UNIVERSITY OF EDUCATION, WINNEBA

ASSESSMENT OF WATER POLLUTION AND BIODIVERSITY CHANGE OF THE MUNI-POMADZE LAGOON AND ITS CATCHMENT IN WINNEBA, GHANA

NELSON YEBOAH BOANU

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DECLARATION

STUDENT'S DECLARATION

I, Nelson Yeboah Boanu, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE……

DATE……

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for the supervision of thesis laid down by the University of Education, Winneba.

…….. (Supervisor)

SIGNATURE……..

DATE……

DEDICATION

To my parents, Mr. John Kwame Yeboah and Mrs Elizabeth Boanuaa. Also to all my family and friends.

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ABBREVIATIONS

ARER - The Annual Review of Environment and Resources

CAFOs - Concentrated Animal Feeding Operations

CBD - Convention on Biological Diversity

CENR - Committee on Environmental and Natural Resources

CSIR - Council for Scientific and Industrial Research

CWMP - Coastal Wetlands Management Project

EEA – European Environment Association

EIAs – Environmental Impact Assessment

ENWRA - Ethio Wetlands and Natural Resources Association

GEF - Global Environment Facility

GERMP - Environmental Resource Management Project

IPCC - Intergovernmental Panel on Climate Change

IUCN - International Union for Conservation of Nature

IWRB - Idaho Water Resource Board

MEA – Millennium Ecosystem Assessment

MEST - Ministry of Environment, Science and Technology

MoEF - Ministry of Environment and Forests

NOAA – National Oceanic and Atmospheric Administration

NPDES - National Pollutant Discharge Elimination System

NPS - Nonpoint source

NWCMP - National Wetlands Conservation and Management Programme

NWCS – National Wetlands Conservation Strategy

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organization
USEPA – United States Environmental Protection Agency
USGS – United States Geological Survey
WHO – World Health Organization
WQS – Water Quality Standards
WRI – World Resources Institute

ABSTRACT

The study sought to investigate water pollution and biodiversity change of the muni-Pomadze lagoon and its catchment in Winneba, Ghana. This is an onsite study hence much of the data were taken in the form of water samples. This notwithstanding, the views of the residents in and around the lagoon and the Wildlife Division of the Forestry Commission were sought hence purposive sampling technique was used to select fifteen (15) participants. Content analysis were also done to validate the responses obtained from the field. The research instruments used for the study were in-depth interview guide, field observations, content analysis, field measurements of physical parameters in-situ, as well as photographs taken on the field. All the parameters tested in the Muni catchment were within the threshold provided by WHO and USEPA with the catchment having WQI range of (51-70) all of fair water quality in the wet season. For the dry season, the WQI values for Muni lagoon and Ntakofa were within (26-50) being good water quality with Pratu having an excellent water quality. It was revealed that, there have been great decline in biodiversity which has affected the socio-economic lives of people who depend on the lagoon. Radio, community and outreach programs. are carried out on routine basis to ensure effective management. It can be concluded that, anthropogenic activities determined greatly the water quality index and status of pollution in the study area more than nature does. It is recommended that, there should be a thorough and continuous monthly water quality assessment of the Muni catchment as well as continuous collaborative governance model bringing all stakeholders together to manage the Muni catchment.

CHAPTER ONE

INTRODUCTION

Background to the study

In developing countries, water pollution constitute a primary challenge for sustainable water resources management. Despite the World Health Organization (WHO) and the United State Environmental Protection Agency's (USEPA) guidelines for drinking and surface water quality, water pollution in various sources has been continuously increasing in most countries. Thus ensuring water quality must be an issue of scientific and public concern. Scientists and researchers have identified several factors that threaten water quality. These include but not limited to habitat destruction, invasive species, pollution and human overpopulation. Several studies also have shown that many fresh water bodies are continuously being disturbed and polluted due to human activities which influence changes in hydrologic regime, water quality and biodiversity of water bodies. Wetlands are not truly aquatic, as they often have soil, but neither are they truly terrestrial, as they have standing water (Keddy, 2006). They form at the edge of terrestrial and aquatic environments, having characteristics of both (Gibbs, 1993).

The Ramsar Convention on Wetlands (1971) defines wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh brackish or salt including areas of marine water the depth of which at low tide does not exceed six meters. Ghana is a signatory to the Ramsar Convention and there are five Ramsar sites of international importance in the country: i) Densu Delta; ii) Songor; iii) Keta Complex; iv) Muni-Pomadze; v) Sakumo Lagoons. All these are protected areas and have been gazetted as such. Other wetlands located in the forest and wildlife reserves are the Mole National Park, Black Volta, Sene, Bia and Owabi

Wildlife Sanctuaries. These are also protected areas. Some wetlands, which fall outside the conserved wetland areas, are subject to traditional conservation practices such as the rivers Ankobra and Pra.

Ghana has been a signatory to the Ramsar Convention, an international treaty focusing on the conservation of wetlands of international importance, since 1988. Wetlands including lagoons, provide series of services and functions both socioeconomically and ecologically (Kabii, 1997). Further, wetland provides water for both household and industrial use Due to improper utilization and misconceptions about wetlands, the health of wetlands is continuously decreasing from time to time casting doubt about their existence in the near future (Uluocha & Okeke, 2004; Akpofure, 2009; Asibor, 2009). However, it is asserted that Wetlands have been historically considered "wastelands" (Ryan &Ntiamoa-Baidu, 2000) and the result being degradation through dredging, flooding, filling and excavation for various agricultural and industrial uses. Thus, the attraction and values of wetlands as important wildlife habitats among other uses has been hindered. Coastal wetlands are especially important as a nutrient-rich habitat for fish spawning and nursery (Ntiamoa-Baidu & Gordon, 1991). It is, however, important to understand what constitutes high quality, clean water. In nature, pure water does not actually exist, hence it is not possible to find water that has absolutely nothing in it (Guptaa, Sunitaa & Saharanb, 2009).

Water is always found in combination with minerals and chemicals. The types of minerals and chemicals found in water will depend on a number of factors such as human activities, precipitation, and runoff from adjacent land, surrounding vegetation and wildlife or soil, geologic formations and terrain in the catchment area (Oluyemi, Adekunle, Adenuga & Makinde, 2010). If water quality is degraded its adverse effect on the ecosystem is very somber. Similarly, when ecosystems become degraded, it has a negative impact on the water. Water resources are important to the viability of the ecosystem on

which our livelihoods depend (Biney & Amuzu, 1995). Despite this fact, many of our water resources have been poorly managed. The Muni-Pomadzi wetland is one of Winneba's major sources of natural resource that has received a growing amount of attention from different groups of people with the general aim of preservation and maintenance. The Muni lagoon receives discharges from the major tributaries being the Pratu, Ntakofa and Ayensu rivers.

Quality water is of great significance to life. It is a requirement by every creature for their survival without which, living becomes nearly impossible. Water makes up about 70% of the earth's surface but only 2.53% is fresh water whereas the remaining percentage is salty water (UNESCO, 2003). Without adequate fresh water in its appropriate quantity and required quality, sustainable maintenance of development will not be possible (Adeyeye & Abulude, 2004). However, anthropogenic activities such as farming along the banks of rivers, flow of domestic effluents into rivers, small scale industries located close to rivers and other human activities are beginning to impact on these tributaries leading to changes in water quality (Hill, 1999). These tributaries are very important in the maintenance of the flora and fauna in the wetland. Farming activities therefore play an important role in the changes in water quality among many river basins including the Pratu and its associated tributaries that feed the Muni wetland. According to Dix (1981), a river may be said to be polluted when the water in it is altered in composition or condition, directly or indirectly as a result of the activities of man, so that it is less suitable for all or any of the purposes for which it would be suitable in its natural state.

The Muni Pomadze Ramsar site is constantly degrading due to pollution from the people who stay around the catchment area of the lagoon. People have begun to dump refuse in the lagoon which is causing the pollution, degradation and silting of the Lagoon. It is therefore against this background that this study was conducted to explore the link

between pollution, water quality and biodiversity focusing on the Muni Pomadze Ramsar site in Winneba, Ghana.

Statement of the problem

Wetlands continue to decline globally, both in area and in quality (Seid, 2017). As a result, the ecosystem services that wetlands provide to society are reduced. Water resources come in different forms and have multiple uses ranging from aquatic biome to livelihood activities for humans. Despite this fact, the management of our water resources leaves much to be desired. Though the Muni catchment would have been a scenic landscape and supported socio-economic activities in the Effutu Municipality, it is rather receiving uncontrolled discharges of domestic and agricultural wastes from the inhabitants from Akosua village and those who farm along the two rivers that feed the muni lagoon. This has caused biodiversity in the Muni catchment to dwindle. Mangroves planted to support birds, plants and the lagoon as well have drastically gone down to near extinction. Birds and fish population have also reduced. This compounded deposition of waste in the lagoon is increasing its shallowness whiles reducing the drainage basin of the Muni lagoon, thereby, undermining its socio-economic and ecological functions. Human activities within the sites threaten the life of species, their habitat and the basic livelihood of communities within the sites who depend on these resources. Human activities such as encroachment for building or settlement, farming, grazing, fuel wood harvesting etc. all affect the lagoon. The infiltration of chemicals from farmers especially vegetable farmers, household waste to the lagoon and farm residue or waste are deposited into the Muni catchment. This has caused joblessness to some fishermen which also in a way reduced the level of eco-tourism as the population of migratory birds has greatly reduced. Millennium Ecosystem Assessment, (2005) asserts that when wetland is degraded or polluted, its quality is disturbed and hence prevents the wetland ecosystem from performing its functions such as

regulating, supporting, provisioning, and cultural services or functions. The siltation of the lagoon has reduced its floodwater carrying capacity with the result that serious flooding occurs during the wet season and drastic reduction in volume in the dry season. The disposal of waste into the Muni Pomadze Ramsar site eventually affect its physico-chemical parameters, hence making it unfavorable habitat for biodiversity and even for household usage.

Wetlands are among the most threatened ecosystems in the world, being subjected to unsustainable resource utilization, vegetation disturbance, habitat degradation, sedimentation, drainage and pollution (Millennium Ecosystem Assessment, 2005). According to Wuver and Attuquayefio (2006), the degradation in and around the wetland could be largely attributed to neglect and unsustainable human activities upland. It is imperative to analyze physico-chemical parameters in order to get precise knowledge about the water quality and compare the study results with standard values. Patil, Sawant and Deshmukh, (2012), underline that it is important to check the quality of drinking water regularly at time interval, because human population is usually harmed from waterborne diseases due to use of contaminated drinking water. Abdourahamane, (2010), conducted a study on the Muni lagoon, but her work centered on accessing the ecological status of the lagoon by looking at the role of water bird communities' play as well as water birds as bioindicators of wetland health. Again, Tay, Asmah & Biney, (2010) also conducted a comparative study on pollution status of the Sakumo II and Muni lagoons in Ghana. These works were centered solely on the Muni lagoon but little attention was given to the Pratu and the Ntakofa rivers that empty into the lagoon. A study by Tiakor, (2015) was also about the impact of farming activities on the water quality of the Pratu River and its tributaries in the Muni- Pomadze Wetland. Though some attention was given to the Muni lagoon and the Ntakofa River, the main focus was on the pollution aspect of the Pratu River. This work looked at the assessment of water pollution and biodiversity change of the three water

bodies (Muni lagoon, Pratu and Ntakofa rivers) forming the Muni catchment and use the water quality index to examine the extent of pollution in the three main water bodies in the Catcthment in Winneba, Ghana. This study was conducted to examine the extent to which these activities affect the quality of water of the Muni Pomadze Ramsar site and its catchment using the water quality index and its implication for wetland management.

Research objectives

The purpose of this study was to explore the extent to which pollution is affecting the Muni Pomadze Ramsar site and its implications for wetlands management. However, the following specific objectives guided the study. The specific objectives are to:

1. Assess the water quality of the three main water bodies (Muni lagoon, Pratu and Ntakofa rivers) based on its physicochemical parameters.
2. Compare the extent of pollution among the three main water bodies in the Muni Catchment.
3. Analyze the implication of pollution on biodiversity change and on the ecological and socio-economic functioning of Muni catchment.
4. Evaluate the effectiveness of management strategies in maintaining the Muni Pomadze Ramsar site and its catchment.

Research questions

The study provided answers to the following research questions.

1. What is the water quality of the Muni Pomadze wetland and its catchment based on its physico-chemical parameters?
2. What is the water quality of the Pratu River based on its physico-chemical parameters?
3. What is the water quality of the Ntakofa River based on its physico-chemical parameters?

4. What is the extent of pollution among the three main water bodies in the Muni Catchment?
5. How has pollution affected the ecological functions or biodiversity in the Muni catchment?
6. What is the implication of pollution on the socio-economic functioning of the Muni catchment?
7. Are there management strategies used in sustaining the Muni lagoon and its catchment?
8. How effective are the management strategies in maintaining the Muni Pomadze Ramsar site and its catchment?

Significance of the study

Historical evidence shows that the Muni Pomadze Ramsar site supported commercial fisheries with attendant socio-economic activities. In addition to this, the lagoon is supposed to provide ecosystem functions including providing habitat for biodiversity (Millennium Ecosystem Assessment, 2005) and serves as a floodwater storage facility. However, the continuous siltation and pollution of the lagoon resulting from waste are undermining its functions. The study will, therefore, help in understanding water pollution and biodiversity change of the Muni lagoon and it's catchment in Winneba, Ghana. This will inform the people to take a second look at their activities that pollutes the environment. It will also help to understand why the uncontrolled discharge and dumping of waste into the lagoon is causing rapid decrease in population of species in the study area. The study will equally serve as a policy document for government and other international bodies on issues of wetlands management. Moreover the management policies and recommendations that will be brought forth, if taken into accounts will help revive the life in the ecosystem as it used to be some years ago. This will help the local people revive the

income level if life is finally restored back in the Lagoon and its catchment. Finally, the study will add up to the literature existing on wetland management.

Scope and delimitation

The study looked at the water quality of the Muni Pomadze Ramsar site based on its physico-chemical parameters, compare the extent of pollution among the three main water bodies (Pratu, Ntakofa and Muni lagoon) sources of the continuous pollution and degradation of the Muni lagoon, impact of the pollution and degradation of the Muni Pomadze Ramsar site on its ecological and socio-economic functions and management strategies that are effective to managing the pollution of the Muni lagoon. The study was limited geographically to only Muni-Pomadze Ramsar site and its catchment (Pratu and Ntakofa rivers) which is located in Winneba in the Central Region of Ghana. It is made up of the Muni Lagoon, the surrounding floodplains and the adjacent sandy beach on the seafront with coordinates 5°22'N 0°40'E. With respondents, the study was limited to the five of the communities that are part or very close to the catchment area of the wetland. The five communities that are located very close to the catchment area are; Winneba, Aboaku, Pratu, Onyadze, and Pomadze.

Organization of the study

The work comprises Six Chapters. The First Chapter talked about the introduction which took a critical look at the background of the study and the statement of the problem, research objectives, research questions and significance of the study. Chapter Two discussed some of the existing literature on wetland (Ramsar site), water quality and pollution or degradation. Chapter Three looked at the methodology. This chapter focused on the research design and methods that were used to conduct the study. Chapter Four devoted to the discussing the physical properties and extent of pollution of the Muni catchment. Chapter Five discussed the implication of pollution and effective management

strategies toward maintain the Muni catchment. Chapter Six dealt with summary, conclusions, and recommendations of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This chapter explored and reviewed available literature related to the study. It is important to note that wetlands, lagoons and ramsar sites differ but are being used interchangeably in this document/context to mean wetlands. For this purpose, literature information was reviewed under themes such as the meaning and definition of wetlands, classification of wetlands, wetlands in Ghana, Laws and principles guiding wetlands, the Ramsar Convention of 1971, wetland conservations and conventions, policies and laws in Ghana, functions of wetland, wetland degradation and pollution, sources of pollution, effects of pollution, implications of pollution on the ecological and socio-economic functioning of wetlands, measures and strategies to address and reduce wetland degradation and pollution, Wetland management in Ghana, Water quality, and biodiversity change, causes of biodiversity change, effects of biodiversity change, measures to address and reduce biodiversity loss and management strategies. The study was buttressed by Driver- Pressure-State- Impact- Response Propounded by the European Environment Agency (EEA, 1998)

Meaning of wetlands

The common and overriding theme of most definitions of wetlands consists of some component related to hydrologic conditions (Zedler & Kercher 2005; Moore 2008). Despite this, the degree and extent of conditions constituting a wetland is not widely agreed upon (Zedler & Kercher 2005; Ramsar 2011). Turner, van der Bergh, Soderqvist, Barendregt, Van der Straaten and Maltby, (2000) defined Wetlands as generally transitional area between permanently flooded deep water environments and well drained uplands. The (Ramsar Convention Secretariat, 2006), further postulated that wetlands are “natural or artificial,

permanent or temporary, with water that is static or flowing, fresh, brackish, including areas of marine water the depth of which at low tide does not exceed 6 metres". This definition is more biological, defining a wetland on the basis of the species occurring there.

The Ramsar convention on wetlands of international importance defines wetlands as "areas of marsh, fen, peatland or water whether natural or artificial, permanent or seasonal with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six metres" (Ramsar, 1971). In the view of Niering (1985), wetlands are described as areas in which water controls both the environment and associated biota of an area. Wetland areas "may incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands" (Ramsar 2011). By these definitions, wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. Wetlands are important since they stabilize water supplies and clean polluted water as downstream receiving water bodies (Mitsch & Gosselink, 2000).

According to the United States Environmental Protection Agency, wetlands are often wet, a wetland might not be wet year-round. In fact, some of the most important wetlands are only seasonally wet. Wetlands are the link between the land and the water. They are transition zones where the flow of water, the cycling of nutrients, and the energy of the sun meet to produce a unique ecosystem characterized by hydrology, soils, and vegetation, making these areas very important features of a watershed. Using a watershed-based approach to wetland protection ensures that the whole system, including land, air, and water resources, is protected. Although wetlands are best known for being home to water lilies, turtles, frogs, snakes, alligators, and crocodiles, they also provide important habitat for waterfowl, fish, and mammals. Migrating birds use wetlands to rest and feed during their cross-continental journeys and as nesting sites when they are at home. As a result, wetland loss has a serious impact on these species. Habitat degradation since the

1970s has been a leading cause of species extinction. Wetlands provide habitat for thousands of species of aquatic and terrestrial plants and animals. When rivers overflow, wetlands help to absorb and slow floodwaters. This ability to control floods can alleviate property damage and loss and can even save lives. Wetlands also absorb excess nutrients, sediment, and other pollutants before they reach rivers, lakes, and other water bodies. In addition, nonnative species of plants and animals and global climate change contribute to wetland loss and degradation.

EPA has a number of programs for wetland conservation, restoration, and monitoring. EPA, along with the U.S. Army Corps of Engineers (EPA & USACE, 1990), establishes environmental standards for reviewing permits for discharges that affect wetlands, such as residential development, roads, and levees. Under Section 404 of the Clean Water Act, the Corps issues permits that meet environmental standards (after allowing the public to comment). In addition to providing regulatory protection for wetlands, EPA works in partnership with states, Ramsar (1971). Ramsar Convention on Wetlands of International Importance, tribes, and local governments, the private sector, and citizen organizations to monitor, protect, and restore these valuable habitats. EPA is helping states and tribes incorporate wetland monitoring, protection, and restoration into their watershed plans. Nationally, EPA's Five-Star Restoration Program provides grants and promotes information exchange through community-based education and restoration projects. EPA works with a variety of other federal agencies to protect and restore wetlands, including the U.S. Fish and Wildlife Service, the U.S. Department of Agriculture, and the National Marine Fisheries Service. EPA is working with these agencies and others to achieve an overall increase of wetlands over the next successive years.

Classification of wetlands

Since 1971, when the Convention on Wetlands of International Importance (Ramsar Convention, 1971) came into force, wetlands have been internationally recognized as ecosystems of considerable importance, comparable to our forests, rangelands and marine ecosystems. The term 'wetland' groups together a wide range of habitats that share common features, the most important of which is continuous, seasonal or periodic standing water or saturated soils. Kulser and Kentula (1992), explains classification of wetland as involving the grouping of wetlands by specified characteristics (vegetation, hydrology, soils, animal species present, function, value, etc.) to serve specific goals. Based on HGM dynamics of wetlands (Gwin, Kentula, & Shaffer, 1999) defined four classifications of naturally occurring wetlands. These are depression, lacustrine fringe, riverine, and slope. However, Brinson (1993) identifies a more detailed listed wetland classes that are distinguishable at the content scale as depression, tidal fringe, lacustrine, fringe, slope, mineral soil flats, organic soil flats, and riverine. The water found in wetlands can be freshwater, brackish, or saltwater. The main wetland types include swamps, marshes, bogs, and fens; and sub-types include mangrove, carr, pocosin, and varzea. On a broader perspective, wetlands can be classified or grouped into open and closed.

A report compiled by Tamakloe to the Environmental Protection Agency in 2007, gives a useful summary description of Ghana's coastal lagoons, he asserts that over 90 coastal lagoons fringed by intertidal mud or sandflats and in some places by mangrove swamps occur along the coastline of Ghana. The lagoons form important vulnerable ecosystems, housing a wide variety of fish, shrimps, crabs, mollusk and polychaete species. Some of the lagoons have been recognized both nationally and internationally as migratory water bird habitats (Ntiamoa-Baidu & Grieves 1987, Ntiamoa-Baidu 1991, 1993) while some may serve as nursery areas for juveniles of marine fish and shrimp. Two main types

of coastal lagoons are encountered in Ghana. These are 'open' and 'closed' lagoons (Armah 1991).

The open lagoons have a permanent opening to the sea and are normally fed by rivers that flow all year round. They occur mostly on the central and western parts of the coastline where higher rainfall results in a more continuous flow of the rivers and streams. The closed lagoons are separated from the sea by a sand barrier. They are more common on the eastern segments of the coastline where rainfall is low and highly seasonal. Some closed lagoons open to the sea in the wet season when floodwaters break the sand barrier (Kwei, 1977). Storm surges may also erode sandbars and open up closed lagoons to the sea (Armah, 1991). Under other circumstances the sandbar may be manually breached during the wet season to reduce the risk of flooding adjacent settlements where this is considered a threat. Depending on the size of the barrier which impedes the flow of water in and out of the lagoon, coastal lagoons may be partially or entirely enclosed (Kennish & Paerl, 2010). Kjerfve (1994), states that, lagoons can be classified into three types according to how water is exchanged with the ocean. These are choked, restricted and leaky lagoons.

Choked lagoons

Choked lagoons usually have a narrow channel to the sea and form in areas where the energy of waves in the sea is high (Kjerfve, 1994). The narrow inlet mostly prevents the tides from entering, and also prevents much mixing of water (Kjerfve, 1994). In arid areas, high evaporation rates and reduced tidal inflow result in this type of lagoon becoming temporarily or permanently hypersaline (Kjerfve, 1994). Mundel Lagoon and Rekawa Lagoon in Sri Lanka, the Songkhla Lake in Thailand and the Lagoa dos Patos, Brazil are examples of choked lagoons (Jayasiri & Rajapaksha, 2000; Kjerfve, 1994).

Restricted lagoons

Restricted lagoons have more than one channel to the sea, temporarily 'restricting' water exchange, but in reality there is good water exchange, and a net transport of water to the sea (Kjerfve, 1994). Wind plays a role in restricted lagoons, as surface currents can develop because of the wind and result in mixing of water (Kjerfve, 1994). The flushing time is very much shorter than in choked lagoons. Uppar Lagoon, in eastern Sri Lanka and the Laguna de Terminos, Mexico are example of restricted lagoons (Kjerfve, 1994).

Leaky lagoons

Leaky lagoons have wide channel(s) to the sea, unhindered interchange of water and fast water currents. As Kjerfve (1994) says, 'leaky lagoons occupy the opposite end of the spectrum from choked lagoons'. The Mississippi Sound, USA is an example of a leaky lagoon (Kjerfve, 1994).

Laws guiding wetlands; Ramsar conventions, (1971)

The Convention on Wetlands of International Importance, especially as Waterfowl Habitat, or Ramsar Convention, is an international treaty designed to address global concerns regarding wetland loss and degradation. The primary purposes of the treaty are to list wetlands of international importance and to promote their wise use, with the ultimate goal of preserving the world's wetlands. Methods include restricting access to the majority portion of wetland areas, as well as educating the public to combat the misconception that wetlands are wastelands. The treaty, which now encapsulates 1,916 "wetlands of international importance", The Convention works closely with five International Organization Partners. These are: Birdlife International, IUCN, International Water Management Institute, Wetlands International and World Wide Fund for Nature. The partners provide technical expertise, help conduct or facilitate field studies and provide financial support. The IOPs also participate regularly as observers in all meetings of the

Conference of the Parties and the Standing Committee and as full members of the Scientific and Technical Review Panel.

Wetlands in Ghana

Based on the criteria of the Ramsar convention, three major types of wetlands are identified in Ghana (Ministry of Lands and Forestry (MLF), 1999; Ramsar Convention 1971).

