *A river is more than an amenity; it is a treasure.*
  —Justice Oliver Wendell Holmes

- *Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land.*
  —Luna Leopold

Water quality, therefore, is of fundamental concern for ecological and human health. Meanwhile, enormous resources are expected to be committed to water monitoring, while access to clean water and the prevalence of waterborne diseases are among the most debilitating concerns that continue to face the world, especially the developing world. Consequently, the concept of sustainable water resource management emphasizes the need to consider the long-term future needs in the present (Arimoro and Musa 2020, 3). This concept also ensures the provision of an adequate water quantity and appropriate water quality for a given need without compromising the future ability to provide this capacity and quality (Arimoro and Musa 2020, 3). The significance of water resource systems being managed to satisfy the changing demand placed on these systems now as well as in the future without system degradation cannot be overemphasized. This requires strategies to be put in place to ensure that fresh water is not only made available for use in the present but also that future generations are not deprived by misuse in the present. This raises the need for various regulatory instruments to be ratified in developed countries to ensure the environmental health and sustainability of aquatic ecosystems. Some of these instruments include Section 314 of the Clean Water Act which requires the classification of lakes according to their "eutrophic" character, and Section 305(b) of the Clean Water Act, which further requires that "fishable" and "swimmable" goals be constructed for each state (Nojavan *et al.* 2019, 1). The Water Framework Directive 2000/60/EC also requires that the European Union (EU) member states assess and document the ecological state of all lake waters (Phillips *et al.* 2013, 3). For instance, the demand of the EU Water Framework Directive (WFD; European Union, 2000) was that all lakes must attain a "good ecological status" by the end of 2015 from five ecological classes, classified as "bad quality", "poor quality", "moderate quality", "good quality" and "high quality" (Søndergaard 2007, 49). These requirements have been cautiously designed and promulgated to guarantee the sustainability of aquatic resources. Most of these requirements have since become the guiding principle in other countries (Phillips *et al.* 2013, 3). Nevertheless, some other countries have adopted these requirements with some modifications (Napiórkowska-Krzebietke and Hutorowicz 2014, 29-30). However, in the developing world, efforts to characterize aquatic ecosystems to ensure environmental health and sustainability are limited. Meanwhile, surface waters including lakes in these regions are progressively growing "greener", principally due to anthropogenic activities. Notwithstanding, the difficulties in scheduling appropriate water monitoring programs aimed at the recovery of productively high (eutrophic) water resources both technically and financially are comparatively greater than the scheduling of appropriate water monitoring programs aimed at the protection of productively low (oligotrophic) water resources. It is, therefore, of paramount importance to use regulatory instruments to characterize lakes to inform underlying research needs and approaches toward sustainable and effective management.