These are: (1) Marine /coastal (2) Inland (3) Man-made

Marine and Coastal Zone wetlands, Inland wetlands and Constructed or Human-made wetlands. The Government of Ghana recognizes the importance of wetlands as habitat for wildlife, in the maintenance of the water table, mitigation of flood conditions and water purification. Wetlands resources are also known to be of socio-economic importance and have been harvested for construction poles, fuel-wood, timber for furniture and craft work.

a) Marine and Coastal Zone wetlands

These are the types of wetlands that are found within the coastal zone of Ghana and are mainly saltwater ecosystems. They are primarily associated with flood plains of estuaries of large rivers and watercourses. The major coastal wetlands or salt-water ecosystems are: the Rocky Marine shores found at Senya Bereku and Cape three points etc, Estuarine Waters, which include the mouth of Volta, Pra, Butre and Ankobra etc. Again we also have mangrove and tidal forest encompassing the lower reaches of Volta, Oyibi, Kakum and Ankobra etc and lastly we have the Brackish or saline lagoons which include the open Korle, Amisa and closed Songor and the Muni. It extends to marine waters, the depth of which at low tide does not exceed six meters. This is exemplified by areas such as the sandy beaches and shallow waters along the Brenu Akyim seashore in the Central Region. Marine and Coastal Zone wetlands includes Marine waters-permanent shallow waters less than six metres deep at low tide; includes sea bays, straits), Subtidal aquatic beds; includes(kelp beds, Sea grasses, tropical marine meadows,) Coral reefs, Rocky

marine shores; includes rocky offshore islands, sea cliffs. National Wetlands Conservation Strategy (NWCS, Ministry of Lands and Forestry, 1999).

b) Inland wetlands

Inland waters are mainly freshwater ecosystems.

They occur wherever groundwater, surface springs, streams or run-off cause saturated soils, frequent flooding or create temporary and/or permanently shallow water bodies. Inland or freshwater wetlands, especially freshwater marshes are the most widespread and important world-wide. In Ghana, this is the most extensive as it encompasses all the natural drainage systems. They are as follows; Freshwater marshes (Black, Red and White Volta), Freshwater swamp forest (Amansuri), Permanent river or stream (Densu, Afram, Oti and Ankobra) and Permanent freshwater lake (Bosumtwi). These are some of the numerous examples according to the (Ramsar Convention,1971) Permanent rivers and streams; includes waterfalls, Seasonal and irregular rivers and streams, Inland deltas (permanent), Riverine floodplains; includes river flats, flooded, river basins, seasonally flooded grassland, savanna, and palm savanna, Permanent freshwater lakes and ponds includes large oxbow lakes, Seasonal/intermittent freshwater lakes, floodplain lakes, etc. (NWCS Ministry of Lands and Forestry, 1999).

c) Constructed or Human-Made Wetlands

The Ramsar Convention also recognizes four categories of man-made or artificial wetlands. These are wetlands constructed for aquaculture, agriculture, salt exploitation, water storage and urban/industrial purposes. In Ghana, these are as follows: Irrigated land (Tono, Vea, Dawhenya, Anum Valley), Salt Pans (Elmina Salt Pans, Songor, Densu Delta), Reservoirs (Volta Lake, Kpong head pond, Brimsu reservoir), Urban/Industrial (Tema Sewerage Treatment Plant). All the above mentioned wetlands are classified as wetlands made by man for their various practices which seem to serve various needs for the human

population. (NWCS Ministry of Lands and Forestry, 1999). But Armah (1991), is of the view that two main types of coastal lagoons are encountered in Ghana. These are 'open' and 'closed' lagoons. The open lagoons have a permanent opening to the sea and are normally fed by rivers that flow all year round. They occur mostly on the central and western parts of the coastline where higher rainfall results in a more continuous flow of the rivers and streams. The closed lagoons are separated from the sea by a sand barrier. They are more common on the eastern segments of the coastline where rainfall is low and highly seasonal. Some closed lagoons open to the sea in the wet season when floodwaters break the sand barrier (Kwei, 1977). Storm surges may also erode sandbars and open up closed lagoons to the sea (Armah, 1991). Under other circumstances the sandbar may be manually breached during the wet season to reduce the risk of flooding adjacent settlements where this is considered a threat.

Wetland conservation and conventions, policies and laws in Ghana

Ghana became party to the Convention in 1988, with the establishment of the Owabi Ramsar Site (Ashanti Region). Serious wetland conservation efforts in Ghana started in 1991, with the publication of a management strategy document for Ghana's coastal wetlands (Ntiamoa-Baidu & Gordon, 1991). The document essentially outlined the importance of, threats to, Ghana's coastal wetlands, and provided recommendations on strategies to maintain the ecological integrity of these wetlands. In 1994, the Ghana Coastal Wetlands Management Project (CWMP) was commissioned with the objective of restoring and maintaining the ecological integrity of the five coastal Ramsar sites in Ghana. According to the Ministry of Lands and Forestry - to ensure the judicious use of the nation's land and all its natural resources, the Ministry of Lands and Forestry launched the National Land Policy in June 1999. The policy recognizes wetlands as environmental conservation areas and precludes the following practices:

- physical draining of wetland water;
- draining of streams and water courses feeding the wetlands;
- human settlements and their related infrastructural developments in wetlands;
- disposal of solid waste and effluents in wetlands, and
- Mining in wetlands.

(Ministry of Lands and Forestry - the National Land Policy in June 1999)

The policy also seeks to promote the use of wetlands for farming, grazing, fishing, timber production and salt-winning, provided that such uses also serve to conserve the ecosystem, biodiversity and sustainable productivity of the wetlands.

The Government of Ghana, through the implementation of the Ghana Environmental Facility, funded Coastal Wetlands Management Project from 1993 to 1999; carried out public education and awareness- creation programmes to enlighten the general public on the values, benefits and functions of wetlands and the need for their conservation and sustainable use. In order to integrate wetlands issues into national land- use planning and decision-making in other sectors of the Ghanaian economy, the Ministry of Lands and Forestry has, in consultation with key stake-holders, prepared this document – Managing Ghana's Wetlands: A National Wetlands Conservation Strategy – to promote participation of the local communities and other stake-holders in the sound management and sustainable utilization of Ghana's wetlands and their resources. These pieces of legislation are scattered throughout the statute books, and though outmoded and failing to address adequately the problem of wetlands in their entirety, do provide a starting point for the formulation of appropriate laws. Such policies and laws include the Fisheries Decree (1972), the Land Policy, the Water Resources Act, Ghana Vision 2020 and the Decentralization Policy. The protection and conservation of wetlands resources involve a number of activities. They are carried out by a number of government and non-governmental institutions including:

Wildlife Department, Ministry of Environment, Science and Technology (MEST), Environmental Protection Agency (EPA), District and Metropolitan Assemblies, Ministry of Food and Agriculture, Survey and Meteorological Services Department, Ministry of Lands and Forestry, Forestry Department, Universities, Council for Scientific and Industrial Research (CSIR) as well as NGOs.

The Ghana Coastal Wetlands Management Project (CWMP), funded by GEF and implemented by the Wildlife Department as a component of the Ghana Environmental Resource Management Project (GERMP), was aimed at establishing and managing five Ramsar sites along the coast. Many of the traditional management strategies were geared at controlling resource use by placing limits on access, both spatially and temporally, through the use of taboos and outright bans. For many years, this traditional approach has been sufficient to maintain the ecological integrity of the lagoon environment (Gordon 1992, Ntiamoa-Baidu 1992) as cited in Adu-Boahen, Dadson and Atubiga, (2018). Unfortunately, education, religion and acculturation have resulted in the breakdown of traditional management systems. Many of the areas, operate under 'common property' laws. With rising economic pressures, these areas are being exploited unsustainably with local fines and punishments being ignored or disregarded. The modern system for natural resource management in Ghana follows a three tier approach (Government of Ghana 1995 (Vision 2020). The three tiers are the district, regional and national levels. One key institution is the District Environmental Management Committee, which has representation from the decentralized departments, such as Fisheries, Forestry and Wildlife. For coastal wetlands and the five Ramsar sites in particular Muni-Pomadze, Densu Delta, Sakumo, Songor and Keta all have site management committees with representation from primary stakeholders. From the conception of the CWMP (Ntiamoa-Baidu & Gordon 1991), it was emphasized that the successful management of the coastal wetlands would require a multi-

disciplinary approach. The Department of Wildlife was therefore to seek the expertise and involvement of relevant organizations for the execution of programmes.

Functions and services of wetland

Wetlands potentially perform a number of different and often critical environmental and ecological functions benefiting humans (Kusler & Opheim; 1996; National Research Council (NRC) 1992; 2001). The National Wetlands Conservation and Management Programme of Uganda identified wetland services/functions as flood impact reduction, flow regulation and drought alleviation, ground- water recharge, water quality protection and purification, drinking water supply and storage, erosion and sediment control, wastewater treatment, carbon retention, climate modification, wildlife and habitat function, biomass export, recreation, eco-tourism and transport (NWCMP, 2000) cited in Mafabi (2018).

Some maintain base flow, and may enhance the water quality within streams and lakes with important fish and wildlife species. Correspondingly, some provide habitat for federally and State threatened and endangered species, as well as for a wide diversity of important invertebrates, amphibians, birds, furbearers and small mammals. In fact, the diversity of birds (Richter & Azous 2001c) and small mammals (Richter & Azous 2001b) in wetlands may exceed that found in upland habitats. Because of the unique mix of water and biodiversity, wetland area are also used for a broad range of recreational and esthetic activities including hunting, bird watching and the appreciation of natural beauty and solitude. Decreased turbidity allows sunlight to penetrate more effectively, encouraging the growth of phytoplankton and other tiny organisms that make up the base of the food web and add oxygen to the water through photosynthesis.

Again, Wetlands vegetation may also evaporate or transpire much of the water into the atmosphere and help to maintain stable climatic conditions. Atmospheric levels of carbon

and sulfur, both of which have increased dramatically as a result of fossil fuel and peat burning, are lowered by wetlands' ability to act as sinks (natural catch basins) and as environments capable of reducing these elements to harmless or inert forms. (Chidi & Ominigbo, 2010)

Also, Wetlands provide habitat for high concentrations of birds, mammals, reptiles, amphibians, fish and invertebrates species. Biological productivity attracts life, namely, the many plants and animals that utilize wetlands for food, shelter, spawning, nesting, or predatory opportunities. 80% of all breeding bird populations in the United States, along with more than half of the protected migratory bird species, rely on wetlands at some point in their life cycle. 95% of all U.S. commercial fish and shellfish species depends on wetlands to some extent. Chidi & Ominigbo, (2010).

Furthermore, Wetlands prevent surface run-off from moving swiftly downstream and overflowing. Thus they prevent erosion and flood conditions. Many studies have confirmed the correlation between wetland losses and increased downstream flooding. Wetlands left in place can act as protective natural sponges by capturing, storing, and slowly releasing water over a long period of time, thereby reducing the impact of floods. For every 3 miles of wetland, flooding is reduced by one foot. Also they are responsible for flood and erosion prevention, as they prevent surface run-off from moving swiftly and overflowing the river banks downstream (Managing Ghana's Wetlands: A Nationals Conservation Strategy 1999).

Moreover, Wetlands such as mangroves and other forested coastal areas act as wind-breaks and help to dissipate the forces and impact of coastal storm surges. Coastal marshes, mangrove swamps, and other estuarine wetlands act as effective storm buffers. Studies have concluded that more than half of normal wave energy is dissipated within the first 3 meters (3.3 yards) of encountering marsh vegetation such as cordgrass. Within 10

meters (11yards) the destructive energy is completely absorbed. The erosive power of tides is also dampened by wetland plants because their roots hold soil in place and their stalks reduce the destructive energy of waves and wind. In fact, dense plant growth traps additional sediment that gradually increases wetland acreage, providing further coastal protection. Chidi & Ominigbo, (2010). Wetlands aid in Waste Treatment. Wetlands can be remarkably effective in treating controlled amounts of human and animal wastes. Several factors contribute to wetlands' performance in processing waste: A high rate of biological productivity that leads to a large capacity for consuming waste, heavy deposition of sediments that bury waste, a high level of bacterial activity in sediment layers that breaks down and neutralizes waste. Cities like Philadelphia and Calcutta, India, have incorporated wetlands into their wastewater treatment schemes for decades, with persuasive results. While it is important to pay attention to a wetland's capacity, these urban wastewater treatment wetlands have removed coliform bacteria and suspended solids, reduced the turbidity of wastewater by nearly half, and added tons of oxygen to the water every day on a sustained basis. Chidi and Ominigbo, (2010). Wetlands helps to provide Food. Chidi and Ominigbo, (2010) asserts that, wetlands are valuable to humans, as they aid in food production especially the cultivation of swamps for rice (rice paddies), cranberries, fish, salmon, etc. wetlands also provides humans with commercial animal populations; peatlands are useful in production of fuels just as wetlands are used as timber and/or fiber.

Wetland soils are nutrient-rich, full of organic material, and generally less prone to erosion than other soils. They tend to be highly productive. Drained wetland soils in the U.S., taken as a whole, produce more than 25% of all major crops, a monetary value of roughly $9 billion. Wetlands also aid in Fuel, Timber and Fiber Harvest -For centuries, peat has been harvested, dried, and burned. In areas without fossil fuels or extensive forests, peat is the most viable local energy source. Worldwide, minable peat reserves have been estimated at 1 billion acres. Prolific growth rates and dense stands of vegetation make

wetlands attractive area for wood and fiber industries. Although draining and clear-cutting have been the wetland timber-cutting norm until recently, more advanced timber and logging practices like selective cutting and vigorous replanting have now been initiated in some areas, with good results. Mangrove swamps in tropical and subtropical regions have been heavily cut at a pace that cannot be sustained. In the Philippines nearly 50% of all mangrove areas were cut between 1967 and 1976. Chidi & Ominigbo, (2010). Recreation, Aesthetics, and Education is a major function or service provide by wetlands. It was estimated that 107 million people took advantage of wetland-related recreational activities in 1885. In that year hunting, fishing, and non-consumptive wildlife-related activities were valued at $55 billion. That aside, wetlands serve as biological laboratories and educational field stations with the potential to handle thousands of students learning lessons in natural history, cultural heritage, and other disciplines. Wetlands are also used extensively for recreational aesthetic and educational purpose. All over the world, wetlands are used as recreational sites in various ways – boating, picnics, yatching, fishing festival, boat regatta etc (Asibor, 2009; Chidi & Erhabor, 2009).

Lastly wetlands facilitate the movement of large volumes of water into the underground aquifer resulting in the recharge of the water table. Because of their ability to purify and retain large volumes of water, wetlands provide clean and reliable sources of water for human consumption, agriculture and industry. Many rivers flow throughout the year because the wetlands, like our rain forest, release their stored water slowly into them, thus extending the period when water is available in dryer times. Wetlands are, therefore, important in maintaining perennial rivers and streams. Managing Ghana's Wetlands: A National Conservation Strategy, (1999). It is based on these importance and among others that the 2nd day of February is celebrated as world wetland day every year.

Causes of wetland degradation and pollution

Dugan (1990) claims that 65% of wetland disturbances are of human origin, while the remainder have natural origins. Out of these human origin disturbances 73% are thought to result from direct human actions, while the remaining 27% are believed to come from indirect sources. Wetlands have been historically considered "wastelands" (Williams, 1993; Ryan & Ntiamoa-Baidu, 2000) and, therefore, subjected to degradation through dredging, flooding, filling and excavation for various agricultural and industrial uses. In recent times, however, the attraction and value of wetlands as important wildlife habitats, among other uses (e.g. provision of fin and shell fish, salt, thatch, wood, etc.) (Sather & Smith, 1984; Ryan & Ntiamoa-Baidu, 2000) have been increasingly recognized. Coastal wetlands are especially important as nutrient-rich habitats for fish spawning and nursery (Ntiamoa-Baidu & Gordon, 1991). The wetland is particularly important to the local Effutu people, serving as their traditional hunting grounds, especially during their annual "Aboakyer" Festival. In recent times, the previously diverse fauna (e.g. bushbucks, leopards, antelopes, lions, mongooses, etc.) of the area has dwindled, with some of the animals (e.g. lions), presumed locally extinct or existing in very low numbers (Ryan & Attuquayefio, 2000). Current evidence indicates that the degradation of the wetland could be largely attributable to neglect and unsustainable human activities (e.g. bushfire setting, hunting, farming, fuelwood harvesting, estate development, etc.) (Ntiamoa-Baidu & Gordon, 1991; Ryan & Ntiamoa-Baidu, 1998) over the years. This is against the background of the wetland being particularly vulnerable to degradation because of its more extensive (98%) dry land coverage (Amatekpor, 1995) than the other coastal wetlands in Ghana. The current situation, if allowed to continue, is likely to result in biodiversity loss from the wetland, consequently diminishing both the local and international significance of the "Aboakyer" Festival. Despite all the benefits provided by wetlands, extensive losses

have occurred, and more than half of our original wetlands have been drained and converted to other uses.

Firstly, the dumping of refuse, discharge of industrial and domestic sewerage, as well as agricultural run-off into wetlands increases the organic loading of the wetlands waters. This increases the biochemistry oxygen demand (BOD) of the water body, leading to inadequate oxygen supply to support plant and animal life. This may seriously contaminate the water, endangering the plant, animals and people living in or near to the water. Typical example of such polluted systems can be found in the Densu and subin river basins and the Sakumo and Korle Lagoon. The Pra and Ankobra rivers typify this state of affairs. (Managing Ghana's Wetlands: A Nationals Conservation Strategy 1999).

Secondly, improper agricultural practices and expansions also leads to wetland pollution. According (Dixon, 2002; Dixon & Wood 2007), the debate about the future of wetlands tends to divide between those seeking to develop these areas for agricultural production (crop producers and livestock rarer) and those who believe that wetlands must be preserved as much as possible in a stable state to maintain their ecological contributions to the ecological system (Ecologists). The perception of the premier extends up to assuming wetlands as west lands. In concentrating on the first big argument, it is very serious issue especially in developing countries that dominate the balance of debate. Accordingly, converting to agricultural land is better than keeping the wetlands and gaining their values. The flat topography, fertile soil and reliable provision of water at dry season etc. of wetlands are some of the attracting factors. But, in the years 1911-1918, wetland cultivation has extended beyond the use of wetland margins to include much larger areas. Nowadays the complete drainage and cultivation of wetlands becomes common phenomena throughout the area (Hailu 1998; Dixon & Wood 2007).

Moreover in the views of Hengsdijk, Meijerink, Hellegers and Snellen (2008), cited in Gebresllassie, Gashaw & Mehari (2014) stated that over grazing by domestic stocks has

also been identified as threats of wetlands. When grazing follow continuous cultivation wetlands easily become degraded and loss their natural characteristics. Livestock trample the soil and compact it and their grazing destroys natural vegetation. They erode drainage channels leading to gullies and increase water out flow. These effects often result complete degradations of wetlands by reducing the water table and by changing the original vegetation.

According to the (Managing Ghana's Wetlands: A Nationals Conservation Strategy 1999). Continuous Land degradation and Over-Exploitation is a factor. During times of draught, people tend to migrate into wetland areas. Increased demand on wetland resources, such as livestock grazing, fuel-wood, timber, water abstraction and fisheries lead to over-exploitation. This leads to the disruption of the ecological and socio-economic functions of the wetland, resulting in the loss of livelihood for many local communities. Wetlands in degraded area can share biological, chemical and physical problems. For example, if the vegetation covers of a catchment drain to a wetland decline, sediment loads will be increased (Abebe & Geheb 2003).

Again, Urbanizations and Industrialization in the view of (Dugan 1993) also leads to wetland degradation. Accordingly, considerable numbers of wetlands are near rural towns and cities, especially in Ethiopia where business activities are expanding in many sectors. Wetlands near urban centers are suffering negative consequences from the expanding sectors sources (e.g. hotels, hostels, health centers, households and factories). For instance, the amount of solid and liquid wastes generated by different sources is increasing in size and composition. This is more severe as most of the wastes from developing societies are organic, although toxic inorganic and pathogenic wastes are not absent (Lardinois & Klundert 1993). In Uganda, Akello (2007) maintains that there are adequate provisions available in policies, laws, regulations, and guidelines protecting wetlands in the country, but encroachment still persists and people still unlawfully hunt,

fetch wood, and farm along the fringes of wetlands. The illegal settlements in and around wetlands also affect the health and size of the wetlands significantly.

Lastly, not everything that can damage or diminish wetlands is the result of human actions. Natural processes can sometimes impact wetlands. Here are some natural events that can damage or reduce wetlands: Natural and Ecological problems or Disruption of Stable Climatic Conditions can cause wetland degradation. (EWNRA, 2008) asserts that the loss of water and vegetation reduces evapo-transpiration from wetlands. This leads to the disruption of the stable climatic conditions leading to drought, and under extreme conditions can lead to the disappearance of the wetlands. Climate change and recurrent droughts are threats to wetland ecosystems of the country. An increase in temperature due to global warming is generally affecting wetlands and other ecosystems. Such phenomena adversely affect hydrological cycles, which in turn affect the biodiversity resources and various services of wetlands. During recurrent drought and dry times, the pressures on wetlands are very serious, as they are the only major sources of water, fodder, and crop production, and save lives of humans, livestock and wild biodiversity. Though they have their own beauties and various advantages, rugged terrains and mountains of the country have their own contribution, especially in enhancing soil erosion and runoff agrochemicals into the wetland ecosystems and contributing to eutrophication and siltation of wetlands (Dereje 2003).

Water pollution

Our survival on Earth depends on three basic resources – water, air and soil, nature's three valuable gifts to mankind. The surface water and groundwater resources of the country play a major role in agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, recreational activities etc. In the view of Olaniran (1995), water pollution could be defined as the presence of excessive amounts

of a hazard (pollutants) in water in such a way that it is no long suitable for drinking, bathing, cooking or other uses. So in this sense, it is hazardous to both plants and animals. Webster.com, (2019) defined Pollution as the addition of harmful chemicals to natural water. According to Wikipedia as cited in Shahid and Saba, (2018), Water pollution occurs when unwanted materials enter in to water (e.g. lakes, rivers, oceans, aquifers and groundwater) and contaminate the quality of water. This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds. This is harmful to environment and human health. This simply means that water pollution occurs when harmful substances often chemicals or microorganisms contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic to humans or the environment. Water pollution affects the entire biosphere of plants and animals living in these water bodies, as well as organisms and plants that might be exposed to the water. In almost all cases the effect is damaging not only to individual species and populations, but also to the natural biological communities. According to world health organization (WHO) 80% diseases in the world are water borne. 3.1% deaths occur due to the unhygienic and poor quality of water (Pawari, & Gawande, 2015). Safe drinking water is necessary for both plant and animal health all over the world. According to Okeke and Igboanua, (2003), human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. Anthropogenic activities related to extensive urbanization, agricultural practices, industrialization, and population expansion have led to water quality deterioration in many parts of the world (Wang, Han, Xu, & Zhang, 2010). In addition, deficient water resources have increasingly restrained water pollution control and water quality improvement (Bu, Tan, Li, and Zhang, 2010). Water pollution has been a research focus for government and scientists. Therefore, protecting and ensuring water quality is extremely urgent because of serious water

pollution and global scarcity of water resources. Water pollution also occurs globally, and is a particular problem in economically developing regions. While some chemical inputs have been reduced, new pollution threats have emerged from substances such as endocrine disrupters (McMaster 2001).

Sources of pollution

Water pollution may occur from different angles from household waste to industrial pollution. Generally, these pollution can be categorized into two main sources. These are point sources and non-point sources.

Point sources

Point sources of pollution or contamination are those which have direct identifiable and recognizable source. Example includes pipes joined to a processing plants or factories, oil spill from a tanker, effluents coming out from industries. Point sources of pollution include wastewater effluent (both municipal and industrial) and storm sewer discharge and affect mostly the area near it. The U.S. Environmental Protection Agency (EPA) defines point source pollution as "any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack" (Hill, 1997). Factories and sewage treatment plants are two common types of point sources. Factories, including oil refineries, pulp and paper mills, and chemical, electronics and automobile manufacturers, typically discharge one or more pollutants in their discharged waters (NOAA, 2007**).** Some factories discharge their effluents directly into a waterbody. Others treat it themselves before it is released, and still others send their wastes to sewage treatment plants for treatment. Sewage treatment plants treat human wastes and send the treated effluent to a stream or river.

Another way that some factories and sewage treatment plants handle waste material is by mixing it with urban runoff in a combined sewer system. Runoff refers to storm water

that flows over surfaces like driveways and lawns. As the water crosses these surfaces, it picks up chemicals and pollutants. This untreated, polluted water then runs directly into a sewer system. When it rains excessively, a combined sewer system may not be able handle the volume of water, and some of the combined runoff and raw sewage will overflow from the system, discharging directly into the nearest waterbody without being treated. This combined sewer overflow is considered point source pollution, and can cause severe damage to human health and the environment. Unregulated discharges from point sources can result in water pollution and unsafe drinking water, and can restrict activities like fishing and swimming. Some of the chemicals discharged by point sources are harmless, but others are toxic to people and wildlife. Whether a discharged chemical is harmful to the aquatic environment depends on a number of factors, including the type of chemical, its concentration, the timing of its release, weather conditions, and the organisms living in the area. (NOAA, 2007)

Large farms that raise livestock, such as cows, pigs and chickens, are other sources of point source pollution. These types of farms are known as concentrated animal feeding operations (CAFOs). If they do not treat their animals' waste materials, these substances can then enter nearby waterbodies as raw sewage, radically adding to the level and rate of pollution. To control point source discharges, the Clean Water Act established the National Pollutant Discharge Elimination System (NPDES). Under the NPDES program, factories, sewage treatment plants, and other point sources must obtain a permit from the state and EPA before they can discharge their waste or effluents into any body of water. Prior to discharge, the point source must use the latest technologies available to treat its effluents and reduce the level of pollutants. If necessary, a second, more stringent set of controls can be placed on a point source to protect a specific waterbody. This issue is not different from what happens to the Muni-Pomadze ramsar site. This is because the biggest drains in the Winneba Township have been directed to empty into the Lagoon.

Non - point source

Nonpoint source (NPS) pollution comes from many sources unlike pollution from industrial and sewage treatment plants. NPS pollution is caused by rainfall or snowmelt moves over and through the ground. This is so because as runoff moves over the land, it picks up and carries away both natural and human-made pollutants, which are finally deposited into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include: excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks; salt from irrigation practices and acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes, and faulty septic systems; and atmospheric deposition and hydro modification are also sources of nonpoint source. Nonpoint or diffuse pollution is the water pollution associated with land-use activities. Most nonpoint source pollution occurs as a result of runoff. When rain or melted snow moves over and through the ground, the water absorbs and assimilates any pollutants it comes into contact with (USEPA, 2004b). Following a heavy rainstorm, for example, water will flow across a parking lot and pick up oil left by cars driving and parking on the asphalt. When you see a rainbow-colored sheen on water flowing across the surface of a road or parking lot, you are actually looking at nonpoint source pollution. (NOAA, 2007). National Oceanic and Atmospheric Administration (2007) stated that runoff then runs over the edge of the parking lot, and most likely, it eventually empties into a stream. The water flows downstream into a larger stream, and then to a lake, river, or ocean. The pollutants in this runoff can be quite harmful, and their sources numerous. We usually can't point to one discreet location of nonpoint source pollution like we can with a discharge pipe from a factory.

Nonpoint source pollution not only affects ecosystems; it can also have harmful effects on the economy. U.S. Coastal and marine waters support 28.3 million jobs, generate $54 billion in goods and services through activities like shipping, boating, and tourism, and contribute $30 billion to the U.S. economy through recreational fishing alone (Leeworthy, 2000). If pollution leads to mass die-offs of fish and dirty-looking water, this area and others like it will experience deep financial losses. Nonpoint source pollution affects the beauty and health of coastal lands and waters. If the physical and environmental well-being of these areas is diminished, people will naturally find it less appealing to visit the coast. Beaches will not provide the tranquility and leisure activities many people expect to experience. You can see how nonpoint source pollution plays an indirect, though powerful role in tourists' contributions to a coastal community's economic status. The population in many coastal communities is also increasing at a rapid rate, and the value of waterfront property often relies on environmental and aquatic conditions. Excess nonpoint source pollution impacts the overall quality of life, and subsequently can drive property values down. If nonpoint source pollution continues to plague the waters surrounding coastal communities, their economies and social conditions may rapidly deteriorate (USEPA, 2004c). Although the concentration of some pollutants from runoff may be lower than the concentration from a point source, the total amount of a pollutant delivered from nonpoint sources may be higher because the pollutants come from many places.

Crossett, Culliton, Wiley and Goodspeed (2004) postulates that high densities of population along coastal regions can place great stress upon the environment, particularly through the effects of nonpoint source pollution. With increased control over point source pollution, scientists have begun to focus on nonpoint source pollution, how it affects the quality of the environment, and, even more importantly, how it can be controlled. Nonpoint source pollution is difficult to control because it comes from multiple locations. It also varies over time in terms of the flow and the types of pollutants it contains.

Meaning and Causes of water pollution

Water pollution is generally caused by humans. It is as a results of the actions of humans carried on to better self or satisfy a need.

Eguabor, (1998) argues that, the growth of human population, industrial and agricultural practices is the major causes of pollution. Water pollution becomes worse as a result of overcrowding in urban areas. Agricultural, domestic and industrial wastes are the major pollutants of agnatic habitats. There are various causes of water pollution. A report from the Forestry Commission in the Effutu Municipality suggests that major causes and sources of pollution is mainly domestic and agricultural waste. This is evident in the fact that, majority of the inhabitants of the Effutu municipality engage in vegetable farming. These farmlands are mostly situated along the stretch of both Pratu and Ntakofa rivers. These two rivers also empty into the lagoon. Since most of these farmers cultivate varieties of vegetables, they end up using different chemicals or pesticides in controlling pests and as a result some get into the lagoon through run-off.

This changes the quality of the water for aquatic species. Management of solid waste is not successful due to huge volumes of organic and non-biodegradable wastes generated daily. Sewage can be a fertilizer as it releases important nutrients to the environment such as nitrogen and phosphorus which plants and animals need for growth. Chemical fertilizers used by farmers also add nutrients to the soil, which drain into rivers and seas and add to the fertilizing effect of the sewage. Together, sewage and fertilizers can cause a massive increase in the growth of algae or plankton that facilitate huge areas of oceans, lagoons, lakes, or rivers creating a condition known as algal bloom thereby reducing the dissolved oxygen content of water and killing other forms of life like fish.

An online publication by Denchak (2018) suggested that not only is the agricultural sector the biggest consumer of global freshwater resources, with farming and livestock

production using about 70 percent of the earth's surface water supplies, but it's also a serious water polluter. Around the world, agriculture is the leading cause of water degradation. In the United States for example, agricultural pollution is the top source of contamination in rivers and streams, the second-biggest source in wetlands, and the third main source in lakes. It's also a major contributor of contamination to estuaries and groundwater. Every time it rains, fertilizers, pesticides, and animal waste from farms and livestock operations wash nutrients and pathogens such bacteria and viruses into our waterways. Nutrient pollution, caused by excess nitrogen and phosphorus in water or air, is the number-one threat to water quality worldwide and can cause algal blooms, a toxic soup of blue-green algae that can be harmful to people and wildlife. The striking consequence is a substantial and immediate drop in the amount of dissolved oxygen in the water. This happens because organic matter stimulates decomposers especially bacteria which break down suspended solids in the sewage. As they respire, the decomposers use up dissolved oxygen (O2) and the biological oxygen demand (BOD) reduces. The flora and fauna of the rivers experience change and reduction in number due to death by suffocation (Tudge, 1991).

Urbanization is also one of the major causes of water pollution as it generally leads to higher phosphorus concentrations in urban catchments (Paul & Meyer, 2001). Increasing imperviousness due to the tarred and concrete surfaces, increased runoff from urbanized surfaces, and increased municipal and industrial discharges all result in increased loadings of nutrients to streams. This makes urbanization second only to agriculture as the major cause of stream impairment. Mougeot (2000) also mentions that urban development results from population growth and rapid urbanization causes rapid industrial development. With a growing world population, more available land has been demanded for residential and industrial development.

In the case of Effutu, the Muni-Pomadze have been encroached upon due the increasing number of student intake by the University of Education. People clear the land, burn it and put up buildings. The remains or the dirt enters the lagoon which then pollutes it. In addition, ground water contamination by nutrients has taken place in the inhabited sections of the wetland as a result of human and animal wastes. Moses (2008) is of the opinion that, one underlying factor for rapid changes, pollution and loss of wetlands is that governments often sanction land-use that are detrimental to wetlands as opportunity cost for economic gains and urbanization. Though it is well established that there are legislations that define improper land-use and which also establishes the legal framework within which land can be utilized but often these Acts are not implemented. Protected areas and the right to their usage are defined within these Acts of law.

When these laws are not well implemented, pollution, rapid loss, encroachment and changes are inevitable. Keddy (2000) postulates hat encroachment is a term used to describe the advancement of structures, roads, railroads, improved paths, utilities, and other development, the placement of fill, the removal of vegetation, or an alteration of topography into such natural areas as floodplains, river corridors, wetlands, lakes and ponds, and the buffers around these areas. These encroachments cause impacts to the functions, values and services of these natural areas, such as a decline in water quality, loss in aquatic and terrestrial habitat, disruption of equilibrium or naturally stable conditions, loss of flood attenuation, or reduction of ecological processes etc.

Implications of pollution on the ecological and socio-economic functioning of wetlands

Masese, Raburu, and Kwena (2012) asserts that, all over the world, wetlands are hot spots of biodiversity and as a result they supply a plethora of goods and services to people living within them and in their adjoining areas. As a consequence, increased human pressure pose the greatest challenge to the well-being of wetlands, with Climate Change

and nutrient pollution becoming increasingly important. Globally, the processes that impact on wetlands fall into five main categories that include the loss of wetland area, changes to the water regime, changes in water quality, overexploitation of wetland resources and introductions of alien species.

The effect of pollution originates from primary and secondary pollution. The primary pollution is the entering into water or aquatic environment of solid waste, municipal sewage, runoffs from farms, etc. The secondary pollution on the other hand is the impacts that the pollutants may have on the aquatic ecosystem for example eutrophication (Oslo & Burgees, 1967). Adverse effects on wetlands are as a result of processes that are either natural occurrences or events that are directly or indirectly related to human activities or the absence of such activities (IUCN, 1999).

The main processes that impact on wetlands can be placed into five main categories: loss of wetland area, changes to the water regime, changes in water quality, overexploitation of wetland products and introductions of alien species (IWRB, 1993). Such processes cause damage to wetlands where, individually or cumulatively, they lead to the modification of the ecological conditions essential for the existence of a particular habitat type or the survival of a wetland-dependent species. To consider the impact of wetland loss on local community, there are good examples of wetlands which are already lost (Haromaya Lake) and in loss such as Abijata and Cheffa in Ethiopia (EWNRA 2008). Bringing these wetlands in to mind, most communities are dependent on these wetlands for fisheries, dry season food crops, raw materials for construction, water, feed for animals, medicinal plants, income from sale of the products including handicraft, have lost or is in loss of the stated uses. According to Managing Ghana's wetlands: A National Conservation Strategy 1999), the loss of wetlands directly impacts the surrounding ecosystem and those organisms that rely on wetlands to provide either food or shelter.

Effect on aquatic and forms of life

Pollution of natural water may be disastrous to fish and other organisms naturally inhabiting the stream. This may suffocate the fish and other aquatic animals which require the presence of an appreciable concentration of dissolved oxygen. Within mild pollution, fish acquire a flavor that renders their flesh unfit for uses as food; whereas with more severe contamination; the fish sickens or die (Pandey, 1997). This will eventually reduce the quantity of fish catch thereby having a greater effect on the local people and the world at large.

Loss of wetland area

In many parts of the world, wetlands are drained and reclaimed for development activities, or to create room for forestry and farming or as part of public health and sanitation initiatives (IUCN, 1999; Keddy, 2000). Once developed, wetlands are permanently destroyed and lose their potential to be rehabilitated. In many developing countries, wetland reclamation is often done illegally in areas where population growth causes a shortage of land, especially in and around cities and towns (Ntambirweki, 1998). Ways through which wetland areas are lost include:

- dumping of wastes that claim land and fill waterlogged areas, especially in towns and settlements that lack proper waste management practices
- development activities that cause infilling or draining of wetlands e.g., building of roads, ports and houses and farming
- alterations to catchment hydrology, which impact the quantity and quality of water in wetlands e.g., interbasin water transfers, excessive water abstractions and damming
- excavation or cementing of beds and banks of streams and rivers, in which case groundwater recharge is hampered, thus affecting riparian vegetation

- Burning of wetland vegetation, thereby changing its hydrology and composition of biological communities.

Increased flooding events

Wetland loss leads to Increased flooding events**.** A wetland temporarily stores floodwater by trapping it and slowing the water down as it passes through the wetland. This reduces the volume of water and protects areas downstream during flooding events. If a wetland is modified or degraded, then the water that would usually utilize this wetland has nowhere to go and will consequently move into areas it would not otherwise have done. This is likely to result in an increased occurrence of floods, as well as soil erosion. (Managing Ghana's wetlands: A National Conservation Strategy 1999).

Changes in the water regime

Hydrological and other wetland functions are closely linked to the maintenance of surface and groundwater flows and sediment flows at their natural level, a characteristic that is often seasonally variable (IUCN, 1999). Infiltration of surface water helps to replenish groundwater supplies and eventually discharge as springs and exfiltrate into surface aters. However, these exchanges and flow patterns can be significantly altered by human interventions e.g., construction of drainage systems, surface and groundwater abstractions, diversions of water flowing into wetlands and siltation.

Loss of wildlife habitat

According to Managing Ghana's wetlands: a national conservation strategy (1999), wetland loss leads to Loss of wildlife habitat. Removing the wetland directly removes the plants or animals that once existed in the wetland ecosystem. This shifts the food chain out of balance and may actually result in the extinction of those species with close associations with the environment. All these species are closely linked to wetlands and to each other,

forming a life cycle and a complex set of interactions. If one species disappears, the whole food web is endangered, which could lead to the loss of an entire ecosystem over time. For this reason, protecting wetland habitats is essential for maintaining biodiversity.

Changes in water quality

The quality of water flowing into wetlands may be impaired indirectly by alterations to the water regime or directly by pollutants. Changes in water quality in wetlands can occur as a result of:

- discharge of domestic sewage, industrial wastewaters and forestry and agriculture operations
- thermal pollution caused by the operation of thermoelectric power stations, nuclear reactors and industrial operations or the construction of large reservoirs and dams along watercourses, which slow normal water flow
- atmospheric pollution from industrial activities that cause acid rain
- energy generation and transport that can damage upland wetlands and dependent flora and fauna
- Recreational activities that use toxic substances or pollutants e.g. the use of lead pellets in waterfowl hunting, application of herbicides and fertilizers on golfing lawns.

These land-based activities generate pollutant substances and energy that enter wetlands by runoff from land, rivers and discharge outlets as well as through the atmosphere. Whereas it is possible to control point source pollution, the control of diffuse/nonpoint source pollution presents greater technical and legal difficulties. Activities that generate diffuse pollution to surface and ground water include underground and surface mining operations, timber production and agricultural operations involving the application of pesticides, herbicides and fertilisers, as well as run-off from roads and human settlements.

The effects of such contamination are cumulative and can adversely affect wetlands far from the area of application or impact. Again**,** Managing Ghana's wetlands: A National Conservation Strategy 1999, asserts that, wetland loss leads to decline in water quality**.** Removing a wetland can cause a change in the chemistry of major water systems that those wetlands would otherwise filter out. With increasing use of cars, fertilizers and pesticides, there are an increasing number of pollutants entering our waterways. In and around the globe, one of the best known cases of water quality being affected by loss of wetlands is the Mississippi River.

Nutrients from fertilizer used on farmland and large amount of sediment from erosion are being washed into streams and rivers. Without the Everglade wetlands, this used to filter out these components from the water, the nitrate, phosphorus, bacteria, and sediment carried by stream and river systems in the Midwest, now run directly into the Mississippi River. These pollutants ultimately flow into the Gulf of Mexico, having drastic negative effects on the ecosystem. (Ethiopia Wetlands and Natural Resources Association, EWNRA 2008). For example, the conversion of wetlands in Illubabur (south western Ethiopia) is a means to loss the natural sedge (which is collected for roofing), drying of about 150 springs causing extra loads to women and poor , loss the use that medicinal healers gained from medicinal plants collection (Fricker 1999; Wood 1996).

Considerable health problems like malnutrition of children also reported for this area due to the complete conversion of the wetlands (Abebe & Geheb 2003). Thus, at community level since the significance of wetlands in poverty reduction and ensuring food security is immense, their losses cause starvation. Since wetlands are sources of water and forage for livestock at dry season, it is major asset next to land in agricultural areas and may be asset number one in pastoral communities (Wood, 1996) which will be absent due to the degradation and complete loss of wetlands. The consequence of wetland loss extends to

aggravating climatic disturbances by increasing carbon build up in the atmosphere and biodiversity loss (Abebe & Geheb, 2003; EWNRA, 2008). As Ethiopia is prone to desertification and recurrent drought, the effects of wetland loss could be more visible in complicating the situation locally. This will create shortage of water and narrow opportunities for irrigation based agriculture. The loss of these wetlands is devastating to several endemic species and particularly to wetland dependent species (Gebresllassie, Gashaw, & Mehari, 2014).

Measures and strategies to address and reduce wetland degradation and pollution

The question raised after discussing wetland degradation and its consequences is how can we minimize the extent of degradation? No doubt at all that the wetlands of the world are facing degradation or pollution in one way or the other. At the same time, efforts to assure the health and normal functioning of this ecosystem are negligible. So, this section considers ways in which to reverse existing damaging trends and to improve the situation.

According to Mengistu (2008) as cited in Asmamaw (2019), Building knowledge and awareness about wetlands is a way of addressing wetland degradation**.** To manage wetlands effectively and make an informed and sound decisions that improve the livelihoods of local people dependent on wetland areas while safeguarding wetland functions, values and attributes (including biodiversity), it is necessary to have adequate knowledge of their status and functioning. In this regard, it is of high priority to assess, carry out national inventory of wetlands and compile a National Directory of Wetlands.
A strong information database on wetlands, which is currently almost non-existent in most countries (Mengistu 2008), is a vital basis for achieving objectives related with conservation and wise use of wetlands.

The desired information on wetlands can be attained through resource base assessment, which involves survey, inventory, compilation of national directory of

wetlands and construction of updatable computer database. Not only relevant information, but also knowledge and awareness on wetlands, are lacking in most part of the world especially Africa at all levels (Mengistu 2008). This knowledge gap needs to be bridged through dissemination of information and data on wetlands to the public at large, as increasing of public awareness is one of the most important ways to conserve wetlands. This objective can be achieved through a series of public awareness raising campaigns, which include:

i. production and distribution of awareness raising materials (posters, flyers, fact sheets, booklets)
ii. making use of mass media to put out features on wetlands,
iii. a series of awareness raising seminars and workshops on identified knowledge gaps,
iv. promotion of environmental education and
v. establishment of wetland clubs/support groups (Eshete, 2008; Mengistu, 2008).

The training and education programs can be geared to wetland policies, legislation and regulation, community empowerment, pollution control, initiatives related to climate change, invasive alien species control, threatened species conservation, and programmes on adaptive management of ecosystems in response to a changing environment. Furthermore, the value and role of indigenous knowledge/practices should not be left out when setting up awareness, advocacy and capacity building programmes. Ages of accumulated knowledge systems on the perceptions and management of wetlands have to be tapped in from the ones using them rather than the other way around (Leykun, 2003; Mengistu, 2008).

Also (Mengistu, 2008) averse that, impact assessments and Continuous Monitoring of Wetlands entails putting in place and implementing detailed environmental impact assessments (EIAs) before any form of development (e.g. draining, damming, diversion or

using for irrigation) occurs in wetland areas to ensure that the new modification will not bring hazardous consequences on the wetlands and the wider ecology of a given area (Mengistu, 2008). It also involves implementing integrated management plans covering every aspect of the wetlands and their relationships with their catchments. There is a need to put wetland habitats high on the agenda of list of conservation areas that require priority in terms of impact assessment. Monitoring is the process of measuring changes in ecological character in any wetland over a period of time. It addresses both the issue of wetland integrity, i.e. change in wetland area, and change in wetland quality. It can be carried out at different levels of intensity, depending on available funding and/or technology (Mengistu, 2008). Monitoring methods include simple field observations, remote sensing, quantitative sampling techniques such as annual counting of birds, and, where changes in social values and uses are concerned, participatory observation. This activity is envisaged to take place at least at selected priority wetlands.

Then again (Ethiopia Wetlands and Natural Resources Association, EWNRA, 2008) is of the view that, building partnerships with stakeholders to some extent help prevent the degradation. Some of the many stakeholders of wetlands are Ministry of Agriculture, Ministry of Water Resources, Environmental Protection Agency, Biodiversity Institute, Ethiopian Agricultural Research Organization and the Ethiopian Wildlife Conservation Organization and the Regional States. The joint collaborative work among the concerned institutions and stakeholders is extremely vital in coming up with robust and holistic wetland management approach that supports a more natural, healthy ecosystem – one which is cost-efficient and secure - for people, businesses and wildlife. For example, experience has shown that seizing land from the people and setting aside a conventional protected area is not workable (EWNRA, 2008).

Fostering Political Conviction (Policy). For example successful wetland conservation in Ethiopia is being challenged by absence of Wetland Policy and lack of

suitable legislative frameworks as a result of insufficient political conviction to formalize wetland conservation (Abebe & Geheb, 2003). Such a policy and political convections would need to be able to cope with the multiple functions of wetlands, and ensure into which wetlands are integrally managed. In addition, the policy would need to be able to deal with the multiple uses of wetlands, such as grazing, rain-fed agriculture, irrigated agriculture, conservation, recreation etc (EWNRA, 2008).

Moreover, Prioritization and management plans for wetlands is a sure way to reduce wetland degradation if not totally prevent it. Undertaking a prioritization process through consultation and full involvement of all concerned stakeholders to identify wetlands that need immediate conservation actions is important. The process helps to target limited resources or options for conservation to those wetlands in most urgent need of conservation attention. Once priority wetlands for immediate conservation actions are identified, there is a need to prepare management plans for each of the priority wetlands. This can be learnt from two wetlands, namely Berga Flood Plain (Mengistu, 2008) and Abijata-Shalla Lakes National Park (Yilma, 2003) cited in Gebresllassie, Gashaw, & Mehari, (2014) for which action plan is already prepared.

Water quality parameters

The term water quality describes a broad spectrum of items related to how we identify water concerns and how we collectively address them. Thus, the term water quality can be confusing and mean different things to different people. The most widely used definition of water quality is "the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use." As we all know, water has many uses, such as for recreation, drinking, fisheries, agriculture and industry. Each of these designated uses has different defined chemical, physical and biological standards necessary to support that use.

For example, we expect higher standards for water we drink and swim in compared to that used in agriculture and industry. (https://www.uaex.edu/publications/pdf/FSA-9528.pdf)

Water quality standards are put in place to protect the various designated uses of a waterbody. The concept of quality, however, raises a number of questions which are often controversial because of wide differences in technological and individual perceptions. The economic and the aesthetic considerations describing water quality also come to blows. Technologically, water quality can be catalogued in terms of appropriate physical, chemical and bacteriological parameters which must be accurate, unambiguous, quantitative and reproducible. Many authors prefer to describe water quality in terms of the processes occurring in a catchment ecosystem. This consists of a source of water such as a river with its associated drainage areas, and is a complex combination of biotic and abiotic components and the interactions amongst them.

According to Diersing, (2009) as cited in Tiakor, (2015) water quality is the chemical, physical, biological, and radiological characteristics of water. Johnson, Ambrose, Bassett, Bowen, Crummey, Isaacson, Johnson, Lamb, Saul and Winter-Nelson (1997) also states that it is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Water quality is a topmost priority for good river wellbeing. This is because it is fundamental to continuous ecological processes that supports the vast ecosystem and hence biodiversity such as fish populations, vegetation, wetlands and all other aquatic fauna and flora. Similarly, many anthropogenic uses depend on water quality that is reliable for irrigation, watering stock, drinking, fishing and recreation, and to meet psychological needs stemming cultural to spiritual needs (New South Wales (NSW) Office of Environment and Heritage, 2014).

According to Abdul-Razak, Asiedu, Entsua-Mensah, and deGraft-Johnson (2009), indicators of the quality of water are mainly linked to the presence of contaminants and the

features of water. These water quality indicators can be categorized as biological (bacteria and algae), Physical (temperature, salinity, dissolved solids, conductivity, hardness), Chemical (pH, dissolved oxygen, biological and chemical oxygen demand, nutrients (including nitrogen, sulphates and phosphorus), organic and inorganic compounds (including pesticides and petroleum) and finally radioactive (alpha, beta and gamma radiation emitters). Danquah, (2010), asserts that measurements of these indicators or parameters can be used to assess, and monitor changes in, water quality, and determine whether it is suitable for the health of the natural environment and the uses for which the water is required

pH

pH, one of the most common analyses in soil and water testing, is the standard measure of how acidic or alkaline a solution is. It is measured a scale from 0 -14. pH of 7 is neutral, pH less than 7 is acidic and pH greater than 7 is basic. Aquatic organisms need the pH of their water body to be a certain range optimal growth and survival. The presence of acid rain can lower the pH in lakes making them more acidic. pH is the measure of hydrogen ions, or acidity, in the water. Water has hydrogen ions and hydroxyl ions. When there are equal numbers of both, the water is neutral. As the hydrogen ions increase, the water becomes more acidic; as the hydroxyl ions increase, the water becomes more basic. Most aquatic organisms have a narrow pH tolerance range of 6.5 – 8.5. Acidic waters can cause toxic heavy metals to be released into the water. Gallagher (2011) asserts that since the scale is logarithmic, a drop in the pH by 1.0 unit is equal to a 10-fold increase in acidity. This means that a sample of water with a pH of 5.0 is 10 times as acidic as one with a pH of 6.0, and pH 4.0 is 100 times as acidic as pH 6.0. pH has an impact on many chemical and biological systems in the water and varying organisms have their specific range of pH within which they survive comfortably. The majority of fishes and other aquatic organisms

survive between a pH of 6.0 - 8.0. According to USGS (2007) averse that, pH that deviates from this range reduces the biodiversity in the stream because the physiological systems of most of these fauna is stressed and can decrease reproduction. Low pH concentrations can peak the solubility of trace metals. There are a variety of circumstances that can affect pH in water, which can be classified into natural and man-made factors. Most changes that occur by reason of nature can be attributed to interactions with surrounding geology. pH can also remain unstable with the effect of rainfall, wastewater or mining effluents (USEPA, 2012). Human induced causes of pH changes are usually connected to pollution. A common cause is point source pollution which can either increase or decrease pH depending on the pollutants involved. The recommended pH range for most fish is between 6.0 and 9.0 with a minimum alkalinity of 20 mg/L, with ideal CaC levels between 75 and 200 mg/L (Wurts & Durborow, 1992).

Conductivity

The USEPA (2012) defines conductivity as a measure of water‘s ability to pass electrical flow. This is directly proportional to the concentration of ions in the water. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 C). The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Distilled water has a conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in

the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm. The more ions found in the water, the higher the level of conductivity. The opposite is also true for lower levels of conductivity, that is, the fewer ions that are in the water, the less conductive it is. Deionized water can act as an insulator due to it's near to negligible conductivity value (Perlman, 2013). Sea water, however, has a very high conductivity. Ions are able to conduct electricity because of their positive and negative charges (USEPA, 2012). Conductivity is useful as a general measure of water quality. Each water body tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered the aquatic resource (USEPA, 2012).