Ghana, a developing country on the west coast of Africa is home to a significant portion (42%) of the transboundary Volta River basin that transcends six West African countries. The basin is drained by the Volta River and its four main tributaries; the Black Volta, the White Volta, the Lower Volta, and the Oti in Ghana. The importance of the Volta Lake was originally tied to the generation of hydroelectric power in Ghana. However, its fisheries potential has been observed to contribute to the food and nutritional needs of Ghana (Abban 1999). The literature indicates that the Volta Lake provides 90% of national freshwater fish production (Abban 1999). According to MoFAD (2012), cage aquaculture fish production from the Volta Lake is currently estimated to account for more than 80% of total fish production from aquaculture. However, there has been a sizeable increase in human population in and around the lake's watershed with corresponding environmental issues such as lakeshore deforestation, loss of biodiversity, fluctuating water levels, water-borne diseases, growth of aquatic weeds, seasonal flooding of riparian areas, climate variability and water quality degradation, lakeshore erosion and sedimentation, the proliferation of aquatic weeds, problems associated with lake transportation, water governance and downstream hydrological changes and the consequential changes in the ecological conditions of the residual river and adjoining floodplain. These environmental issues coupled with the dwindling annual rainfall levels within the lake basin have a greater propensity to disrupt the lake's functions and degrade water quality, thereby endangering the lake's ecosystem. The subsequent changes in water quality may result in enormous pressure on these ecosystems leading to a decrease in water quality and biodiversity and a loss of essential habitats with a consequential overall decrease in the quality of life of local inhabitants (Herrera-Silveira, *et al.* 2009, 72-86). Appraisal of the water of the lake is critical since it is an integral component of the framework for effective and sustainable management. A holistic approach to support the development of best management practices for the Volta Lake can be expressively achieved through the integration of water quality indices (WQIs) and multivariate statistical techniques for water pollution assessment and the application of trophic state indicators and nutrient ratios for the characterization of trophic state and primary productivity as well as assessing the sediment quality for pollution indicators. Nutrient concentrations, especially phosphorus, in the overlying water of a lake which comes from the sediment, may be regarded as a major component of the internal source. Such a release from the bottom sediment may have a significant impact on water quality and may result in sustained eutrophication (Hou *et al.* 2013, 2). Bottom sediments therefore, play a very important role in lake-water quality by acting as sinks or sources for pollutants such as nutrients (phosphates and nitrates), organic matter, organic carbon, and metals in aquatic ecosystems due to the association of these compounds with particulate material and the subsequent influence on the quality of the overlying water, thereby reducing the lake's productivity (Reuther 2009, 3). Sediment is also considered as a source of these compounds due to processes that release nutrients back into the water. Characteristically, sediments tend to accumulate organic and inorganic pollutants which may find their way into a lake or river and either adsorb to particulates or dissolve in pore water. Sediments are also responsible for the circulation of elements in the ecosystem (Kuriata-Potasznik *et al.* 2018, 2). Additionally, sediments may in turn act as a source of these pollutants that could potentially be released into the overlying water under favorable environmental conditions (Reuther 2009, 3). Lake sediment constitutes the "lowest" portion of the lake where organic matter and material added to the lake from the outside or produced within the lake are deposited and accumulated (Søndergaard, 2007, 18). Assessment of pollutant concentrations in sediments, therefore, has been widely employed to control discharge and exposure concentrations in streams and lakes (Reuther 2009, 3-4). Given this, sediment monitoring has become an integral part of existing water management and protection programs, particularly in assessing the ecological status of a water body to detect toxic substances and control their fate and effect on the aquatic ecosystem (Reuther 2009, 3-4). Within the context of the importance of the Volta Lake to the millions of people that it serves now and, in the future, it is imperative to ensure that the Volta Lake is properly managed to satisfy the changing demand placed on the lake now and in the future without system degradation through the improvement of its water and sediment quality to safeguard quality of life, protect its ecosystem and preserve it for future generations.

This book occasions a broader understanding of the water quality of the Volta Lake within the framework of its overall status and its quality in comparison to guidelines for freshwater and ecosystem health. This book proposes to establish the water quality characteristics of the Volta Lake through the adoption of three selected WQIs and multivariate statistical techniques. The selected WQIs are; the weighted version of the Solway Index (WQI) previously developed to evaluate a selected number of water quality parameters through the standardization of each observation concerning a maximum concentration specific to each parameter in lake basins (Bharti and Katyal 2011, 154-173), the CCMEWQI previously developed to evaluate the quality of water in comparison to established guidelines for freshwater life in inland lakes (Bharti and Katyal 2011, 154-173) and, the water pollution index (WPI_{KR}) previously developed to appraise the chemical health status of surface waters (Atique and An 2019, 1046). These three WQIs are very suitable for appraising the water quality status and characterizing the degree of pollution and the freshwater life in an important transboundary West African inland basin that stretches through six riparian countries for sustainable management in terms of determining how best to maximize the lake's potential as a thriving ecosystem. This book further seeks to employ the concept of trophic status based on the principle that changes in nutrient levels (measured as total phosphorus) cause changes in algal biomass (measured as chlorophyll-*a*) which simultaneously cause changes in lake clarity (measured as Secchi disk transparency); integrating the trophic state index (TSI) is a convenient way to quantify this relationship in order to quantify the trophic state and assess the primary productivity of the Volta Lake, assess its limiting nutrient and recommend future underlying research needs as well as the direction of funding to either protect or restore the Volta Lake for sustainable and efficient management. Essentially, this book adopts a model that integrates a skillful tool which offers an explicit understanding of the general status of the Volta Lake based on a single index (WQI) towards the identification of its designated uses and its trophic status which provides explicit knowledge of its primary productivity and limiting nutrient to ascertain the lake's future research needs towards sustainable management.

This information is crucial for water resource management as well as knowledge-based enhancement which are central to future water quality evaluations and monitoring programs in a shared basin and river-linked lake such as the Volta Lake.

This book seeks to achieve these goals in three (3) ways:

- Apply water quality indices and multivariate statistical techniques for a water pollution assessment of the Volta Lake;
- Apply trophic state indicators and nutrient ratios for the characterization of the trophic state and primary productivity of the Volta Lake; and
- Assess the nutrient content in the bottom sediment of the Volta Lake.

1.1 Previous Studies on the Volta Lake

Within the framework of attaining effective and sustainable management of the lake, several scientific types of research have previously been conducted in the Volta Lake in Ghana. Some of these research studies include the limnochemical conditions of the Volta Lake (Ntow 2003, 263-265), the Volta convention: an effective tool for transboundary water resource management in an era of impending climate change and devastating natural disasters? (Matthews 2013, 273-308), cage fish farming and its impact on water quality in the Volta Lake (Asmah *et al.* 2014, 33-47), a water resources assessment of the Volta Basin (Mul *et al.* 2015, 1-78), a limnological assessment of the Afram portions of the Volta Lake (Obeng-Asamoah 1977, 257-264); a mercury and selenium assessment in the edible tissue of freshwater fish from the Volta Lake in Ghana (Kwaansa-Ansah *et al.* 2013, 109-118), an assessment of water quality and primary productivity characteristics of the Volta Lake in Ghana (Karikari *et al.* 2013, 88-108), and the potential effect of characteristics of water quality on the fish population in Lake Volta (Olalekan *et al.* 2015, 1-5).

However, none of these research studies have focused on characterizing the Volta Lake with the explicit understanding of the general status of the lake water using the integration of WQIs and multivariate statistical techniques as well as characterizing the trophic state and primary productivity of the Volta Lake using trophic state indicators and nutrient ratios to (1) identify and characterize the chemical health status of the lake for ecosystem sustainability, and (2) identify and characterize the trophic state and primary productivity of the lake to significantly inform future underlying research needs and approaches for effective and sustainable management towards a healthy balance of aquatic life and socio-economic development. It is also worth noting that, through the earlier zonation of the lake to identify the best potential areas for aquaculture production on the lake within the framework of maximizing fish production from aquaculture without adverse environmental degradation, the Volta Lake is zoned into eight (8) strata. However, most of these previous works were not extended to cover all these strata. This book offers an appraisal of the water quality of seven (7) out of the established eight (8) strata.

It is, therefore, imperative to conduct this study to significantly inform the underlying future research needs and approaches as well as the direction of funding towards the sustainable and effective management of the Volta Lake.

1.2 Objectives of the Study

1.2.1 Main Objective

The main objective of this book is to elucidate the chemical health status of the Volta Lake ecosystem within the framework of changes in chemical parameters as potential indicators of pollution to ensure the proper management of the lake to satisfy the changing demand placed on the lake now and in the future without system degradation through the improvement of its water and sediment quality to safeguard quality of life, protect its ecosystem and preserve it for future generations. This study seeks to adopt an integrative approach to address the general chemical health status of the lake for ecosystem sustainability as well as the trophic state and primary productivity of the lake to significantly inform future underlying research needs and approaches as well as the direction of funding towards effective and sustainable management.

1.2.2 Specific Objectives

The specific objectives of this study are to:

- Appraise the baseline water quality conditions;
- Identify and characterize the effects of the changing water quality of the Volta Lake on use impairments towards sustainable and efficient management;
- Quantify the trophic state and assess the primary productivity of the Volta Lake;
- Assess the limiting nutrient in the Volta Lake;
- Assess the environmental pollution of sediment nutrients in the Volta Lake; and
- Recommend future underlying research needs as well as the direction of funding to either protect or restore the Volta Lake for sustainable and efficient management.

CHAPTER 2

LITERATURE REVIEW

2.1 What is a Lake?

A lake is an ecosystem comprising a physical and chemical environment in which biological communities such as animals, plants, and microorganisms live and interact (Prok *et al.* 2004, 1). According to Adam (2018), a lake is an area filled with water, localized in a basin and surrounded by land; it is different from a river or an outlet that feeds or drains the lake. A lake has also been defined by limnologists as a water body that is simply a larger form of a pond, which may have wave action on the shoreline or wind-induced turbulence playing a major role in mixing the water column. Lakes frequently undergo gradual evolutionary variations that reflect the changes that occur in their watersheds. The gradual variations in the physical, biological, and chemical environments of a lake affect the development, competition, and succession of many different plants and animals (Prok *et al.* 2004, 1). Generally, the natural process by which lakes form, evolve, and become extinct takes thousands of years. However, anthropogenic activities within the watershed of a lake can cause changes in a lake which may result in its extinction within one generation (Prok *et al.* 2004, 1).