Salinity

According to the USEPA (2012), Salinity is the dissolved salt content of a body of water. It is a strong contributor to conductivity and helps determine many aspects of the chemistry of natural waters and the biological processes within them. Salinity, along with temperature and pressure, helps govern physical characteristics of water such as density and heat capacity. Salts can be toxic to freshwater plants and animals and can make water unsafe for drinking, irrigation and livestock watering. Excess salinity can occur in areas where evaporation is high and made worse by repeated use of water for irrigation or water withdrawals, where road deicers are applied and in mining, oil and gas drilling and wastewater discharges. The major contributing ions in seawater (with a practical salinity of 35) are: chloride, sodium, magnesium, sulphate, calcium, potassium, bicarbonate and

bromine (Sommer & Spitzer, 2004). Freshwater sources also have these ions present in them, but in smaller concentrations (Wetzel, 2001).

Dissolved oxygen (DO)

Dissolved oxygen is one of the most important indicators of water quality as it is essential for the survival of fish and other aquatic organisms. According to Talib and Amat (2012). Dissolved oxygen (DO) is basically oxygen measured in its dissolved state. If the oxygen is expended more than is yielded, dissolved oxygen concentrations decrease and some sensitive organisms migrate, become weak, or die. The amount of oxygen dissolved in water, such as a lake, river or stream. Dissolved oxygen is the most important indicator of the health of water bodies and its capacity to support a balanced aquatic ecosystem of plants and animals. Most aquatic organisms need oxygen to survive. Dissolved oxygen is the oxygen present in water available to aquatic organisms. It is not the oxygen that is part of the water molecule but rather oxygen gas. Oxygen enters the water from the air through rain, turbulence and wind, and through the photosynthesis of aquatic plants. Organisms absorb the oxygen through structures such as gills or their skin. Waters with higher dissolved oxygen have ecosystems that are generally more diverse and stable. D.O concentrations vary in seasons and even during the day (over a 24-hour period). They fluctuate along with water temperature and altitude. Roelofs (1991) stated in his report that, cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes. Warm water released from industrial outlets, flowages or storm sewers can also reduce dissolved oxygen levels. Dissolved oxygen may play a large role in the survival of aquatic life in temperature lakes and reservoirs during summer months. Cunningham and Saigo (1995), asserts that, the DO should not be less than 2mg/L and therefore it should be more. Others also suggest that it should be 5mg/L or more. However when oxygen concentrations are less than 2mg/L, the water is defined as hypoxic or aquatic hypoxia,

(CENR, 2000). Decomposition of organic material is a major cause of low dissolved oxygen resulting in fewer species. Dissolved oxygen is measured in parts per million (ppm) or milligrams per liter (mg/L).

Temperature

According to Brown (1999) as cited in Tiakor (2015) defines Water temperature as a physical property that gives an indication of how hot or cold water is. Temperature is the most importance environment factor with effect on plants and animals. Water has several unique thermal properties which combine to minimize temperature change. The Water temperature depends on the depth of the water column, climatic and topographic changes. Temperature affects aquatic organisms in a variety of ways. The body temperature of most aquatic organisms is the same as the surrounding water and fluctuates with the water temperature. Most aquatic organisms are adapted to live in a narrow temperature range and they die when the temperature becomes too low or too high. Temperature affects their metabolism, reproduction and emergence (Wetzel, 2001). Temperature also affects the rate of photosynthesis of aquatic plants, the base of the aquatic food web. Temperature can also reduce plant respiration and photosynthesis (Wetzel, 2001). Conventionally, algal photosynthesis will rise with temperature increase, though a variety of species possess varying peak temperatures for optimum photosynthetic activity (Wetzel, 2001). Pollutants can become more toxic at higher temperatures. The amount of dissolved oxygen becomes lower as the water becomes warmer. Temperature is measured in degrees Fahrenheit or Celsius (Centigrade).

Total dissolved solids (TDS)

Total dissolved solids are the total amount of mobile charged ions, including minerals, salts or metal dissolved in a given volume of water in mg/L. TDS is directly related to the purity of water and the quality of water purification system and affects

everything that consumes, lives in, or uses water, whether organic or inorganic, whether for better or for worse. Common inorganic salts that can be found in water include calcium, magnesium, potassium and sodium, which are cations and carbonates, nitrates, bicarbonates, chlorides and sulphates which are anions. The USEPA (2012), asserts that, Total solids are dissolved solids plus suspended and settleable solids in water. In stream water, dissolved solids consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ions particles that will pass through a filter with pores of around 2 microns (0.002 cm) in size. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. In ―clean‖ water, TDS is approximately equal to salinity.

Thompson, AWWA Research Foundation, Water Reuse Foundation, & Water Quality Association, (2006) again stated that in wastewater or polluted areas, TDS can include organic solutes (such as hydrocarbons and urea) in addition to the salt ions. The USEPA (2012) again postulated that the concentration of total dissolved solids affects the water balance in the cells of aquatic organisms. An organism placed in water with a very low level of solids, such as distilled water, will swell up because water will tend to move into its cells, which have a higher concentration of solids. An organism placed in water with a high concentration of solids will shrink somewhat because the water in its cells will tend to move out. This will in turn affect the organism's ability to maintain the proper cell density, making it difficult to keep its position in the water column. It might float up or sink down to a depth to which it is not adapted, and it might not survive. This means that a high concentration of total solids will make drinking water unpalatable and might have an adverse effect on people who are not used to drinking such water. Levels of total solids that are too high or too low can also reduce the efficiency of wastewater treatment plants, as well as the operation of industrial processes that use raw water. Total solids also affect water clarity. Higher solids decrease the passage of light through water, thereby slowing

photosynthesis by aquatic plants. Water will heat up more rapidly and hold more heat; this, in turn, might adversely affect aquatic life that has adapted to a lower temperature regime. At most, freshwater can have 200 mg/L of total dissolved solids and most sources should have much less than that (American Public Health Assoc., American Water Works Assoc. & Water Environment Federation. 1999). When total dissolved solids ranged above 2200-3600 mg/L, salmonids, perch and pike all showed reduced hatching and egg survival rates (Scannell & Jacobs, 2001) Sources of total solids include industrial discharges, sewage, fertilizers, road runoff, and soil erosion. Total solids are measured in milligrams per liter (mg/L).

Biodiversity change

Wetlands are sites of high biodiversity and productivity (Mitsch & Gosselink, 2000). They provide essential services, such as maintenance of atmosphere composition, key habitats for migratory species, and important nursery areas (Basset & Abbiati, 2004), but these ecosystems have suffered a serious decline worldwide due to human influence (Shine & Klemm, 1999; Solimini, Cardoso, Carstensen, Free, Heiskanen, Jepsen, No˜ges, Poikane & van de Bund, 2008; Stenert & Maltchik, 2007). Declining water quality, drainage, eutrophication and catchment disturbances such as development, loss of natural vegetation and poor agricultural practices are changing the fundamental ecology of shallow lakes in much of the world (Drake, Kelly, & Schallenberg, 2011). Different management strategies have been developed to solve these conservation problems, for instance the Europeans Natural 2000 network and Water Framework Directive (WFD). Among these aquatic systems, coastal wetlands have been subject to massive environmental degradation and habitat destruction worldwide (Goudie, 1990). For example, more than 50% of the original area of coastal wetlands that existed in 1900 has been lost in most countries of Western Europe (Jones & Hughes, 1993).

Biodiversity is the variety of and among the living organisms, biological system and biological process found on Earth". Biodiversity underpins life on Earth, and refers to the variety found in biota from genetic makeup of plants and animals to cultural diversity. The term is neolosim obtained by joining words biology, the study of life and diversity, meaning difference and variety. Biodiversity (or biological diversity) then is the diversity of and living nature (Wilson, 1988). The first most standard definition sponsored by the United Nations was included in the Convention on Biological Diversity (CBD) (UNEP, 1992). According to this definition, biodiversity refers to "The variability among living organisms, *inter alia*, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

The second most–used definition of biodiversity is sponsored by the Global Biodiversity Strategy (WRI, IUCN & UNEP, 1992) as "The totality of genes, species and ecosystems in a region". This means that diversity within the natural environment is important. It provides variety that people enjoy, both in species and landscape. Biodiversity has several components, such as the numbers abundance, composition, spatial distribution and interactions of genotypes, populations, species, functional types and traits and landscape units in a given ecosystem (Diaz, Fargione, Chapin III& Tilman, 2006). All these components may play a role in maintaining life support systems in the long term. A community comprises the populations of different species that naturally occur and interact in a particular environment. Some community are relatively small in scale and may have well-defined boundaries and other communities are larger, more complex and may be less clearly defined (Stachowicz & Tilman, 2005). The factors that determine the diversity of a community are extremely complex. Environmental factors, such as temperature, sun-light and the availability of inorganic and organic nutrients etc. are very important in shaping communities and ecosystems.

Physical pollutants (temperature change and large objects) cause visual water pollution e.g. plastic bags released into water bodies by human activities (Hogan, 2014). According to the WHO's report published, People depend on biodiversity in their daily lives, in ways that are not always apparent or appreciated. Human health ultimately depends upon ecosystem products and services (such as availability of fresh water, food and fuel sources) which are requisite for good human health and productive livelihoods. Throughout the history of angiosperms, diversification has been a complex process, in which the propensity to diversify was highly liable and dependent upon many different traits at different times (Davies, Barraclough, Chase, Soltis, Soltis, & Savolainen, 2004). Species variety plays a dual role of ensuring and signaling the variety of the natural environment. Furthermore, it protects the health of natural environments, which provide services, on which people need to depend. Recent studies indicate that a more diverse ecosystem has greater capacity to withstand environmental stress and consequently is more productive. The total loss of species is thus, likely to decrease the ability of the system to maintain itself or to recover from damage or disturbances.

Just like a species with high genetic diversity, an ecosystem with high biodiversity may have a greater chance of adapting to environmental changes. Moreover, we are still only beginning to understand in depth the processes that generate and maintain the global biodiversity (Storch, Marquet, & Brown, 2007). Biodiversity loss can have significant direct human health impacts if ecosystem services are no longer adequate to meet social needs. Indirectly, changes in ecosystem services affect livelihoods, income, local migration and on occasion, may even cause political conflict. Indeed, habitat destruction caused by human economic activity is described as a major cause of current rapid loss of species and as one of the main cause of biological invasions on all spatial scales (di Castri, 1989; Kowarik, 1990). Direct and indirect anthropogenic changes in climates, rates and other environmental constraints will have a major impact on successional dynamics and the

maintenance of biodiversity (Schulze & Mooney, 1993) as well as on plant invasions (Kowarik,1990). The biological causes of the loss of biological diversity include the loss of habitats, the introduction of exotic species, over-harvesting of biodiversity resources, and homogenization of species in agriculture. The common factor of all these elements is that they are human-driven.

According to an article published by The Annual Review of Environment and Resources, ARER, (2012), biodiversity change refers to both biodiversity loss and biodiversity alterations. Biodiversity alterations are human-induced changes that lead to modifications of community structure or to shifts in species distributions and biodiversity loss is the local or global extinction of an allele or species. All these are initiated by drivers which are direct or indirect pressures on biodiversity that induce a change (either negative or positive) Many organisms modify the environment and as a result increase their fitness or affect resource availability to other species, processes known as niche construction of ecosystem engineering. Current biodiversity loss occurs at an unprecedented rate and in an unnatural trend (MEA 2005). While some species populations are increasing, other species are rapidly declining. Humans and their hominid ancestors are no exception; they have been modifying ecosystems throughout history to improve food availability and decrease the success of their ecological competitors. The ARER (2012), again suggested that an important distinction should be made between biodiversity loss and biodiversity alterations. This issue is particularly important as it implies that not all biodiversity change is inherently a bad thing, and therefore we often need to define a set of criteria to assess the benefits and disadvantages of biodiversity change. Recent global species extinctions correspond to net biodiversity loss, as the number of species created by evolutionary processes occurs at a much slower pace than the recent extinction rates. The most vulnerable species are at the top of food chains (EEA 2006). The loss of genetic diversity, particularly the disappearance of populations and particular alleles, also corresponds to

biodiversity loss, although small alterations of genetic diversity may not correspond to significant biodiversity loss. There is scientific consensus that ecosystem productivity declines as species diversity reduces (EEA 2006). Therefore, biodiversity loss causes a serious decline in ecosystem services, consequently bringing about socio-economic losses (MEA 2005; Kettunen & ten Brink 2006). Much of human action alters the species composition and the relative species abundances in an ecosystem, changing the structure. Globally, freshwaters, wetlands are experiencing declines in biodiversity at rates greater than those in terrestrial systems:

Factors underlying biodiversity declines include overexploitation of water and organisms, water pollution, and habitat destruction and degradation (including modification of natural flow regimes and invasions of exotic species), all of which are linked to human activities. Superimposed on these factors are global scale environmental changes, such as climate warming and acidic deposition. The overharvesting of wild stocks of freshwater fishes is occurring worldwide (Allan, Abell, Hogan, Revenga, Taylor, Welcomme, & Winemiller. 2005). A primary reason for concern over the current accelerated loss of species is the associated loss of ecological function. Although the linkages between biodiversity and ecosystem function are an area of intense research, there are significant gaps in our understanding of how biodiversity declines affect ecosystem function (Hooper, Chapin, Ewel, Hector, Inchausti, Lavorel, Lawton, Lodge, Loreau, Naeem, Schmid, Setälä, Symstad, Vandermeer, Wardle. 2005)

Significance of biodiversity change

According to The Annual Review of Environment and Resources (2012), our world is changing, and biodiversity is no exception. Yet, not all biodiversity change is inherently bad, and we should avoid a static view of conservation biology. The maintenance of the landscapes or the biological communities we know should not be the a priori management

target. We need to assess biodiversity change with objective criteria. The ecosystem services framework with the appropriate inclusion of species existence values, is an excellent tool to assess the management priorities for biodiversity change. It allows us to identify not only the benefits and costs of biodiversity alterations for human well-being but also to prioritize the biodiversity losses that are more important to address. ARER (2012) averse that, biodiversity alterations and losses have to be assessed for their contribution to ecosystem processes, such as nutrient cycling and soil formation, and to ecosystem services, such as climate regulation, water quality regulation, water provisioning, timber provisioning, disease and pest regulation, and cultural services.

An appropriate inclusion of existence values is essential; people place large values on the conservation of particular species or taxonomic groups. Therefore, not all species extinctions can be treated equally from a utilitarian point of view. But in many more cases, the loss of biodiversity is impoverishing us and making our planet more unequal for its human inhabitants: It is often the poor that suffer the first negative impacts of biodiversity change. Some biodiversity alterations, such as the conversion of the Amazon forest to agricultural areas, may lead to tipping points in ecosystems that are hard to reverse, but the majority of biodiversity alterations are reversible through management (ARER, 2012). In contrast, biodiversity loss is usually irreversible: Extinction is forever, at least with the current biotechnology level. Scientists can inform society about how biodiversity is changing and what the likely consequences of those changes are for ecosystems and for human well-being, but it is up to society to decide what should be done about these issues (ARER, 2012).

Causes of biodiversity change

Biodiversity is rapidly declining worldwide, and there is considerable evidence that ecosystem functioning (e.g., productivity, nutrient cycling) and

ecosystem stability (i.e., temporal invariability of productivity) depend on biodiversity (Naeem, Daniel, Bunker, Andy, Michel, Charles, 2009). Thus, biodiversity declines may diminish human wellbeing by decreasing the services that ecosystems can provide for people (Millennium Ecosystem Assessment 2005). There is considerable evidence that contemporary biodiversity declines will lead to subsequent declines in ecosystem functioning and ecosystem stability (Naeem *et al*.2009). Loss of biodiversity appears to impact ecosystems as much as climate change, pollution and other major forms of environmental stress, according to a new study.

"Loss of biological diversity due to species extinctions is going to have major impacts on our planet, and we better prepare ourselves to deal with them," said by University of Michigan ecologist Cardinale, one of the authors (2012).

Population growth and increasing resource consumption

From a population of one billion at the beginning of the 19th century, our species now numbers more than seven billion people. Such rapid population growth has meant a rapid growth in the exploitation of natural resources water, foods and minerals. Humankind's burgeoning numbers have an increasingly voracious appetite: people use or destroy about 40 percent of the net primary productivity of terrestrial and aquatic plants (Peter, Paul, Anne, & Pamela.1986). At the present pace, the Earth's renewable resources are rapidly being depleted; the probable doubling of the world's population over the next 50 years will greatly increase these pressures.

The issue of population is not only a matter of numbers, but also of patterns and levels of resource consumption). Population growth and increasing resource consumption affect biodiversity in two ways: they create pressure to convert wildlife habitat into

agricultural and urban land, and they produce wastes that pollute habitat and poison wildlife. These activities will definitely lead to a declining biodiversity.

Poorly conceived policies

Government policies designed to encourage some sectors, such as agriculture or forestry, can have the side effect of destroying biodiversity. For example, policies that award titles to settlers who "improve" or clear the land can result in the destruction of biodiversity. Modern land laws are generally incompatible with the few remaining community property systems, such as that of the Cree of Canada, in which hunting and gathering are strictly regulated for the long-term benefit of a group (Fikret, 1989). Simple lack of coordination between government agencies with overlapping responsibilities may also result in loss of biodiversity. For example, an environmental agency may be charged with halting deforestation while the agriculture ministry tries to boost crop exports by subsidizing farmers to clear land. A government may embark on a program to link protected areas with rural development but not set aside funds to continue the program once the initial project money has run out (Agnes, 1990).

Over-exploitation for commercialization, habitat destruction and degradation

Overfishing has reduced some commercial fish stocks by more than 90%.Over-exploitation of resources has coasted more environmental degradation than earning. For example; shrimp farming in India, Thailand, Ecuador and Indonesia results in Wetland destruction, pollution of coastal waters and degradation of coastal fisheries (World Bank 1991). Scientific studies have concluded that cost of environmental degradation resulting from shrimp farming was costing more than the earning through shrimp exports.

Mining, agriculture, settlement, industries, highways and construction being primary examples. Degradation caused through poor land use and deforestation. (MoEF, 1999). Wetlands are one of the most productive areas on the planet, a characteristic that attracts

many different groups of users and stakeholders who seek access to and use of their resources. Pressure on wetland resources has increased in recent years with the expansion of human settlements and farmlands. This has often led to competition between or among mutually exclusive wetland uses. Overexploitation in wetlands may take several different forms but often involves unsustainable harvesting of wetland resources. This includes plant harvesting, overgrazing, overfishing and excess hunting pressure. Overexploitation also involves indirect taking of non-targeted species, for instance when a whole wetland is burnt to create room for fishing, as is the case in papyrus wetlands in East Africa (Morrison, Upton, Odhiambo-K'oyooh & Harper (2012). Such acts can deplete essential food resources for non-targeted species that depend on wetlands and disrupt whole ecosystems.

The cumulative effects of extractive and other activities often threaten wetland biodiversity. Overexploitation can also be non-consumptive in nature, where it takes the form of species or ecosystem disturbance. The presence of boats, recreational activities and even intrusive bird watchers and photographers may impact on other wetland products; causing, for example, migratory waterfowl to abandon a site. They can also drive away some animals that cannot withstand disturbance (IUCN, 1999)

Invasive species

Invasive species are 'alien' or 'exotic' species which are introduced accidentally or intentionally by human. These species become established in their new environment and spread unchecked, threatening the local biodiversity. These invasive alien species have been identified as the second greatest threat to biodiversity after habitat loss. The global extent and rapid increase in invasive species is homogenizing the world's flora and fauna (Mooney & Hobbs, 2000).

Pollution

Pollution of aquatic environment means the introduction by man, directly or indirectly, of substances or energy which result in such deleterious effect that are harmful to living resources. It is hazardous to human health, hindrance to aquatic activities including fishing and leads to the impairment of water quality with respect to its use in agricultural, industrial and often economic activities, and reduction of amenities (UNESCO/WHO/UNEP, 1992). Pollution is a major threat to biodiversity, and one of the most difficult problems to overcome; Pollutants do not recognize international boundaries. For example, agricultural run-off, which contains a variety of fertilizers and pesticides, may seep into ground water and rivers before ending up in the ocean. Atmospheric pollutants drift with prevailing air currents and are deposited far from their original source. Population of decomposing microorganisms like bacteria and fungi decline in acidified water which in turn reduces the rate of decomposition of organic matter affecting the nutrient cycling.

The rise in temperature of river water lowers the available dissolved oxygen which supports life that is critical for the self-purification processes taking place in the stream (Arnold, 1992). The critical pH for most of the aquatic species is 6.0. The diversity of species decline below this pH whereas the number and abundance of acid tolerant species increases. Proliferation of filamentous algae rapidly forms a thick mat at the initial phase of the acidification of water. Diatoms and green algae disappear below pH 5.8 Chemicals from fertilizers, pesticides, insecticides, herbicides etc. applied to crops in excess are washed away with rainwater as runoff, then enter into soil and finally arrive at the water bodies. Chemicals from fertilizers result in eutrophication by enrichments of nutrients.

Ammonium from fertilizers is acidic in nature causing acidification of water. Similarly pesticides, herbicides and insecticides also cause change in pH of the water

bodies. Most common effect of these substances is the reduction in photosynthetic rate. Some may uncouple oxidative phosphorylation or inhibit nitrate reductase enzyme. The uptake and bioaccumulation capacities of these substances are great in macrophytic plants due to their low solubility in water. Polluted effluents are often the most common source of adverse effects on coastal and marine ecosystem (Clark, 1992)

Global climate change

Many climatologists believe that greenhouse effect is likely to raise world temperatures by about 2°C by 2030, meaning that sea levels will rise by around 30-50 cm by this time (IPCC, 1992). Global warming, coupled with human population growth and accelerating rates of resource use will bring further losses in biological diversity. Vast areas of the world will be inundated causing loss of human life as well as ecosystems.

Species extinction

Extinction is a natural process. The geological record indicates that many hundreds of thousands of plant and animal species have disappeared over the eras as they have failed to adapt to changing conditions. Recent findings by Cardinale (2012) however indicate that the current rate of species extinction is at least a hundred to a thousand times higher than the natural rate.

Natural calamities

Natural calamities such as floods, cyclones, landslides and avalanches, volcanism, etc., are also responsible for depletion of biological diversity. For example, during the monsoon season in 1998 and also many times after 1998, entire Kaziranga National Park in Assam was heavily flooded which led to the death of 28 rhinos, 70-85 deer, 8 bears and 3 elephants and many plant species were also lost.

Effects of biodiversity loss

Essays, UK. (2018), postulates that, bbiodiversity loss has a negative impact on our societies; it negatively affects or contributes to the health of individuals, the climate, natural resources, pollution, poverty and the extinction of species. In the past years, biodiversity has been increasing faster than at any other time in human history. Consequently, its metamorphosis is anticipated to continue at the same pace. Virtually, all of Earth's ecosystems have been severely transformed as a result of human actions and ecosystems are still being converted for agricultural and other uses. Numerous plant populations and animals have decreased in numbers as well as their geographical spread, or both. The extinction of species is a natural part of Earth's history. However, as a result of human activity, the extinction rate has grown by at least 100 times in comparison to the natural rate. Over the last century, some people have benefited from the conversion of natural ecosystems and an increase in international trade, but other people have suffered from the consequences of biodiversity losses and from restricted access to resources they depend upon. Consequently, changes in ecosystems are harming many of the world's poorest people, who are the least capable to adapt to these changes. (MEA 2005).

Ecological effects

The loss of biodiversity has severe ecological effects. Since our planet has a natural system and species depend on each other, losing a small number of species can lead to big effects. Predator species which lose their prey will also be in danger of extinction now if they are not able to substitute their prey species through another one (Pandey, 1997). Moreover, the extinct prey which may have consumed plants is now no longer be able to do so. Thus, these plants will grow excessively and may dominate other plants and eventually displace them. The decrease in biodiversity has an impact on the extinction of species.

Hautemulle (2010) as cited in UK Essays (2018), argues that the current situation is alarming: there are thirty-four "hot spots" of the globe, areas characterized by both their large number of species and an increased threat to biodiversity. Among them is the Mediterranean. The current extinction rate of species is 100 to 1 000 times faster than the natural rate. Humans are responsible for the extremely high extinction rate. Many plant and animal populations are declining, both in terms of number of individuals, geographical spread, or both. Dirzo and Raven (2003), claim that "565 of the 1137 threatened species of mammals will go extinct within the next 50 years due to habitat loss and fragmentation" (p.162). Furthermore, it was found out that habitat loss is the principal driver of extinction throughout the world. Consequently, the survival times of species in small areas of habitat should be considered in relation to their likely time of survival. One in four mammals, one in eight birds, one third of all amphibians and 70% of all plants assessed in the IUCN Red List 2007 are at risk.

Effect on the health

Neil, (2015) averse that due to a loss in biodiversity, diseases are likely to occur more frequently. Since our environmental system is quite sensible and structured, removing species from the food chain can create serious trouble. For example, if a lion kills an antelope, he will eat part of it. The remaining part will be eaten by other animals. However, if these other animals go extinct and are no longer able to consume the rest of the antelope, it may waste and in this wasting process, several kinds of diseases can be developed. If other animals are contaminated with these diseases, it can also spill over to humans due to our consumption of meat.

The UK Essays, (2018) also postulates that, the reduction of biodiversity has an effect on the health of individuals. A new generation of antibiotics, new treatments against bone loss or kidney problems, cancer drugs, it could all be lost if the world fails to reverse

the rapid loss of biodiversity. Experts warn that many forms of terrestrial and marine life that have economic and medical interest may disappear before the people can learn their secrets. The reduction of biodiversity means that individuals lose the opportunity to experience many chemicals and genes similar to those already given to mankind for their enormous benefits in terms of health. It can limit the potential discovery of new treatments against many diseases and health problems. Diaz, Tilman, Fargione, Chapin III, & Dirzo, (2005) discovered that "the loss of biodiversity-dependent ecosystem services is likely to accentuate inequality and marginalization of the most vulnerable sectors of society, by decreasing their access to basic materials for a healthy life and by reducing their freedom of choice and action" (p. 1302).

Loss of livelihood for locals

The loss of biodiversity also causes a decline in the livelihood of many locals. This can be due to reduced crop yields or other effects. Locals may also raise cattle in order to survive. However, if a loss in biodiversity leads to decrease in biomass of feed, farmers will no longer be able to raise enough cattle due to the feed shortage.

Loss of our recreational space

We can also lose our recreational space as an effect of the loss of biodiversity. Many people are stressed from their work and sometimes need a space to relax. A forest or a lake surrounded by plants may be an optimal area for this. However, if we further destroy our forests in order to get more settlement space, we will lose many of these recreational environments. Moreover, nature provides a relaxing environment which if lost can lead people to become too stressed and mentally ill. (Perrings, 2008)

Effect on food production

A loss in biodiversity can have vast adverse effects on our food production. Since we nowadays exploit many natural living spaces to an unhealthy degree, chances are that

we lose many food sources which we could otherwise use in the future. For example, there may be sources of food in the Amazonian rainforests which we have not even explored yet. However, through the deforestation process, these species are likely to be lost even before we can discover them. Thus, we rob ourselves since we will not be able to use this species in the future. (IWRB, 1993). Consequently, the reduction of biodiversity could have negative consequences on the food security which would affect many countries particularly those with high levels of poverty and food insecurity. Furthermore, biodiversity safeguards human health since fruits and vegetables are grown in plants and trees. Thus, its loss could decrease the production of healthy food.

Economic effects

Apart from the environmental effects which are bad enough, a loss in biodiversity also causes adverse economic effects. For example, if we lost bees, we would suffer from a serious decline in crop yields which would lead the GDP to collapse and would also lead to an increase in famine.

Gibbs, (2000) asserts that biodiversity loss has many devastating consequences on the ecosystem, the climate, pollution and on society. It affects the health of the individuals with the rise of infectious disease as well as the loss of potential new medicines and medical models. Also, its degradation is threatening the fulfillment of basic needs and aspiration of humanity as a whole, but especially, and most immediately, those of the most disadvantaged segments of society. It limits both the capability of species to migrate and the ability of species to survive in fragmented habitats.

Measures to address and reduce biodiversity loss

Some of the measures that could be implemented to address or reduce the rate of biodiversity loss are:

Government restrictions and policies

According to National Wetland Conservation Strategy (1999), several national policies and legislation affect wetlands. These pieces of legislation are scattered throughout the statute books, and though outmoded and failing to address adequately the problem of wetlands in their entirety, do provide a starting point for the formulation of appropriate laws. Such policies and laws include the Fisheries Decree (1972), the Land Policy, the Water Resources Act, Ghana Vision 2020 and the Decentralization Policy. In order to mitigate the problem of the loss of biodiversity, governments are responsible to provide a framework which protects the natural variety of animals and plants. Human greed is endless, thus this will not work without penalizing behavior which threatens a loss in biodiversity.

Education

Eshete (2008) is of the view that people need to be educated on how important a preservation of biodiversity is for the planet as well as for humanity. Many people are so stressed form their jobs or their social lives that they are not even aware what a loss in biodiversity really means. This education on biodiversity should start quite early, probably in the early school age, so that children are already of this issue quite early and can adapt their behavior into adulthood (Mengistu 2008).

Protection of species and habitats

We have to protect many species from hunting or other behavior which threatens their existence. This is especially crucial for species which are already endangered. Species, especially animals, become endangered since people are greedy and want to make as much money as possible. The Government of Ghana (GOG) NWCS (1999) suggests that, government will take measures to identify and conserve wetlands that harbour plants and animals of conservation interest or of particular value to the local people and national

and international communities. Often, just small parts of the killed animal are of interest. For example, many elephants are killed just because of their ivory tusks. We have to end this perverse game in order to avoid a loss of biodiversity. A list of endangered species is given by the International Union for the Conservation of Nature. Another is the protection of habitats. Since the human population increases, we need more settlement space and space to raise crops and cattle. However, this leads to the destruction of natural habitats of many animals and plants. We have to protect those habitats, since if they are destructed, these animals and plants are likely to be endangered from extinction or even go extinct.

Prevent overhunting, overexploitation and overfishing

We also have to prevent overfishing and overhunting. Since populations of many animals decline on an alarming rate, we should protect them by setting strict hunting and fishing limits. Thus, we can make sure that populations are able to reproduce and are not becoming endangered of extinction. EWNRA (2008). Excessive exploitation of resources is mitigated. Many of our industries require metals and other materials in order to fulfill their production goals. However, by extracting these precious resources, the living space of many species will be destroyed. Thus, we should reduce the extraction of resources in order to sustain the species 'living space. Our daily consumption behavior also affects our environmental system to a significant degree. In order to reduce the pollution of our environment and thus to stop the loss in biodiversity, we should be aware how our consumption behavior adversely affects our planet. By avoiding consumption, especially consumption which just relies on the purpose to meet the newest trends, can contribute to sustain the variety of species on earth. EWNRA (2008). This could be ensured by prescribing appropriate gears for fishing and putting sanctions and punishment on those that go contrary to it.

Stop pollution

Another big responsibility for humanity is to stop or at least reduce all kinds of pollution. Our environmental system reacts quite sensitive to changes in its natural living conditions. Since through pollution, many ecological parameters are affected in an adverse way, pollution will contribute to a loss in biodiversity since many animals and plants will not be able to adapt to increased pollution properly and eventually go extinct.

Stop deforestation

About 90% of all species on our planet live in the tropical rainforests. Thus, deforestation is a huge problem to the variety of species. If we lose these forests, we will also lose many species which will have negative chain effects on the whole planet.

Prevent species invasions

We should also be aware that invasive species can pose a serious threat to local species since they can carry many diseases which local species may not be able to deal with properly. Moreover, invasive species may displace local ones which may lead to an extinction of part of the local plant variety.

The loss of biodiversity can be caused by natural phenomena, however, the biggest effects come from human intervention with nature. The loss of biodiversity causes severe adverse effects on our whole environmental system, including humanity. It is therefore crucial to take the steps necessary in order to prevent a loss in biodiversity and thus to ensure a livable future for our children and also for a variety of animals and plants.

Management strategies

Management is the manipulation of an ecosystem to ensure maintenance of all functions and characteristics of the specific wetland type. The loss or impairment of a wetland ecosystem is usually accompanied by irreversible loss in both the valuable

environmental functions and amenities important to the society (Zentner, 1988). Appropriate management and restoration mechanisms need to be implemented in order to regain and protect the physical, chemical, and biological integrity of wetland ecosystems. In this context, a detailed study of wetland management and socio-economic implications is required from biological and hydrological perspectives.

A wetland management program generally involves activities to protect, restore, manipulate, and provide for functions and values emphasizing both quality and acreage by advocating their sustainable usage (Walters, 1986).

Management of wetland ecosystems require intense monitoring and increased interaction and co-operation among various agencies such as state departments concerned with the environment, soil, agriculture, forestry, urban planning and development, natural resource management; public interest groups; citizen's groups; research institutions; and policy makers. All these would help in understanding wetlands better and evolve a more comprehensive and long-term conservation and management strategies. Some of the suggested strategies in this regard are:

1. The management strategies should involve protection of wetlands by regulating inputs, using water quality standards (WQS) promulgated for wetlands and such inland surface waters to promote their normal functioning from the ecosystem perspective, while still deriving economic benefits by sustainable usage.
2. Participatory Approach. To involve all the concerned people and organizations in wetlands management, the Government of Ghana and other countries should co-ordinate a wetlands conservation program that will facilitate popular participatory of traditional authorities, local communities, NGOs, women's groups, youth and private sector. Moreover the ability to involve and identify local opinion leaders and key stakeholders is a key. This is because each local community has its traditional rulers and opinion leaders.

These influential people should be identified and made to participate in the design and implementation of wetland management activities. The existing decentralized administrative structure in the country (beginning from the Unit Committees through District Assemblies) is a useful framework within which the participation of traditional authorities and local communities will be solicited.

3. An interagency regulatory body comprising personnel from departments involved in urban planning and resource management (Forest department, Fisheries, Horticulture, Agriculture, Wildlife etc.), and from regulatory bodies such as Pollution Control Board, local citizen groups, research organizations, and NGO's, would help in evolving effective wetland programs. These programs would cover significant components of the watershed, and need a coordinated effort from all agencies and organizations involved in activities that affect the health of wetland ecosystems directly or indirectly.

4. Government restrictions and policies. In order to mitigate the problem of the loss of biodiversity, governments are responsible to provide a framework which protects the natural variety of animals and plants. Human greed is endless, thus this will not work without penalizing behavior which threatens a loss in biodiversity.

5. Education. The people need to be educated on how important a preservation of biodiversity is for the planet as well as for humanity. This education on biodiversity should start quite early, probably in the early school age, so that children are already of this issue quite early and can adapt their behavior into adulthood. This requires multidisciplinary-trained professionals who can spread the understanding of wetland importance at local schools, colleges, and research institutions by initiating educational programs aimed at raising the levels of public awareness and comprehension of aquatic ecosystem restoration, goals, and methods. Actively participating schools and colleges in the vicinity of the waterbodies may value the opportunity to provide hands-on environmental education which could

entail setting up laboratory facilities at the site. Regular monitoring of waterbodies (with permanent laboratory facilities) would provide vital inputs for conservation and management.

6. Creating buffer zones for wetland protection, limiting anthropogenic activities around the demarcated corridor of the wetland, could revive their natural functioning. The criteria for determining adequate buffer zone size to protect wetlands and other aquatic resources depend on the following (Castelle, Johnson, & Conolly, 1994):

    i. Identifying the functional values by evaluating resources generated by wetlands in terms of their economic costs,

    ii. Identifying the magnitude and the source of disturbance, adjacent land use, and project the possible impact of such stress in the long term,

    iii. Identifying catchment characteristics-vegetation density and structural complexity, soil condition and factors.

The management and restoration programs and strategies with an ecosystem perspective through best Management Practices helps in maintaining and protecting wetlands in all parts of the world. This along with regulations and planning for wildlife habitat and fishes helps in mitigating the declining water quality and the rate in loss of wetlands. These restoration goals require intensive planning, leadership, and funding, with active involvement from all levels of organization (governmental, NGO's, corporate conglomerates, citizen groups, research organizations, media, etc.) through interagency and intergovernmental processes instrumental in initiating and implementing the restoration programs. This will help restore the already degraded wetlands and conserve those at the verge of extinction.

Theoretical perspective

This work was underpinned by the Driver- Pressure- State- Impact- Response theory.

In 1998, the European Environment Agency (EEA) recommended how they should proceed with the development of a strategy for Integrated Environmental Assessment, They proposed the use of a framework, which were driving forces, pressures, states, impacts and responses. This then became known as the DPSIR framework and has since been more widely adopted by the EEA, and most researchers. The framework is seen as giving a structure within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made, or to be made in the future.

According to the DPSIR framework there is a chain of causal links starting with **'driving forces'** which are the need for shelter, food and water etc. (economic sectors, human activities) through **'pressures'** in meeting a need, these human activities exert 'pressures' on the environment, as a result of production or consumption processes. (emissions, waste) to **'states',** As a result of pressures, the 'state' of the environment is affected; that is, the quality of the various environmental compartments (air, water, soil, etc.) in relation to the functions that these compartments fulfil. The 'state of the environment' is thus the combination of the physical, chemical and biological conditions and **'impacts'** The changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words changes in the state may have environmental or economic 'impacts' on the functioning of ecosystems, their life supporting abilities, and ultimately on human health and on the economic and social performance of society which will eventually lead to **'response'** by society or policy makers is the result of an undesired impact and can affect any part of the chain between driving forces and impacts, (prioritization, target setting, indicators).

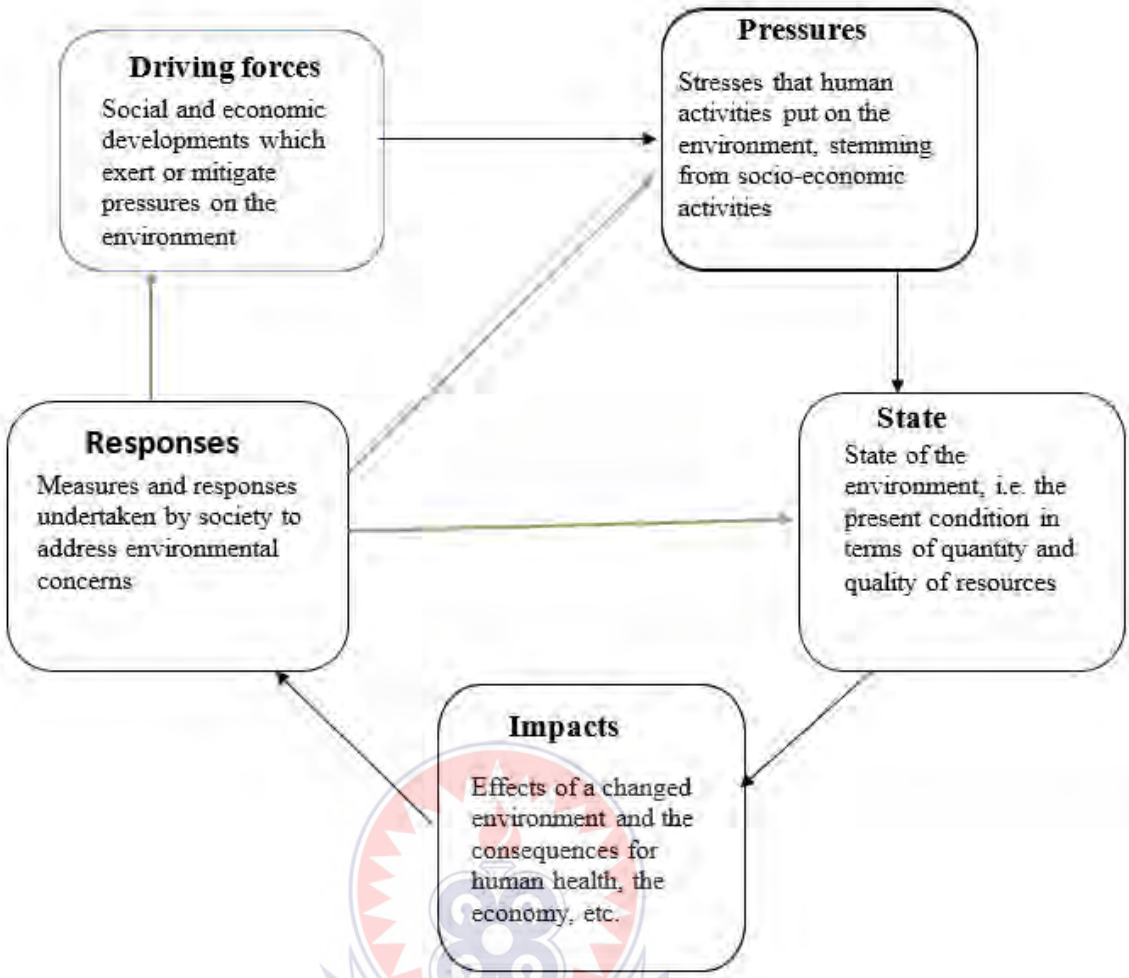

Figure 1: Driver- Pressure- State- Impact- Response by EEA (1998)

CHAPTER THREE

RESEARCH METHODOLOGY

Introduction

This chapter covered the research methodology and the procedure that was used to examine the water pollution and biodiversity change in the study area. It included the profile of the study area, the research approach and design, population and sample size, sampling techniques, research instruments, data presentation and analysis and ethical considerations.

Profile of the study area

Location

The Muni-Pomadze wetland, a closed estuarine coastal lagoon, is found in Winneba in the Central Region of Ghana. It is about 56km west southwest of Accra on the south coast of Ghana. The Muni Lagoon (05º22' N 0º40' W) is situated on the south-western part of Winneba in the Central Region of Ghana. It is a closed lagoon which occasionally opens to the sea, especially during the wet season. The lagoon is usually 3km^2 in extent (Ntiamoa-Baidu & Hollis 1988) but could expand over 6 km^2 of surrounding floodplain in the wet season. The Muni-Pomadze Ramsar Site encompasses an area of about 94.61km² (9,461 ha) (Wuver & Attuquefio, 2006) comprising the water shed of the Muni Lagoon. This area is peri-urban implying a rapid expansion of human activities. The wetland is bounded in the north by the Yenku A and B Forest Reserves, in the south by the Atlantic Ocean (Gulf of Guinea). River Pratu and River Ntakofa feed the Lagoon with fresh water. The lagoon is separated from the sea by a sand bar during the dry season which gets breached intermittently during the wet season. The lagoon which is characterized by shallow, saline, semi-closed, coastal line, with a surface area of 300ha has iconic flood-plains and the adjacent sandy beaches which constitute the southern part of the site (Ntiamoa-Badu, 1991)

serving as nesting sites for marine turtles. These locational characteristics make the wetland an attractive site for all sorts of human activities.

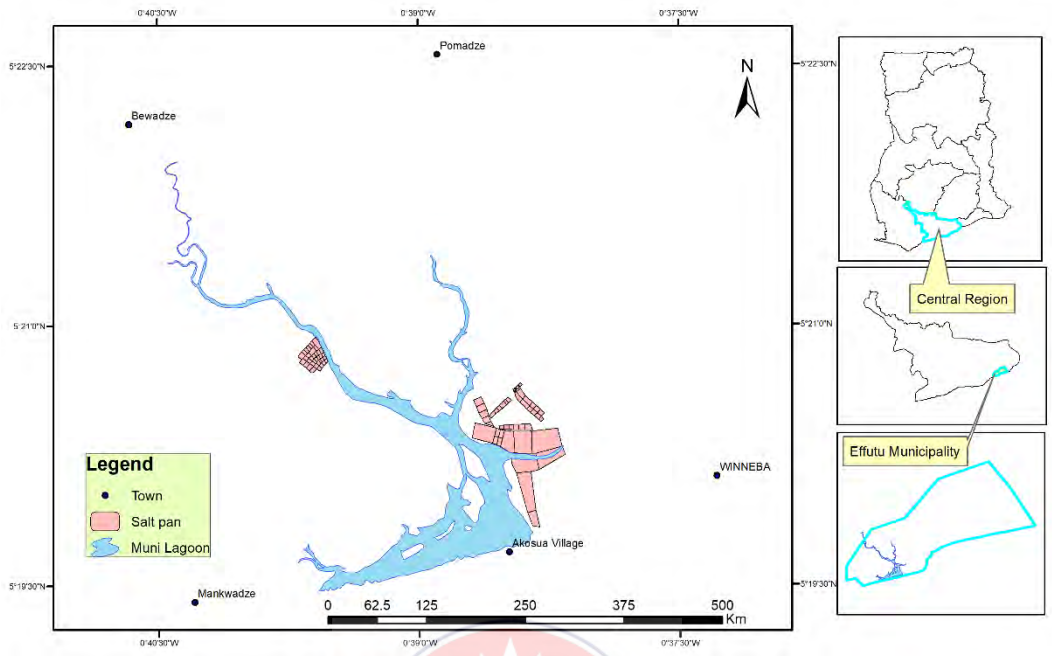

Figure 2: Map of the study area.
Source: Authors' Construct (2020)

Climate and vegetation

The monthly temperature ranges from a minimum of 24ºC in July/August to a maximum of 28.9ºC in March whilst humidity ranges from 75% to 80%. The area is characterized by a low mean annual bimodal rainfall of about 854mm. The major wet season starts from April to June with peak rainfall in June, while the minor season occurs from September to October. The main dry season occurs from November to March, during which exploitation of the wetland is high. The minor dry season is from July to August. The mean annual temperature of Muni Pomadze Ramsar Site is around 27°C with the relative humidity as measured at 15:00 hours GMT averaging 70-80% for the most part of the year and dropping to below 65% in the dry season (Gordon, Ntiamoa-Baidu, Ryan, 2000). These climatic conditions show that the Muni Pomadze Ramsar Site falls within the coastal savanna zone (Wuver & Attuquayefio, 2006). The open Muni Pomadze Ramsar

site is thus influenced by both rainfall and tidal level in the area. Fifty-three (53%) percent of the Ramsar Site is classified as natural vegetation. 32.5% as agricultural land, and the remainder as built-up areas (Gordon *et al*., 2000). The natural flora of the site is divided into four main types (Oteng-Yeboah, 1994): (i) flood plain vegetation (mangrove and wetland vegetation), (ii) dune vegetation, (iii) riverine vegetation, and (iv) terrestrial vegetation on elevated ground (combination of grasslands, thickets, and eucalyptus plantations) (Gordon *et al.*. 2000). The floodplain vegetation surrounding the Muni Pomadze Ramsar site is consistent with the vegetation found at the shoreline of other coastal lagoons in Ghana (e.g. *Sesuvium portulacastrum, Paspalum virginicum and Sporolohus virginicus*). About 53% of the catchment is classified as natural vegetation, 32.5% is agricultural land (Ryan & Ntiamoa-Baidu, 2000).

Geology and soils

The Cape Coast-Wenneba granite complex of the lower Birrimian system and the Accra Marine sandstone are the major rock types along the coast of the then Awutu- Efutu Senya District. The site is generally undulating with the rock type being mainly Birimian consisting of schist and granite as well as pegmatite. The area comprises rocky cliffs and headlands or promontories covered by cobbles. The soils are mainly vertisols which are impervious and are liable to sheet erosion during periods of seasonal flooding. This gives an indication of how sedimentation in the wetland could be worsened if human activities go on unabated. On the hills, the overburdened soils are Solonchaks while the valleys have fluvisols (Amatekpor, 1995). The topography of the Muni-Pomadze Ramsar Site has a slope of not more than 5-20% grades. If left bare, the moderately to highly erodible soils on slopes of 2-25% could yield up to 16 tons per hectare per year of sediment which would eventually end up in the lagoon. According to Gordon *et al.,* 2000), the geomorphology of the Muni Pomadze Lagoon can be categorized into four sections:

• Yenku Hills with a maximum height of 290 m and the Egyasimanku Hills (max. Height = 205) spread from the north to the north-east and the southwest portion of the Ramsar Site.

• A complex of extrusive and hypabyssal rocks (greenstones) from the upper Brimian that serves as a basement to the western part of the catchment area.

• Lagoonal deposits of sand located in the central portion of the catchment.

• Outcrops of Tarkwaian quartz schists and biotite-home blends, with grey and pink phenocrysts in the eastern part of the Muni Pomadze Ramsar Site.

Hydrology

There are two seasonal rivers, the Aboaku, and Pratu that feed the Muni Pomadze Ramsar site with fresh water. The barrier is opened during the wet season, opening up the Muni-Pomadze-Muni Pomadze Ramsar site to the sea (Biney, 1995). The lagoon has a surface area of 4500ha, an average depth of 0.6m and a maximum of 1m which could reduce with human interference. The rainfall in the catchments flows as surface run-off into the two streams that empty into the lagoon. Open water in the lagoon varies seasonally from 100ha in the dry season to over 1000ha in the wet season. It is believed that there is an underground seepage of marine water into the lagoon as a result of human disturbance (Tumbulto & Bannerman, 1995). Salinity varies from 64 g/l at the seaward section to 37 g/l in the northern section.

Demography and socio-economics characteristics

The nine major settlements within the MPRS constituted a population of 32,000 people in 1984. This went up to about 47,327 by the year 2000 (Ghana Statistical Service, 2005). The population growth rate is less than 1% annually (Gordon *et al.,* 2000). Data from the 2010 Population and Housing Census indicates that the Municipality has a population of 68,597 which represents 3.1 percent of the population of the Central region. The dominant ethnic groups are the Fanti, Ewe and migrant Fulani herdsmen. The management of the site

is vested jointly in two local or traditional authorities. The Effutu have responsibility for issues concerning the Muni Lagoon, while the Gomoa manage the wetlands. Chief Fishermen are responsible for fishing-related issues in their respective traditional communities. The major economic activities in the municipality are fishing, wholesale/retail trade, services, manufacturing, salt mining (white gold), crop farming and agro-processing. Fishing, farming, and related work are the leading economic activities in the municipality. (e.g. maize and cassava), but there are other minor activities like hunting (Effutu people), cattle grazing, sand, clay and gravel mining, salt winning and charcoal production. The MPRS is home to the annual “Aboakyir" festival, during which “Asafo” companies compete to capture a live bushbuck (Wuver & Attuquayefio, 2006). These are followed by services with salt mining along the coast of Winneba and Warabeba. The fishing industry is very prominent in the coastal communities of Winneba, Akosua Village and Warabeba within the municipality (GSS, 2014)

Research approach

Yin (1984) argues that, no research method is devoid of limitations and biases and that one method could potentially be checked by the other method. In light of this, the study employed the mixed method approach (qualitative and quantitative methods). The mixed method is a procedure for collecting, analyzing and “mixing” both quantitative and qualitative data at some stage of the research process within a single study, to understand a research problem more completely (Tashakkori & Teddlie, 2003; Creswell, 2002). The rationale for mixing is that neither quantitative nor qualitative methods are sufficient by themselves to capture the trends and details of the situation. It therefore suggests that when used in combination, quantitative and qualitative methods complement each other and allow for more complete analysis to be made (Green, Caracelli, & Graham, 1989; Tashakkori & Teddlie, 1998). In quantitative research, a researcher relies on numerical

data (Charles & Mertler, 2002). The qualitative research on the other hand is "an inquiry process of understanding" where the researcher develops a "complex, holistic picture, analyzes words, reports detailed views of informants, and conducts the study in a natural setting" (Creswell, 1998, p. 15).