2.1.1 Why Manage Lakes?

Healthy lakes and their watersheds not only provide the human population with several environmental benefits but also influence the quality of human life and strengthen the national economy. Besides, the proper functioning of lakes can reduce the impact of floods and droughts through the storage of large amounts of water and its release during periods of shortage. Lakes also replenish groundwater, positively influence the water quality of downstream watercourses, and preserve the biodiversity and habitat of the area (Postel and Carpenter 1997, 195-214). Other important features of lakes include the provision of recreation, sources of drinking water, a water supply for industry, irrigation sources for agriculture, inland transportation, hydroelectric power, the supply of fish, esthetic enjoyment, tourism, and settlements (Postel and Carpenter 1997, 195-214). Lakes are also important ecosystems with the potential for sustaining a healthy balance of aquatic life and above all supporting socio-economic needs. These services are impaired, however, through their utilization as well as the anthropogenic activities within their catchments (Edmondson 1969, 127-128; Harper 1992, 327). Nevertheless, lakes are generally sensitive to pollutants, and with a high-volume water storage capacity and extensive retention times, chemical and organic pollutants can be found in rather high concentrations in the water and can accumulate in bottom sediments (Edmondson 1969, 127-128; Harper 1992, 327). Fundamentally, a lake and its drainage basin are linked and interactions between humans, water, and land resources are critical factors that influence a lake's health and its potential long-term uses. Continuous dependence on the services provided by lakes implies a gradual degradation of the water quality and the lake ecosystem, and the subsequent impairment of the services from many ecosystems and their environment as well as their sustainability (Arrow *et al.* 1995, 91-95; Levin 1996, 12-32). The concept of sustainable management of lakes generally addresses social, economic, environmental, biotic, and abiotic factors (Carpenter and Cottingham 1997, 1-16). Nonetheless, changes in abiotic factors in a lake, such as water and sediment in terms of their quality as a result of pollution from natural and anthropogenic activities affect living organisms (biotic), the environment, the proper functioning of the ecosystem, and therefore, the social and economic factors. It is, therefore, imperative for the proficient management of such abiotic factors, to prevent a negative impact from inappropriate management of these factors, thereby ensuring sustainable management of these resources to meet the demands and expectations of current and future generations.

2.1.2 Deciding on Lake Management

Lake management is the act of protecting the health of a lake ecosystem through a planned preventive or restorative action. Reliable information on water quality data, levels of use, and use impairment is critical in determining the health of a lake as well as developing a management plan to protect the lake. A prerequisite for deciding how to protect a lake through the study of its trophic state and primary productivity is to develop a fundamental understanding of the physical, biological, and chemical properties. These properties, such as light, temperature, and nutrients, affect plants and animals as well as the lake itself (Prok *et al.* 2004, 1). On the other hand, lake restoration has proven to be a very challenging and expensive process with variable and often unpredictable success rates (Spears *et al.* 2022, 173-182). Early actions to prevent the degradation of lakes in good ecological condition are preferable to attempting to restore lakes that have been allowed to degrade; this thereby allows a continuity of ecosystem services (Spears *et al.* 2022, 173-182). It is imperative to identify mainstream preventive lake management including the building of a robust evidence base to support initiatives aimed at reversing the early stages of changes in the ecological state. Vollenweider (1976, 53-83) documented the relationships between nutrient loading, algal biomass, and lake clarity. This represented a milestone in lake management since it allowed managers to predict the outcome of nutrient control strategies through the characterization of lakes to inform the underlying research needs and approaches towards sustainable and effective management as well as identify the future research needs of a lake. The concept of using trophic state indicators and nutrient ratios to characterize the trophic state and primary productivity in lakes thus became a model that limnologists used previously to identify the future research needs (either protection or restoration) of a lake towards effective and sustainable management.

2.2 The Position of Ghana in Africa

Ghana is a country located on the continent of Africa, more precisely in West Africa (Figure 2.2-1). It is bordered to the west by Cote d'Ivoire (Ivory Coast), to the east by Togo, to the north by Burkina Faso and to the south by the Gulf of Guinea. The Atlantic Ocean is directly below the southern border of Ghana, whereas the Gulf of Guinea is located along the southeastern edge of Ghana.