A major tenet of pragmatism is that quantitative and qualitative methods are compatible. Thus, both numerical and text data, collected sequentially or concurrently, can help better understand the research problem. This method is applicable to this work because it helped to understand the contradictions between the physico-chemical and water quality index results (quantitative results) and the interviews (qualitative findings) with regards to the issue being discussed. It also reflects on participants' point of view and gives a voice to the study participants and hence ensuring that the study findings are grounded in participants experiences.

Research design

In this study, a sequential explanatory research design was employed in order to broadly explore and understand the water pollution and biodiversity change of the Muni Pomadze wetland and its catchment. In a sequential explanatory design, quantitative data is first collected and analyzed followed by a collection and analysis of qualitative data (personal experience) (Creswell 2002, 2003, 2013); where the qualitative findings are used to contextualize the quantitative data (Creswell, Plano-Clark, Gutmann & Hanson, 2003). Qualitative data can also enhance and enrich the findings (Taylor & Trumbull, 2005; Mason, 2006) and, help generate new knowledge (Stange, 2006). The researcher interprets how the qualitative results help to explain the initial quantitative results. The Qualitative research design was used because of the personal involvement and due in-depth responses of individuals who secure a sufficient level of the truthfulness of the results. These approaches would assist in doing a detailed contextual analysis of the ways in which

pollution is affecting the water quality of the Muni Pomadze Ramsar site and the subsequent impact biodiversity in the catchment.

Data sources

Like many similar types of research, this study made use of two basic datasets: primary and secondary. Whereas the secondary data was obtained from articles, books, and other published materials related to the study, the primary data included information that were obtained through a face-to-face administration of in-depth interview guides, field-works, observations and GIS and remote sensing.

Materials and description of research process

Observation was used to get firsthand information on rate of pollution, degradation and biodiversity change on the Muni Pomadze Ramsar site and its catchment area. In-depth interview guide was used gather data from the Wildlife Division of the Forestry Commission and the inhabitants of the communities bordering the muni catchment. Global Positioning System called Garmin 12XL was also used to locate exact locations where samples were taken. The Lagoon and the Pratu and Ntakofa rivers were divided into three sections (upper, middle and lower sections). PC60 Premium Multi-Parameter Tester was used to test for pH, conductivity, salinity, temperature and total dissolved solids (TDS). Dissolved oxygen Meter Kit 850081DOK was used to test for dissolved oxygen (DO). To determine the level or status of pollution in the three water bodies forming the Muni catchment, a Water Quality Index (WQI) was calculated.

Measurement of physico-chemical parameters

In measuring the parameters, 33 points were located on the lagoon, together with the Pratu and Ntakofa rivers in wet and dry seasons. The 33 points were located from the upper, middle and lower sections of the water bodies. Twenty one (21) points were located on the Muni lagoon, five (5) points from the Ntakofa and seven (7) points from the Pratu Rivers

where field measurements were done in-situ. In all six (6) parameters were checked. Systematic sampling technique was used to take water samples. A sampling interval of about 100-150m was used. At 100 - 150m, a station was mounted and measurements were taken. A multi- parametric device called Pc60 premium multi-parameter tester was used to test for five (5) parameters namely pH, conductivity, salinity, temperature and total dissolved solids (TDS). Dissolved oxygen meter Kit 850081DOK was used to test for dissolved oxygen (DO).

Water Quality Index (WQI)

Water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water (Horton, 1965).The WQI was calculated by using the standards of water quality recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS), Indian Council for Medical Research (ICMR) and United State Environmental Protection Agency (USEPA). The weighted arithmetic index method by Brown, McClelland, Deininger and Connor (1972) and Chatterjee and Raziuddin (2002) were used for the calculation of WQI of the waterbody. Further, quality rating or sub index (*qn)* was calculated using the following expression.

The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly.

$WQI=\sum q_n W_n / \sum Wn$

(Let there be *n* water quality parameters and quality rating or sub index (q_n) corresponding to n_{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. (S_n)

Where,

q_n = Quality rating of the n^{th} water quality parameter.

W_n = Unit weight of the n^{th} water quality parameter.

The quality rating is calculated using the equation

$$q_n = 100[V_n - V_{id}] / [S_n - V_{id}]$$

Where,

q_n = Quality rating for the n^{th} Water quality parameter

V_n = Estimated value of the n^{th} parameter at a given sampling station.

S_n =Standard permissible value of the n^{th} parameter.

V_{id} = Ideal value of n^{th} parameter in pure water. *(i.e., 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively)*

Unit weight was calculated by a value inversely proportional to the recommended standard value *Sn* of the corresponding parameter.

$$W_n = K / S_n$$

Where,

W_n = unit weight for the n^{th} parameters.

S_n = Standard permissible value for n^{th} parameters

K = Constant of proportionality.

Constant of proportionality is calculated by using the expression given in Equation below

$$K = [1 / (\sum 1/ S_{n=1, 2,..n})]$$

Table 1: Water Quality Index (WQI) and status of water quality

Water quality Index Level	Water quality status	Water quality description
0-25	Excellent water quality	Water quality is protected with a virtual absence of threat or impairment .All measurements are within objectives virtually of all the time.
26-50	Good water quality	Water quality is protected with minor degree of threat or impairment conditions rarely depart from desirable levels.

51-75	Fair water quality	Water quality is protected but occasionally threatened or impaired, conditions sometimes depart from desirable levels.
76-100	Poor water quality	Water quality is frequently threatened or impaired conditions often depart from desirable levels.
101 – 150	Very poor water quality	Water quality is almost always threatened or impaired conditions usually depart from desirable levels.
Above 150	Unsuitable for use or drinking	Water quality is greatly threatened or impaired and greatly departs from desirable levels. Highly polluted

Chatterjee and Raziuddin (2002), Brown et.al. (1972)

To determine the level or status of pollution in the three water bodies forming the Muni catchment, a Water Quality Index (WQI) was calculated.

Expert Interviews

This was an onsite study and hence the human participation was limited to a total of 15 respondents who were selected to participate in the study. Seidu (2012) argues that in studying any problem, it is both difficult and unrealistic attempting to examine the entire population of a study. Purposive sampling was used to select 4 participants from the Wildlife Division of the Forestry Department for expert knowledge and 11 participants from the communities bordering the Muni catchment, who have stayed there for 10 years or more. Creswell (1998) recommends 5-25 participants and Morse (1994) suggest at least six when doing a qualitative research, but the number of participants all depends upon reaching saturation. Both techniques would ensure that the right information is solicited to better answer the research question.

Site Selection

The Muni Pomadze Ramsar Site was purposively chosen for the study. This lagoon was chosen because it is one of the few internationally recognized wetlands in Ghana that houses diverse species (The Ramsar Convention, 2012). It is an area specifically conserved

to continually support ecosystem services hence need carefully study and sustain it. The Pratu and the Ntakofa rivers were selected because they are the main fresh water that empty into the lagoon and people farm along these rivers.

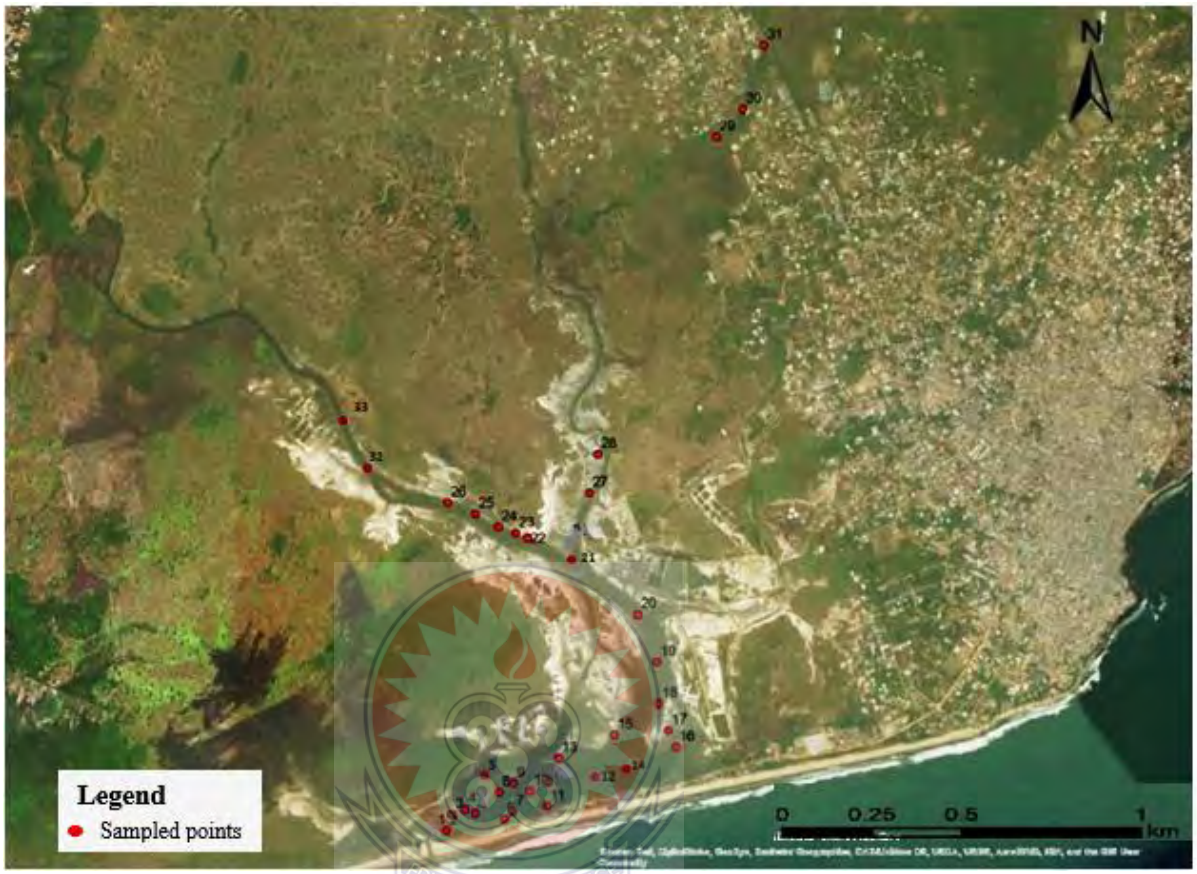

Figure 3: Muni catchment sampling points
Source: Field Survey (2020)

Data processing and analysis

The results from the in-depth interviews were analyzed thematically. The samples of water were tested on the field to analyze for pH, conductivity, salinity, dissolved oxygen (DO), temperature and total dissolved solids (TDS). The GPS coordinates together with the sampling point's value were entered into Arc GIS version 10.1 software to generate an interpolation map for the study area. The Krigging tool in ArcGIS 10.1 helped in the interpolation as it was used to estimate the values of non-sampled points. It also helped to estimate the concentration of the parameters that were measured in the Muni catchment.

Limitations of the study

The study was constrained by a number of factors:

The first was inaccessibility of some areas of the Muni catchment during data collection. This was highly due to the growth of water hyacinth. Also, some section of the Muni catchment were shallow making it impossible to paddle the canoe. Lastly, during data collection for the rainy season, the lagoon had no access to the sea because it was cut off by a sandbar, but in the dry season, the sandbar was cut opened for the lagoon and sea to mix so it affected the results of some parameters that were measured.

Ethical consideration

Permission was sought from appropriate personalities and institutions before interviews were granted. The researcher ensured confidentiality and anonymity of the information which were acquired. The researcher also acknowledged all sources that were cited in this work to prevent plagiarism.

CHAPTER FOUR

PHYSICO-CHEMICAL PROPERTIES AND EXTENT OF POLLUTION IN THE MUNI CATCHMENT

Introduction

This chapter was devoted to discussing the physico-chemical parameters and extent of pollution in the Muni catchment in the wet and dry seasons. The parameters that were discussed were pH, temperature, salinity, conductivity, total dissolved solids and dissolved oxygen. The extent of pollution was also discussed using the water quality index.

Physico-chemical parameters of the Muni catchment

Temperature

Temperature is one of the most important factors that determines the existence of species. Too cold or too warm temperatures mean that either the organism adjust or adapt to the changes or perish. With respect to biodiversity in and around a water body, other factors such as the environment affects the growth of biodiversity more than temperature. According to the USEPA (1986), most aquatic organisms find themselves or exist within temperature range of within 25℃- 30℃. Results from the study indicated some amount of variations in temperature during the period of data collection on the Muni catchment. The Muni catchment comprises the Muni lagoon, the Ntakofa and the Pratu Rivers. The mean temperature for the Muni lagoon in the wet season was 28℃ compared to the Pratu which recorded 27.7℃ with Ntakofa river also recording an average of 28.5℃. The highest temperature recorded for the Muni lagoon was 28.9℃ with a minimum of 27.5℃. The maximum and the minimum temperatures recorded for the Pratu were 28.6℃ and 27.1 respectively. The Ntakofa river recorded 29.8℃ and 27.1 as maximum and minimum respectively.

In the dry season, average temperature for the Muni lagoon was 30.9℃ with 33.2℃ and 29.4℃ as maximum and minimum temperatures respectively. On the Pratu, the average temperature recorded for the dry season was 32.3℃ with a maximum of temperature of 33℃ and a minimum of 31.8℃. the Ntakofa also recorded an average temperature of 31.7℃ for the dry season with a maximum temperature of 32.8℃ and a minimum temperature value of 30℃. Delince (1992) asserts that temperature is very important for aquatic ecosystem as it affects the organisms as well as the physical and chemical characteristics of the water in which they live.

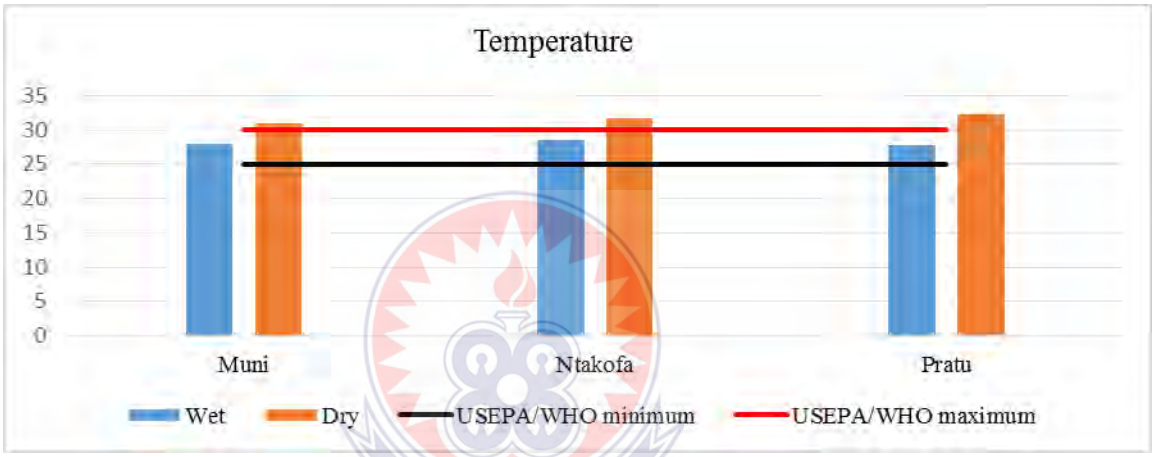

Figure 4: Temperature concentration in wet and dry seasons
Source: Field survey (2019; 2020)

During dry season, temperatures are higher in water bodies; an increase in water temperature is associated with an increase in bacterial numbers that are essential to their growth as asserted by Roberts, Waiser, Arts, & Evans (2005). This confirms what Wetzel (2001) postulates; algal photosynthesis will rise with temperature increase, though a variety of species possess varying peak temperatures for optimum photosynthetic activity. This temperature range favors aquatic organisms. From the results, the highest range or average is 32.3℃ which about 2.3℃ difference between the highest ranges. This study is therefore in conformity with a study by Tiakor (2015) that recorded a temperature value between the ranges of 29.3℃ -32.5℃ on the Muni lagoon. This condition will propel living organisms within that particular area to adjust to the temperature changes. The more these organisms

try to adjust to the changes, the more energy they release and at some point after all their energies are exhausted in trying to adjust, they die off. Those that can't adjust to the changes, may relocate to different environment where temperatures are favorable. The lowest average was 27.7℃ recorded in the wet season which is highly within the threshold of 25℃ and many organisms may survive and grow. With reference to the mean values, temperature regimes among the three parts of the river were fairly stable. However, fluctuating temperatures occurring in the sampling area may be due to the ambient air temperature during sampling. According to Brown, (1999), heat transfer, whether from the air, sunlight, another water source or thermal pollution can change the temperature of water as similarly indicated by Fondriest Environmental, Inc. (2014).

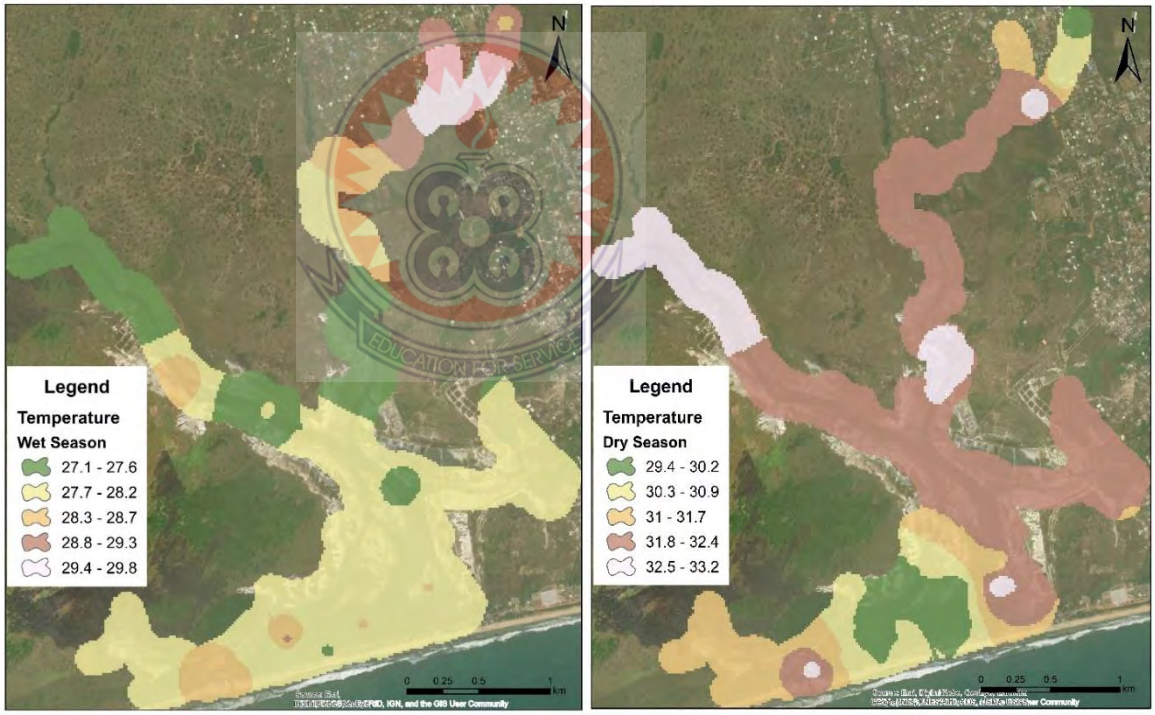

Figure 5: Temperature distribution in wet and dry seasons
Source: Field Survey (2019; 2020)

pH

pH is the measure of hydrogen ions, or acidity, in the water. Water has hydrogen ions and hydroxyl ions. When there are equal numbers of both, the water is neutral. As

the hydrogen ions increase, the water becomes more acidic; as the hydroxyl ions increase, the water becomes more basic. In the wet season, the Muni recorded an average of 8.2 with a maximum and minimum pH values of 8.3 and 8.1 respectively. The Pratu recorded an average pH value of 8.2 with 8.2 as maximum and 8.1 as minimum. An average pH value of 7.7 was recorded for the Ntakofa with 8.3 and 7.2 as maximum and minimum pH values respectively. The pH values recorded in these water bodies were relatively close with little variations. Nonetheless all these pH values were within the threshold provided by the USEPA and WHO, hence a reasonably good buffer range for supporting different aquatic life. Gallagher (2011) asserts that, pH has an impact on many chemical and biological systems in the water and varying organisms have their specific range of pH within which they survive comfortably. Therefore anything beyond or below this range challenges aquatic life or organisms in that water body. This is so because anything above or below, the aquatic organisms within that enclave would have to adjust to that living conditions and the more the fish or organisms adjust, the more the release much energy. If they continue to adjust, at some point they might die or perish and others may also leave to a suitable environment.

The pH of the whole Muni catchment was found to be alkaline since all the mean values were significantly above the minimum threshold of 6.5 and fairly close to the maximum threshold of 9.0. This study is therefore in conformity with a study by Abdourahamane (2010), in the Muni catchment that recorded pH range of 7.43 – 8.70 and concluded that the Muni catchment can be said to be alkaline in nature. Wurts and Durborow, (1992) asserts that the recommended pH range for most fish should be between 6.0 and 9.0 with a minimum alkalinity of 20 mg/L, with ideal CaC levels between 75 and 200 mg/L. However, numerous studies have confirmed that a pH range of 6.5 to 9 is most appropriate for the maintenance of fish communities. The pH of water bodies depends on the underlying rock type, the temperature and the source of the water. The USEPA (1986)

and WHO (1997) stated that the normal pH range for surface water should fall between 6.5 -9.0. According to USGS (2007), pH that deviates from this range reduces the biodiversity in the stream because the physiological systems of most of these fauna is stressed and can decrease reproduction. The pH measures the acid or alkaline nature of water samples or water body. From the results, it is clear that relatively alkaline conditions exists in the water in the catchment. Figure 7 below shows the concentration of pH in the Muni catchment.

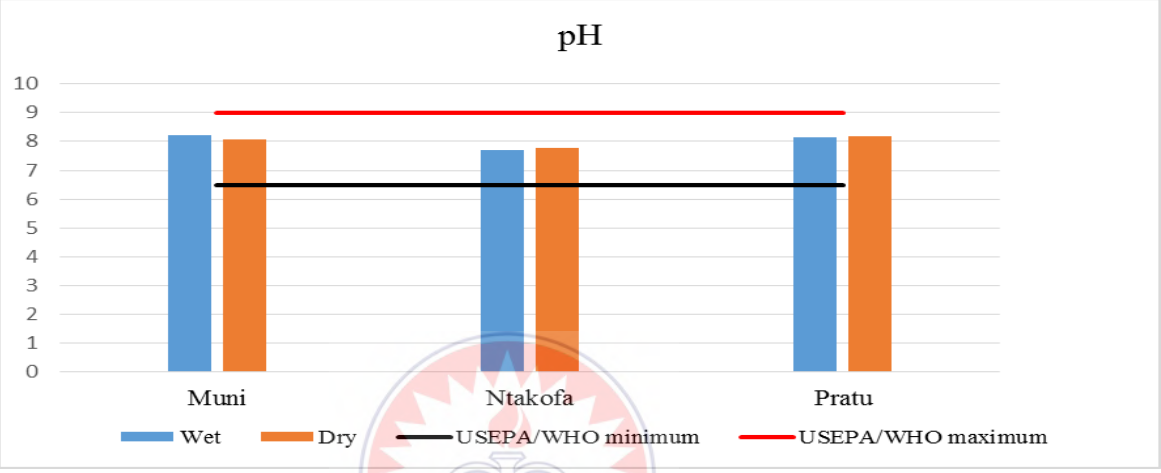

Figure 6: pH concentration in wet and dry seasons
Source: Field Survey (2019; 2020)

In the dry season, the highest average value was recorded in the Pratu with the value of 8.2, followed by 8.1 for the Muni and the Ntakofa River recorded 7.8 all in the dry season. The steady increase in the values may be due to the influence of anthropogenic activities occurring around the area. This is because a large portion of that part of the rivers is located in a comparatively large populated town from whose houses domestic effluents may flow into the river and that of agricultural effluents. The maximum and minimum values for the Muni lagoon were 8.7 and 7.9 respectively. The Pratu River also recorded 8.6 as maximum and 7.9 as minimum and for the Ntakofa, the maximum value was 8.4 and minimum 7.4.

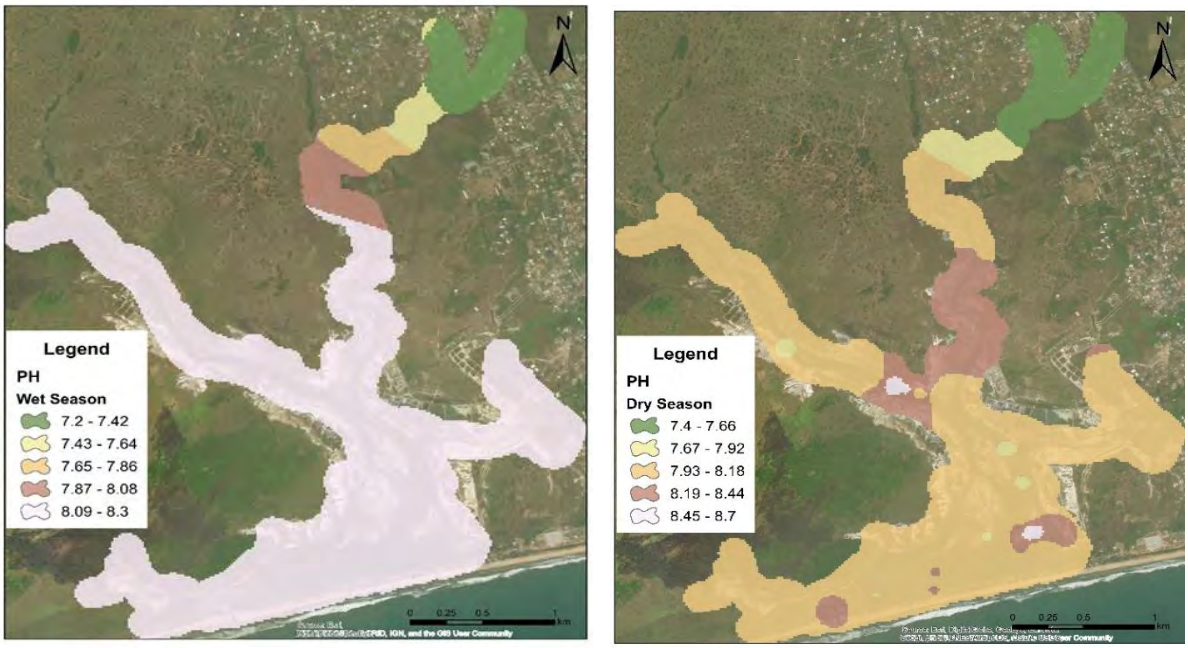

Figure 7: pH distribution in wet and dry seasons
Source: Field Survey (2019; 2020)

Total Dissolved Solids

Total dissolved solids are the total amount of mobile charged ions, including minerals, salts or metal dissolved in a given volume of water in mg/L. Total solids are dissolved solids plus suspended and settleable solids in water. The US EPA, (2012) recommend an upper limit of 500 mg/L TDS for aquatic life, though this is exceeded in some regions with little ill effect. If TDS goes above the range that means that the water body is highly polluted. The implication of this is that below 500 mg/L means the lagoon is a clean water body and will favor aquatic organisms. Total dissolved solids are the total amount of mobile charged ions, including minerals, salts or metal dissolved in a given volume of water in mg/L which also determines the degree of salinity of the water and hence related to the conductivity. Water containing low TDS could be considered to be "Fresh water" and good enough both for drinking and irrigational purposes, as this would not affect the osmotic pressure of soil solution according to Freeze and Cherry (1979) cited in Oyem, Oyem and Ezeweali, (2014). TDS concentrations were monitored in the

catchment, .i.e. Muni lagoon, Pratu and the Ntakofa Rivers. The highest average TDS value was recorded on the Ntakofa River with 233.8mg/L with a high average conductivity value of 328.7 mS/cm and low average salinity value of $1.1^{0}/_{00}$. This high value was recorded because the Ntakofa runs through dense populated areas and hence receives uncontrolled domestic and agricultural waste. The Muni lagoon recorded and average TDS value of 3.5mg/L with an average salinity value of $2.5^{0}/_{00}$ and an average conductivity value of 4.9 mS/cm. with the Pratu, a 3.5mg/L of TDS was recorded with 4.9 mS/cm for conductivity and an average salinity value of $2.5^{0}/_{00}$.

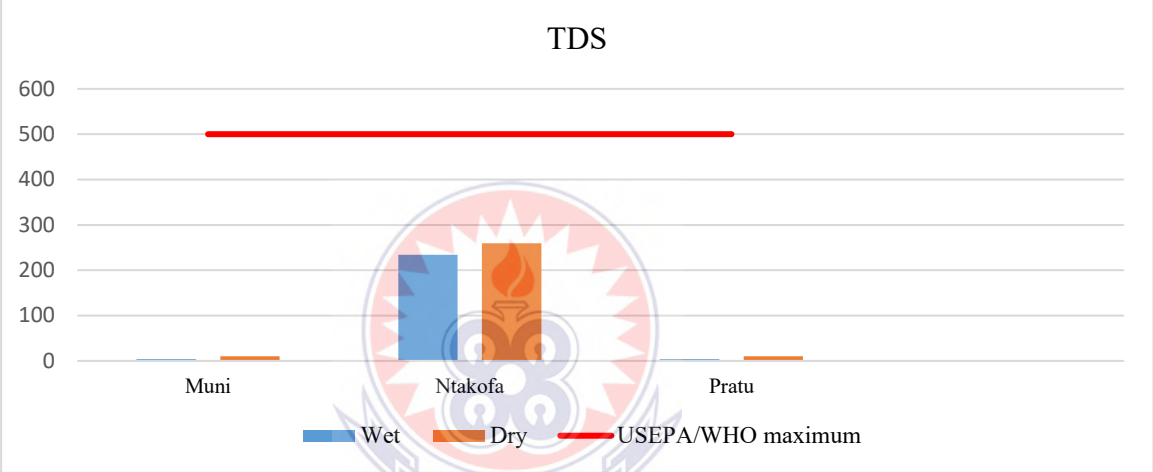

Figure 8: TDS concentration in wet and dry season
Source: Field Survey (2019; 2020)

In the dry season higher average value of 259.5mg/L was recorded on the Ntakofa with a high average value of 366.6 mS/cm of conductivity and a lower average salinity value of $3.5^{0}/_{00}$. The average TDS value for Muni and the Pratu were 10mg/L and it remained constant throughout the period of study. However the Muni lagoon recorded an average salinity value of $8.6^{0}/_{00}$ which was relatively above that of the Pratu with an average value of $8.3^{0}/_{00}$. Conductivity on the other hand remained almost the same with the Muni recording an average value of 17.2 mS/cm and Pratu with 17.3 mS/cm. Total dissolved solids concentrations outside of a normal range can cause a cell to swell or shrink. This can negatively impact aquatic life that cannot compensate for the change in water

retention. However since the average values are less than the recommended threshold, it means it is a clean water body which is a good indicator of fish population growth.

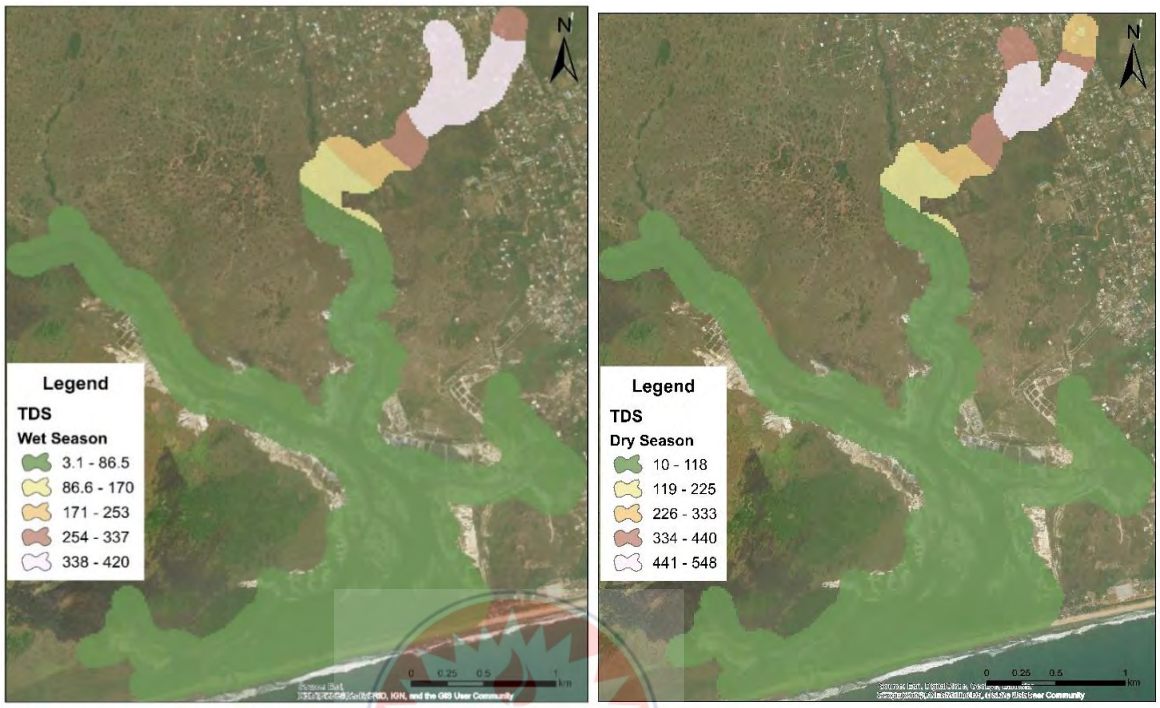

Figure 9: Total Dissolved Solids distribution in wet and dry seasons.
Source: Field Survey (2019; 2020)

Conductivity

This is a measure of the dissolved ionic component in water and hence electrical characteristic. Conductivity is usually measured in micro- or millisiemens per centimeter (uS/cm or mS/cm). It can also be reported in micromhos or millimhos/centimeter (umhos/cm or mmhos/cm), though these units are less common. The conductivity of most waters ranges from 10 to 1000 mS/cm (Chapman, 1992). These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. This could be likened to what Perlman (2013) stated, that distilled or deionized water can act as an insulator due to its very low (if not negligible) conductivity value. Sea water, on the other hand, has a very

high conductivity. From the results, the highest or maximum conductivity was recorded on the Ntakofa at WSP30 which was 593 mS/cm. This was recorded in between Klimovic Hospital and Crown Villa Hostel. The average value on the Ntakofa was 328.7 mS/cm with a minimum value of 4.1 mS/cm all in the wet season. This high conductance readings could be due to either industrial pollution or urban runoff of streets, parking lots or garages. The Ntakofo River passes through the urban centers of Wenneba and hence subject to urban runoff and waste deposition. This therefore reflect the high conductance value. The Muni lagoon and the Pratu river exhibited a relatively closeness of values. The Muni lagoon on the other hand recorded an average of 4.9 mS/cm with a maximum of 5.2 mS/cm and a minimum of 4.8 mS/cm. These low value of conductance could be due to the fact that the Muni lagoon at the time of the study had no interaction with the sea. It was cut off from the sea by a sandbar. On the Pratu, the average value was 4.9 mS/cm same as the Muni with a maximum value of 5.1 mS/cm and minimum value of 4.5 mS/cm. To a greater extent, the Pratu exhibits quite similar characteristics with the Muni Lagoon because the Muni is able to flow and mix with the Pratu that flows on a relatively lower slope than the Ntakofa.

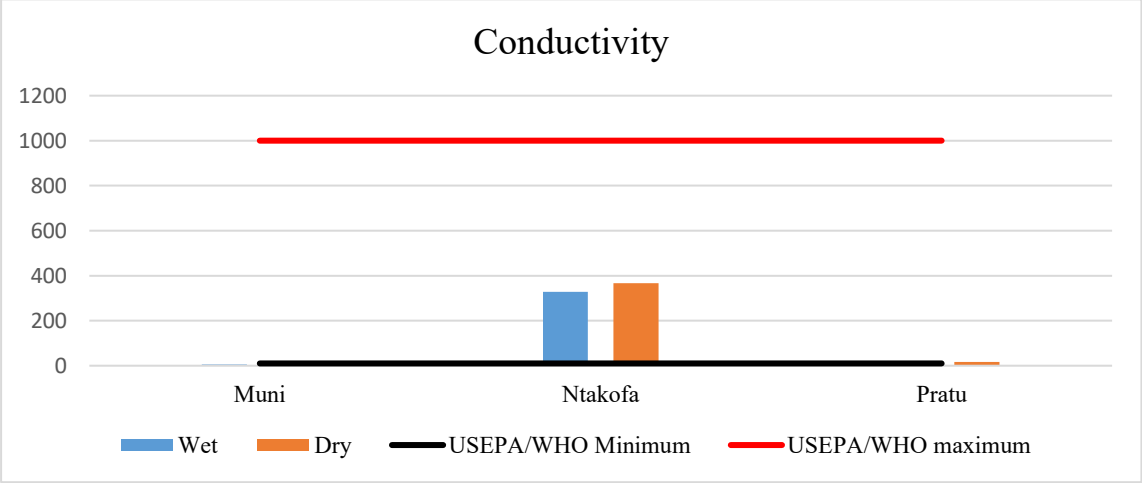

Figure 10: Conductivity concentration in wet and dry season
Source: Field Survey (2019; 2020)

In the dry season, the maximum value recorded on the Ntakofa was 771.5 mS/cm with and average value of 366.6 mS/cm. the minimum value recorded on the Ntakofa was 16.9 mS/cm. As earlier explained, there were more urban runoff and waste disposal with no rainfall to dilute it and hence the high conductance value. The Muni and the Pratu here again exhibited closeness of values, but this time saw a significant rise in values obtained compared to the wet season. The Muni recorded a maximum value of 17.6 mS/cm with an average value of 17.2 mS/cm and a minimum of 16.4 mS/cm. The Pratu recorded an average of 17.3 mS/cm and a maximum value of 17.9 mS/cm with a minimum of 16.9 mS/cm. These relative rise in values for the dry season was due to the fact that, the sandbar was cut open for the Sea to mix with the lagoon and hence there was an interaction between the sea and the lagoon. Also temperature has a role to play and it is said to increase conductivity as it increases. This was confirmed by Dubrovsky, Burow, Clark, Crunberg Hamilton, Hih, & Muller (2010), that, higher water temperature is known to increase the movement of ions in water and therefore increases conductivity.

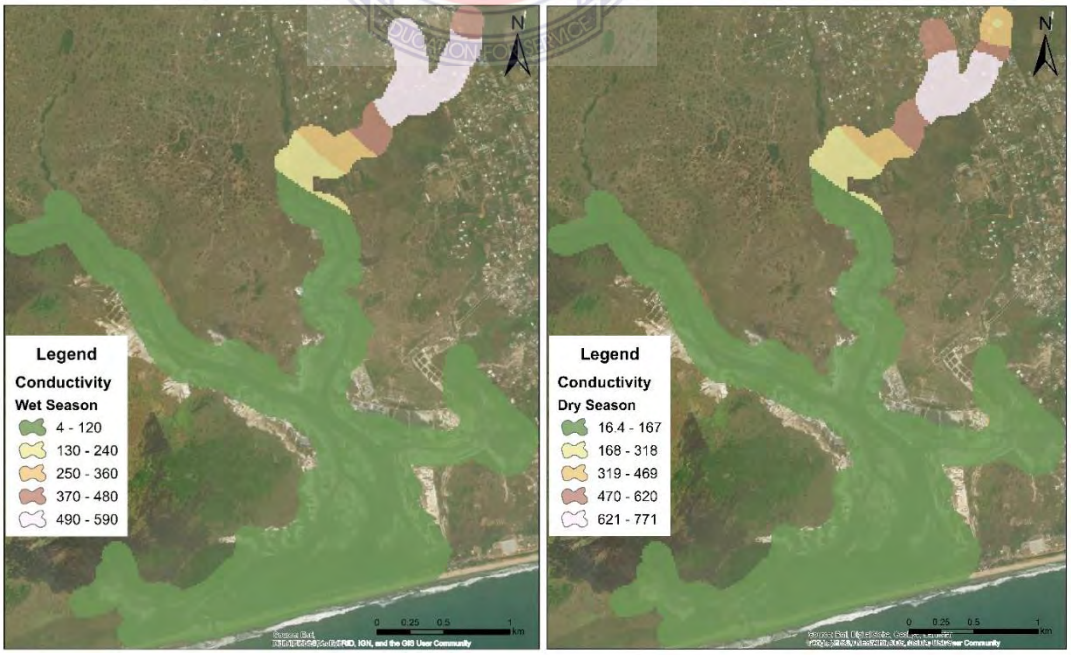

Figure 11: Conductivity distribution in wet and dry seasons.
Source: Field Survey (2019; 2020)

Salinity

The concentration of dissolved salt in a given volume of water is called salinity (USEPA 2012). The salinity should be 0.5 - 17 $^{0}/_{00}$, for brackish water but depending on the location and rate of evaporation of the water, some could have higher values. The maximum value recorded for the Muni lagoon in the wet season was 2.6$^{0}/_{00}$ with an average salinity value of 2.5$^{0}/_{00}$. The minimum value was 2.4$^{0}/_{00}$. The Pratu also recorded a maximum salinity value of 2.6$^{0}/_{00}$ with an average of 2.4$^{0}/_{00}$ while the minimum value recorded was 2.1$^{0}/_{00}$. These values reflect the fact that the Muni Lagoon at the time of the study had no interaction with the Sea because it was cut off by a sandbar. This coupled with less evaporation and much rainfall diluted the salt content in the lagoon for the wet season. The Ntakofa River recorded an average value of 1.1$^{0}/_{00}$ with a maximum of 2.3$^{0}/_{00}$ and a minimum salinity value of 0.2$^{0}/_{00}$.

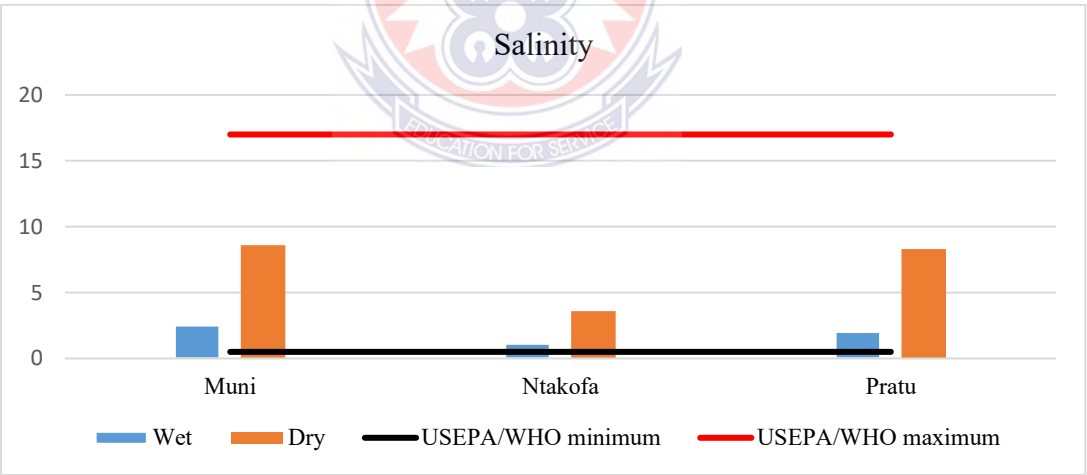

Figure 12: Salinity concentration in wet and dry season
Source: Field Survey (2019; 2020)

In the dry season however, the Muni lagoon recorded the highest average salinity value of 8.6 $^{0}/_{00}$. The maximum and minimum values recorded during the dry season were 8.9$^{0}/_{00}$ and 8.2$^{0}/_{00}$ respectively. The Pratu recorded closeness of values with the Muni

because of the salt pans located on the stretch of the Pratu. The Pratu recorded an average salinity value of $8.3^0/_{00}$ with maximum and minimum values of $8.5^0/_{00}$ and $7.5^0/_{00}$ respectively. These high values recorded may be as a result of the sandbar being cut opened for the sea and lagoon to mix in the dry season. So the interaction between the sea and the lagoon could lead to the rise in the salinity level. Secondly, these rise could be attributed to the high levels of evaporation coupled with salt pans in the area. The Ntakofa recorded an average of $3.5^0/_{00}$ with a maximum value of $8.5^0/_{00}$ which was recorded about 100 – 150m from the Lagoon and with its minimum value of $0.2^0/_{00}$ recorded at WSP31.

For the values obtained for both seasons, most marine species could thrive in this water body all other things being equal. This is because most aquatic organisms can only tolerate a specific salinity range. The physiological adaption of each species is determined by the salinity of its surrounding environment. Most species of fish are stenohaline, or exclusively freshwater or exclusively saltwater. However, there are a few organisms that can adapt to a range of salinities.

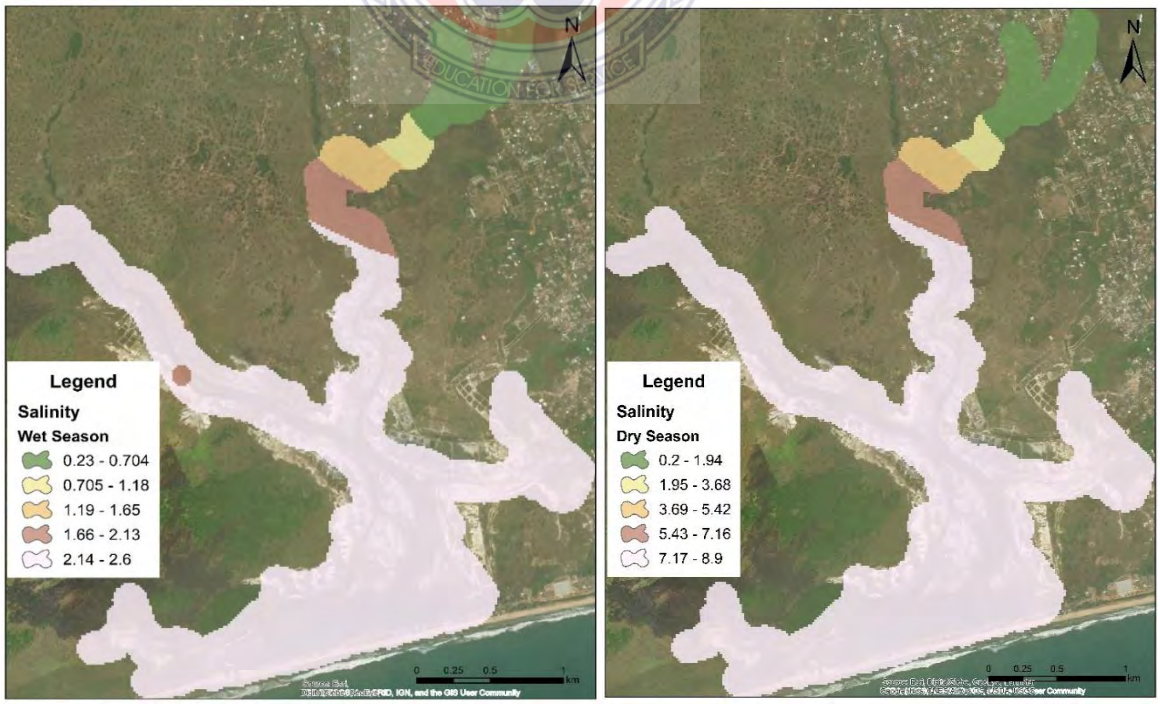

Figure 13: Salinity distribution in wet and dry seasons
Source: Field Survey (2019; 2020)

Dissolved Oxygen

According to Talib and Amat (2012), Dissolved oxygen (DO) is basically oxygen measured in its dissolved state. Dissolved oxygen is the most important indicator of the health of water bodies and its capacity to support a balanced aquatic ecosystem of plants and animals. Cunningham and Saigo (1995), asserts that, the DO should not be less than 2mg/L. This means it should be 2mg/L or more. So if DO is below the expected range that is (2mg/L) organisms will perish. CENR, (2000), stated that, when oxygen concentrations are less than 2mg/L, the water is defined as hypoxic or aquatic hypoxia. The hypoxia kills many organisms that cannot escape, and thus the hypoxic zone is informally known as the "dead zone." From the results obtained, average D.O recorded for the Muni lagoon in the wet season was 6.9mg/L, far above the threshold by CENR (2000) and Cunningham and Saigo, (1995). The minimum and the maximum values recorded on the Muni lagoon during the period of study were 6.6mg/L and 7.4mg/L. These values were far above the threshold. The Pratu recorded an average of 7.2mg/L with a maximum value of 7.4mg/L and a minimum of 6.7mg/L also in the wet season. The values obtained for the Ntakofa during this period did not see any significant change. The maximum value recorded for the Ntakofa was 7.7mg/L with an average of 6.2mg/L while its minimum value was recorded at 5.0mg/L. All these values recorded were above the recommended threshold and hence it would be encouraging for biological productivity within the lagoon and its catchment. This was not surprising as fish ponds were spotted on some section of the Pratu River.

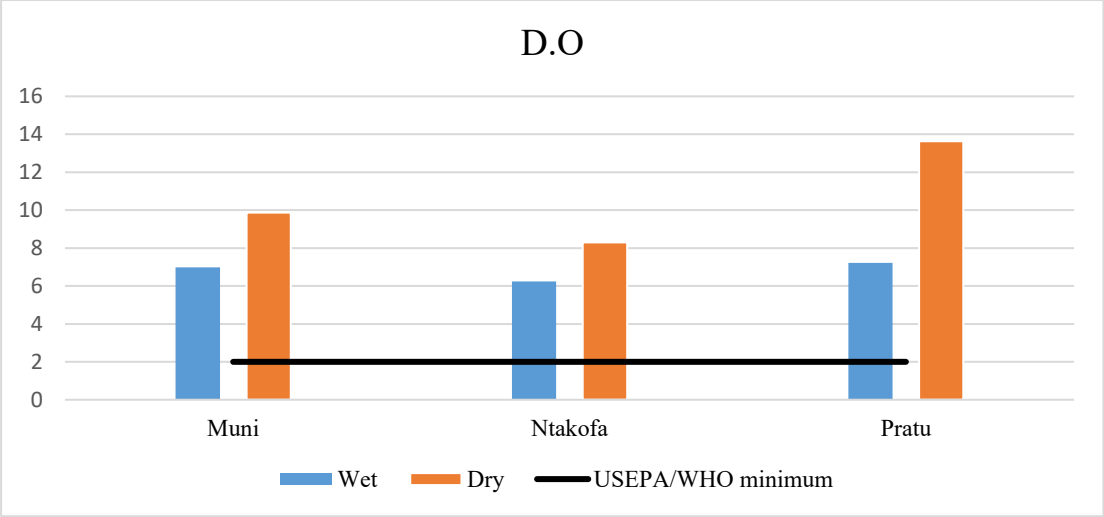

Figure 14: Dissolved oxygen concentration in wet and dry season
Source: Field Survey (2019; 2020)

In the dry season, some changes were observed. On the Muni lagoon, the maximum and minimum D.O value recorded were 14mg/L and 6.5mg/L respectively with an average of 9.9mg/L. The highest average recorded during the period of study was 13.6mg/L on the Pratu river with a maximum and a minimum values of 13.9mg/L and 12.5mg/L. all these values recorded enhances biological productivity of organisms. The Ntakofa River recorded an average value of 8.3mg/L with maximum and minimum value of 8.4mg/L and 2.4mg/L respectively. The values could be attributed to the aerating action of winds and more importantly as a byproduct of aquatic plant photosynthesis from phytoplankton, algae, seaweed etc (NOAA. 2014).