Source: Water Reports/Rapports sur l'eau ISSN 1020-1203

Figure 2.2-1: Map of the Continent of Africa Showing the Position of Ghana

2.2.1 Ghana

Ghana is located between latitude 7.9465°N, and longitude 1.0232°W and has an area of 238,540 km^2 (92,100 square miles), extending 458 km (284 miles) NNE to SSW and 297 km (184 miles) ESE to WNW. The total area of Ghana is divided into 95.4% land and 4.6% water. The total boundary length of Ghana is approximately 2,633 km (1,635 miles), of which approximately 539 km (334 miles) is coastline (Figure 2.2.1-1). Comparatively, Ghana is the 80^{th} largest country in the world based on its total square mileage. Its climate is tropical with temperatures normally between 21 and 32°C. Its weather is typically windy and sunny. There are two rainy seasons. In the South, the rainy season is from March to July and September to October, separated by a short dry season in August and a relatively long dry season from mid-October to March, whereas the North has only one rainy season from July to September. The country is generally hot and humid in the southwest, with annual rainfall averaging 2,030 mm. The extreme southwest, around Axim, records the heaviest rainfall. The southeast coast is warm and comparatively dry, while the north is hot and dry.

Source: https://www.cia.gov/library/publications/the-worldfactbook/maps/maptemplate_gh.html

Figure 2.2.1-1: Map of Ghana Showing its Extent

2.3 Ghana's River Systems

Although Ghana is considered to be endowed with water resources (Figure 2.3-1), the amount of available water significantly varies from year to year and season to season (accessed 29th September 2022, https://www.wrc-gh.org/water-resources-management-and-governance/river-systems/). Surface water resources in Ghana are mainly obtained from three major river systems; notably, the coastal river system, the south-western river system, and the Volta River system. The Tordzie/Aka, Densu, Ayensu, Ochi-Nakwa, and Ochi-Amissah Rivers constitute the coastal river system while, the Bia, Tano, Ankobra and Pra Rivers constitute the south-western river system, and the Red, Black, and White Volta Rivers, as well as the Oti River, constitute the Volta River system (Yeleliere *et al.* 2018, 1-12). The distribution of these water resources within Ghana is relatively non-uniform as the south-western portions are more well-endowed than the coastal and northern regions (accessed 29th September 2022, https://www.wrc-gh.org/water-resources-management-and-governance/river-systems/). Water availability is however, decreasing due to rainfall variability as a result of climate change, increased environmental degradation, river pollution, rapid population growth, and the draining of wetlands (accessed 29th September 2022, https://www.wrc-gh.org/water-resources-management-and-governance/river-systems/). According to the literature, all of Ghana's rivers drain southwards to the Gulf of Guinea. The Volta River alone has a total catchment area of nearly 70% of the total land area of Ghana (approximately 240,000 km^2) and is primarily, the largest river draining the entire northern, central, and eastern portions of the country. The remaining rivers [the coastal river system (8%) and the south-western river system (22%)] have a total catchment area of nearly 30% of the total land area of Ghana and drain the southern and southwestern portions of Ghana (Figure 2.3-1) (accessed 29th September 2022, https://www.wrc-gh.org/water-resources-management-and-governance/river-systems/). Additionally, Lake Bosomtwe, a meteoritic crater lake located in the forest zone with a surface area of 50 km^2 and a maximum depth of 78 m is the sole natural freshwater lake in Ghana (Yeleliere *et al.* 2018, 1-12). Darko et al. (2013, 1318-1327) conducted a four-year (2005-2008) study on "A Number Description of Ghanaian Water Quality – A Case Study of the Southwestern and Coastal Rivers Systems of Ghana" using the Solway weighted water quality index. The study showed that the WQIs of the southwestern and coastal rivers systems were erratic from one year to another, but mostly remained in the Class II ("fairly good") water quality status with an annual water quality in decreasing order of: 2005 > 2007 > 2006 > 2008. According to Darko et al. (2013, 1318-1327), most Ghanaian waters currently are practically in the Class II state; or are of the "fairly good" water quality category. The study recommended that efforts should be made by the managing institutions to prevent further degradation of the water quality in these river basins in order to retain their current status or revert them to the Class I state, which is considered as "good/unpolluted and/or recovering from pollution".