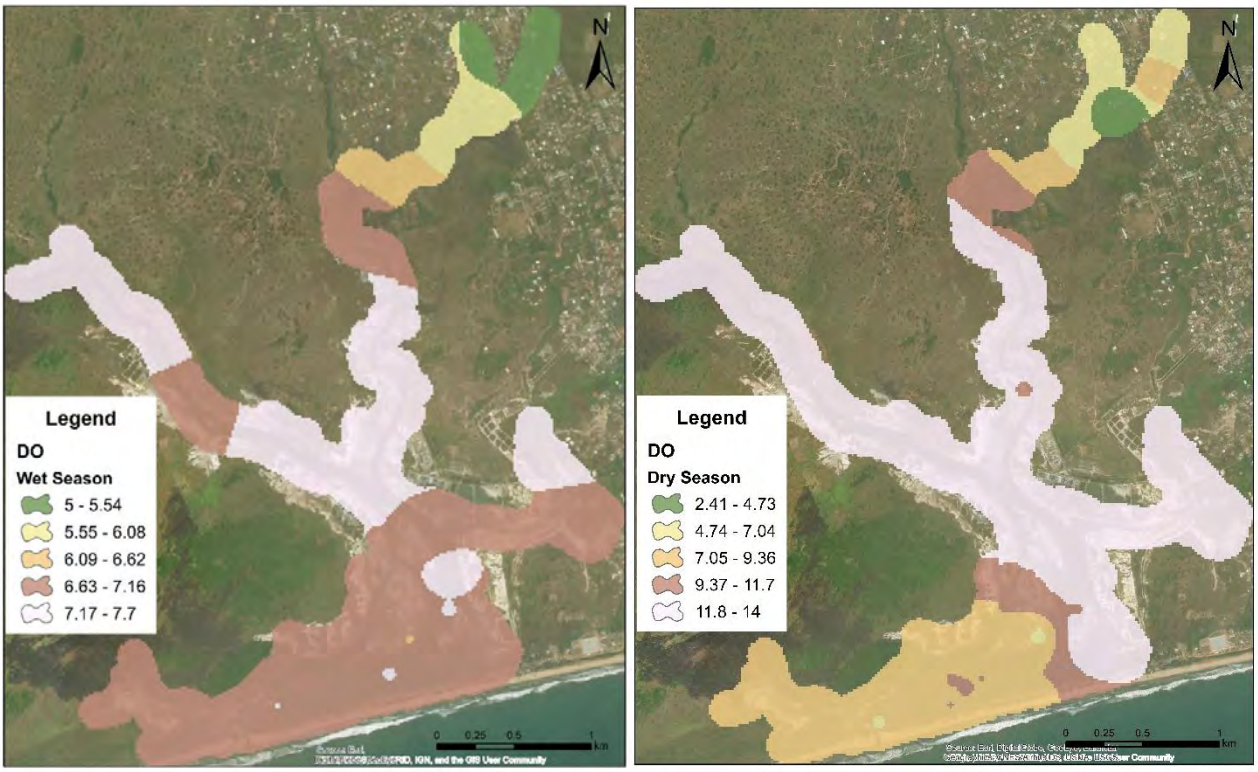

Figure 15: Dissolved Oxygen distribution in wet and dry seasons
Source: Field Survey (2019; 2020)

Comparison of extent of pollution of the three water bodies in the Muni catchment

Water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water (Horton, 1965).The WQI was calculated by using the standards of water quality recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS), Indian Council for Medical Research (ICMR) and United State Environmental Protection Agency. The weighted arithmetic index method by Brown, McClelland, Deininger and Connor (1972) and Chatterjee and Raziuddin (2002) were used for the calculation of WQI of the waterbody. Further, quality rating or sub index (*qn)* was calculated using the following expression.

The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly.

$WQI=\sum q_n W_n / \sum Wn$

(Let there be *n* water quality parameters and quality rating or sub index (q_n) corresponding to n_{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. (S_n)

Where,

q_n = Quality rating of the n^{th} water quality parameter.

W_n = Unit weight of the n^{th} water quality parameter.

The quality rating is calculated using the equation

$$q_n = 100[V_n - V_{id}] / [S_n - V_{id}]$$

Where,

q_n = Quality rating for the n^{th} Water quality parameter

V_n = Estimated value of the n^{th} parameter at a given sampling station.

S_n =Standard permissible value of the n^{th} parameter.

V_{id} = Ideal value of n^{th} parameter in pure water. *(i.e., 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively)*

Unit weight was calculated by a value inversely proportional to the recommended standard value *Sn* of the corresponding parameter.

$$W_n = K / S_n$$

Where,

W_n = unit weight for the n^{th} parameters.

S_n = Standard permissible value for n^{th} parameters

K = Constant of proportionality.

Constant of proportionality is calculated by using the expression given in Equation below

$$K = [1 / (\sum 1 / S_{n=1, 2,..n})]$$

Table 2: Water Quality Index (WQI) and status of water quality

Water quality Index Level	Water quality status	Water quality description
0-25	Excellent water quality	Water quality is protected with a virtual absence of threat or impairment .All measurements are within objectives virtually of all the time.
26-50	Good water quality	Water quality is protected with minor degree of threat or impairment conditions rarely depart from desirable levels.
51-75	Fair water quality	Water quality is protected but occasionally threatened or impaired, conditions sometimes depart from desirable levels.
76-100	Poor water quality	Water quality is frequently threatened or impaired conditions often depart from desirable levels.
101 – 150	Very poor water quality	Water quality is almost always threatened or impaired conditions usually depart from desirable levels.
Above 150	Unsuitable for use or drinking	Water quality is greatly threatened or impaired and greatly departs from desirable levels. Highly polluted

Chatterjee and Raziuddin (2002), Brown et.al. (1972)

To determine the level or status of pollution in the three water bodies forming the Muni catchment, a Water Quality Index (WQI) would have to be calculated before judgment can be made.

Seasonal variations of the physico-chemical parameters of the three water bodies

Table 3: Physico-chemical parameters of the Muni lagoon

S/N	Parameters	Wet Season	Dry season
1	pH	8.2	8.1
2	Dissolved Oxygen	6.9	9.9
3	Salinity	2.5	8.6
4	Conductivity	4.9	17.2
5	Temperature	28.0	31.0
6	Total Dissolved Solids	3.5	10

Source: Field Survey, (2019 & 2020).

Table 4: Physico-chemical parameters of the Pratu River

S/N	Parameters	Wet Season	Dry Season
1	pH	8.2	8.2
2	Dissolved Oxygen	7.2	13.6
3	Salinity	2.4	8.3
4	Conductivity	4.9	17.3
5	Temperature	27.7	32.3
6	Total Dissolved Solids	3.5	10

Source: Field Survey, (2019 & 2020).

Table 5: Physico-chemical parameters of the Ntakofa River

S/N	Parameters	Wet Season	Dry Season
1	pH	7.7	7.8
2	Dissolved Oxygen	6.2	8.3
3	Salinity	1.1	3.6
4	Conductivity	328.7	366.6
5	Temperature	28.5	31.7
6	Total Dissolved Solids	233.8	259.5

Source: Field Survey, (2019 & 2020).

The above tables 1-3 show the differences in values for the parameters that were recorded in. wet and dry seasons

Table 6: Water quality index of the Muni lagoon in the wet season

S/N	Parameters	Observed values (V_n)	Standard Values (S_n)	Unit Weight (W_n)	K value	Quality rating (q_n)	W_nq_n
1	pH	8.2	6.5 – 9.0	0.1577	1.42	60	9.462
2	Dissolved Oxygen	6.9	2mg/L or more	0.71	1.42	61.1	43.381
3	Salinity	2.5	0.5 - 17 $^{0}/_{00}$	0.08352	1.42	14.71	1.228
4	Conductivity	4.9	10 to 1000 mS/cm	0.00142	1.42	0.49	0.0006958
5	Temperature	28.0	25℃-30℃.	0.04733	1.42	93.3	4.415889
6	Total Dissolved Solids	3.5	500 mg/L	0.00284	1.42	0.7	0.00198

	$\sum Wn$ =1.00281	$\sum q_n W_n$ =58.49

$WQI = \sum q_n W_n / \sum Wn = 58.33$

Source: Field Survey, (2019).

From the table 5 above, the water quality index for the Muni Lagoon in the wet season was 58.33 which falls within the fair water quality group of 51-75. This means that, Water quality is protected but occasionally threatened or impaired, conditions sometimes depart from desirable levels. This is in conformity with a study by Tay, Ashma and Biney, (2010) that the Muni lagoon is fairly polluted after a comparative study of pollution in Sakumo II and the Muni lagoon. This could be due to the excess runoff and inflow from the Pratu and Ntakofa during the wet season. During the wet season, farming activities mostly dominate the around the Ntakofa and the Pratu rivers. A study by Blay, (1974) recorded food items including corn seeds and corn chaff in the stomachs of specimens (blackchin tilapia) in Fosu and Benya lagoons signifying that wastes from farmlands do drain into water bodies and the harmful ones could kill aquatic organisms. Runoff carries waste from these farms together with household waste into the lagoon affects its WQI value. Moreover the waste from Ninsen paper factory into the Pratu, which also feed the Muni lagoon with fresh water also its status. This means that the Muni Lagoon of fair water quality, requires monitoring to prevent it from further pollution.

Plate 1: Pollution to the lagoon from the gutters at Traffic light and HFC bank
Source: Field Survey (2019)

One of the biggest gutters in Winneba which is located at Abaseraba Traffic light also carries huge sums of waste and deposited them into the Muni lagoon. All these affect the quality of the lagoon.

Table 7: Water quality index of the Pratu River in the wet season

S/N	Parameters	Observed values (V_n)	Standard Values (S_n)	Unit Weight (W_n)	K value	Quality rating (q_n)	W_nq_n
1	pH	8.2	6.5 – 9.0	0.1577	1.42	60	9.462
2	Dissolved Oxygen	7.2	2mg/L or more	0.71	1.42	58.73	41.6983
3	Salinity	2.4	0.5 - 17 $^{0}/_{00}$	0.08352	1.42	14.12	1.1794436
4	Conductivity	4.9	10 to 1000 mS/cm	0.00142	1.42	0.49	0.0006958
5	Temperature	27.7	25℃-30℃.	0.04733	1.42	92.3	4.368559
6	Total Dissolved Solids	3.5	500 mg/L	0.00284	1.42	0.7	0.001988
				$\sum Wn = 1.00281$			$\sum q_n W_n = 56.711$
	WQI=$\sum q_n W_n / \sum Wn = 56.55$						

Source: Field Survey (2019)

In the wet season, WQI for the Pratu River was 56.55 which also falls within the fair water quality. It is seen that the quality is protected but occasionally threatened or impaired, conditions sometimes depart from desirable levels and hence also requires monitoring to prevent it from pollution since it empties into the Muni Lagoon. This WQI value was not surprising because a paper factory at Bewadze had it waste water channel drained into the river which in turn joins the sea. So all the waste products were emptied into the Pratu River and affected its QWI value, rendering it as fair water quality.

Table 8: Water quality index of the Ntakofa River in the wet season

S/N	Parameters	Observed values (V_n)	Standard Values (S_n)	Unit Weight (W_n)	K value	Quality rating (q_n)	W_nq_n
1	pH	7.7	6.5 – 9.0	0.1577	1.42	35	5.5195
2	Dissolved Oxygen	6.2	2mg/L or more	0.71	1.42	66.67	47.3357
3	Salinity	1.1	0.5 - 17 $^0/_{00}$	0.08352	1.42	6.471	0.540458
4	Conductivity	328.7	10 to 1000 mS/cm	0.00142	1.42	32.87	0.04668
5	Temperature	28.5	25℃-30℃.	0.04733	1.42	95	4.49635
6	Total Dissolved Solids	233.8	500 mg/L	0.00284	1.42	47.76	0.1357
				$\sum Wn = 1.00281$			$\sum q_n W_n = 58.074$
	WQI=$\sum q_n W_n / \sum Wn = 57.911$						

Source: Field Survey (2019)

The Ntakofa River also requires monitoring as it was within the fair water quality and its WQI value was 57.916. This river is occasionally threatened or impaired, conditions sometimes depart from desirable levels. This so because wastes from Klimovic Hospital, From Windy Lodge Hotel, Trauma Hospital as well as domestic wastes all enters the Ntakofa River. Moreover farming is extensively done along the course of the river and the waste and chemicals from these farmers affect the river especially in the wet season when farming is highly intense.

Table 9: Water quality index of the Muni lagoon in the dry season

S/N	Parameters	Observed values (V_n)	Standard Values (S_n)	Unit Weight (W_n)	K value	Quality rating (q_n)	W_nq_n
1	pH	8.1	6.5 – 9.0	0.1577	1.42	55	8.6735
2	Dissolved Oxygen	9.9	2mg/L or more	0.71	1.42	37.30158	26.48412
3	Salinity	8.6	0.5 - 17 $^0/_{00}$	0.08352	1.42	50.59	4.22532

4	Conductivity	17.2	10 to 1000 mS/cm	0.00142	1.42	1.72	0.002442
5	Temperature	31.0	25℃-30℃.	0.04733	1.42	103.33	4.8908
6	Total Dissolved Solids	10	500 mg/L	0.00284	1.42	2	0.00568
				$\sum Wn$ =1.00281			$\sum q_n W_n$ =44.2818
	WQI=$\sum q_n W_n / \sum W_n$ = 44.1578						

Source: Field Survey (2020)

In the dry season, there were relatively significant change with respect to the WQI values of the three water bodies. The WQI for the Muni lagoon was 44.1578, which was quiet encouraging regarding its status of pollution. The WQI value for the Muni Lagoon was within the range of 26-50, which is good water quality. This means that, the water quality is protected with minor degree of threat or impairment conditions rarely depart from desirable levels. In the dry season, discharge into the Pratu and the Ntakofa into the Muni Lagoon were drastically reduced as there were no rains and runoff to carry more pollutants and dispose them off into the lagoon. This made its WQI value of 58.33 in the wet season falling within the fair water quality to drop to a WQI value of 44.1578 which is within the good water quality in the dry season.

Table 10: Water quality index of the Pratu River in the dry season

S/N	Parameters	Observed values (V_n)	Standard Values (S_n)	Unit Weight (W_n)	K value	Quality rating (q_n)	W_nq_n
1	pH	8.2	6.5 – 9.0	0.1577	1.42	60	9.462
2	Dissolved Oxygen	13.6	2mg/L or more	0.71	1.42	7.94	5.6374
3	Salinity	8.3	0.5 - 17 $^0/_{00}$	0.08352	1.42	48.824	4.07778
4	Conductivity	17.3	10 to 1000 mS/cm	0.00142	1.42	1.73	0.0024566
5	Temperature	32.3	25℃-30℃.	0.04733	1.42	107.67	5.09586
6	Total Dissolved Solids	10	500 mg/L	0.00284	1.42	2	0.00568

				$\sum Wn$ =1.00281			$\sum q_n W_n$ =24.2812

WQI=$\sum q_n W_n / \sum W_n$ =24.2131

Source: Field Survey (2020)

The Pratu River however recorded a WQI value of 24.2131 in the dry season which is an indicator of an excellent water quality. As discharge, runoff, waste deposition were reduced, the river was able to regain its quality. There virtual absence of threat or impairment .All measurements are within objectives during this period. This could be as a result of drastic measures taken by the Wildlife Division of the Forestry Commission to order the Paper Factory at Bewadze to disconnect their waste channels from emptying into the Pratu River, which in turn enters the Muni lagoon. This yielded a positive result. Moreover farming or any other anthropogenic activity was very low during the dry season along the Pratu River.

Table 11: Water quality index of the Ntakofa River in the dry season

S/N	Parameters	Observed values (V_n)	Standard Values (S_n)	Unit Weight (W_n)	K value	Quality rating (q_n)	$W_n q_n$
1	pH	7.8	6.5 – 9.0	0.1577	1.42	40	6.308
2	Dissolved Oxygen	8.3	2mg/L or more	0.71	1.42	50	35.5
3	Salinity	3.6	0.5 - 17 $^0/_{00}$	0.08352	1.42	21.1765	1.7686612
4	Conductivity	366.6	10 to 1000 mS/cm	0.00142	1.42	36.66	0.052057
5	Temperature	31.7	25℃-30℃.	0.04733	1.42	105.667	5.001203
6	Total Dissolved Solids	259.5	500 mg/L	0.00284	1.42	51.9	0.147396
				$\sum Wn$ =1.00281			$\sum q_n W_n$ =48.7773

WQI=$\sum q_n W_n / \sum W_n$= 48.641

Source: Field Survey (2020)

The Ntakofa River in the dry season had a WQI value of 48.641, which was within the good water quality. This is as a result of no rainfall to carry most pollutants from other areas to mix with the Ntakofa. Farming activities were also very low along the stretch of the Ntakofa River in the dry season and this could be the reason for its WQI value.

Table 12: WQI for both seasons

Water bodies	Wet season WQI	Water quality status	Water quality description
Muni Lagoon	58.33	Fair water quality	Water quality is protected but occasionally threatened or impaired, conditions sometimes depart from desirable levels.
Pratu River	56.55	Fair water quality	
Ntakofa River	57.916	Fair water quality	
	Dry Season WQI		
Muni Lagoon	44.1578	Good water quality	Water quality is protected with minor degree of threat or impairment conditions rarely depart from desirable levels.
Pratu River	24.2131	Excellent water quality	Water quality is protected with a virtual absence of threat or impairment .All measurements are within objectives virtually of all the time
Ntakofa River	48.641	Good water quality	Water quality is protected with minor degree of threat or impairment conditions rarely depart from desirable levels.

Source: Field Survey (2019 & 2020)

Generally the WQI values for the three water bodies in the Muni catchment can be said to vary with the seasons. This was as a result of the differences in the level of activities that go on in the Muni catchment during the wet and dry seasons. In the wet season, more pollutants are carried from domestic, agricultural to industrial to the various water bodies which in turn empty into the Muni lagoon. All these pollutants change the water quality of

the Muni catchment which in turn affect biodiversity. However these activities are very limited in the dry season and hence the results. This is because in the dry season, most small rivers that feed the Pratu like the Muni river and the Boaku river dry out. These two rivers feed the Pratu river which also feed the Muni lagoon. Moreover farming is greatly reduced along the stretch of these two freshwaters because of less rainfall and less freshwater for irrigational farming. There is also less runoff into the Muni catchment. All these and many other factors play a role in the WQI values in the dry seasons.

CHAPTER FIVE

IMPLICATIONS OF POLLUTION AND MANAGEMENT STRATEGIES ON MUNI LAGOON AND ITS CATCHMENT

Introduction

This chapter was devoted to discussing the implications of pollution on the life forms and on socio-economic life within the Muni catchment. It also discussed the management strategies that are effective in sustaining the Muni Lagoon and its catchment.

Implications of pollution on ecological functions of the Muni catchment

The pollution emanating mostly from human activities possess serious threat to biodiversity or life forms within the catchment. The farming, encroachment for buildings, fuelwood harvesting, overfishing and indiscriminate waste deposition have caused the depth of the lagoon to reduce due to siltation. It has also caused the size of the lagoon to reduce which has increased floods event in the area. There have been loss of wildlife habitat through encroachment since people clear the area for developmental projects.

In order to understand the ecological impact of pollution, an interview was conducted and the findings did not deviate from what was found in the literature. It was revealed that all the participants in one way or the other has gone fishing in the muni lagoon before and further revealed that, they usually get blackchin tilapia, crabs, shrimps which they sell to make income and to consume some at home. However some participants made claims pertaining to their fish catch. A participant stated that:

> *"Indeed we do get fish from the Muni lagoon and its catchment but the quantity of our fish catch has reduced drastically due to the rate at which people dispose of refuse into the lagoon. Moreover most of these aquatic animals consume some of the plastics being dumped into the lagoon, so when they take it, it kills them eventually. Again some people illegally*

use unprescribed nets called the drag nets to fish which scoop both the adults and fingerlings. Because of this sometimes we get poor catch"

Confirming the reduction in fish catch, one of the participants from the Wildlife Division of the Forestry Commission reiterated that:

"As for the quantity of fish catch, it has greatly reduced. Comparing this to the time I came and even comparing previous data and this current data we have, it is glaring that the quantity of fish catch has greatly reduced."

Though the Wildlife Division or the Fisheries department did not have any quantitative data of fish catch from the Muni lagoon to back this claim. This was as because the inhabitants catch the fish and urgently sell them on the field or use for food. No data is also recorded since most of the fishermen cannot read and write. It was therefore made clear that, they rely on their frequent fish observation at the site and most importantly the frequent reports from the fishermen. This findings confirms Pandey (1997) assertion that, within mild pollution, fish acquire a flavour that renders their flesh unfit for uses as food; whereas with more severe contamination; the fish sickens or die. This will eventually reduce the quantity of fish catch thereby having a greater effect on the local people and the world at large. During the wet season the water quality index for the lagoon was 58.33 which falls within the fair water quality group of 51-75. This means that the Muni lagoon is under some sort of pressure and deposition from run off from the urban centers, and hence renders the lagoon and fair. If one species disappears, the whole food web is endangered, which could lead to the loss of an entire ecosystem over time. For this reason, protecting wetland habitats is essential for maintaining biodiversity. Another respondent who has lived in the area for more than 45 years had this to say:

"I fish in the Muni lagoon and its catchment. It is true that I get fish like tilapia which is the most dominant one, crabs and shrimps. I sell some

of the catch for money and use some to feed my family. However the quantity of fish catch has gone down over the years. At first we get plenty of catch but now it has reduced a lot and has affected us greatly. This is because these days we get few catch that is very difficult to feed the family let alone to sell some".

This confirms what the UK Essays, (2018), asserted, that, bbiodiversity loss has a negative impact on our societies; it negatively affects or contributes to the health of individuals, the climate, natural resources, pollution, poverty and the extinction of species.

A loss in biodiversity can have vast adverse effects on our food production. Since we nowadays exploit many natural living spaces to an unhealthy degree, chances are that we lose many food sources which we could otherwise use in the future. According to Managing Ghana's wetlands: A National Conservation Strategy 1999). Wetland loss leads to Loss of wildlife habitat as many wetlands are silted leading to a reduction is size and depth of wetlands.

In an interview, one participant stated that:

"It is true some people living close to the lagoon dump refuse at the banks of the lagoon. The reason for doing this is to prevent the seasonal flooding in those areas. Sometimes when it rains heavily, the lagoon overflow it banks and move to people's houses. We have no mechanism to check it, so we dump the refuse to serve as a barrier to prevent the water from entering our houses. But little did we know that the lagoon can carry all these waste into its basin and some aquatic organisms mistake the plastic waste as food. These things have caused the lagoon to be silted, most of the fish catch are very small in size compared to the previous years. The size and depth of the lagoon has reduced due to the rate at which refuse are dumped into the lagoon."

Plate 2 :Some fish catch from the Muni

Source: Field Survey (2020)

This was however confirmed by the Wildlife Division that the continuous pollution has resulted in siltation of the lagoon and needs to be dredged.

In the interview it was asked if participant could identify a specie that has gone extinct or that has been introduced as a result of the pollution. It was also revealed by most of the participants that, no specific fish, birds or tree species has gone extinct and they have not identified any new fish, birds or tree species either just that their numbers have reduced.

Table 13: Total bird data of Muni Pomadze Ramsar site.

Birds (common name)	**Period/Year**	**Total population**	Authors
Waders	1986-1998	5,604	Ntiamoa-Baidu, Nyame & Nuoh, (2000)
Terns/Gulls		21,175	
Herons/Egret/Others		444	
Waders	2009-2010	1,443	Abdourahamane (2010)
Terns/Gulls		167	
Herons/Egret/Others		1,610	

Waders		446	
Terns/Gulls	2013	334	
Herons/Egret/Others		299	
Waders		518	
Terns/Gulls	2014	428	
Herons/Egret/Others		208	
Waders		440	
Terns/Gulls	2015	327	
Herons/Egret/Others		199	Effutu Wildlife Division (2019)
Waders		546	
Terns/Gulls	2016	250	
Herons/Egret/Others		233	
Waders		304	
Terns/Gulls	2017	97	
Herons/Egret/Others		279	
Waders		173	
Terns/Gulls	2018	82	
Herons/Egret/Others		495	

Source : Ntiamoa-Baidu, Nyame & Nuoh, (2000) ; Abdourahamane (2010) ; Effutu Wildlife Division (2019).

The responses from all the participants were that their numbers have greatly reduced especially the birds and fish population. Confirming this, the 1986 -1998 bird data from Ntiamoa-Baidu, Nyame & Nuoh, (2000), the 2009 – 2010 data from Abdourahamane (2010) and 2013 – 2018 data from Wildlife Division of the Forestry Commission shows a decline in numbers of bird species to the Muni- Pomadze Ramsar site. Table 14 above shows the trends in total bird data from 1986 – 1992, 2009 – 2010 and 2013 – 2018. The changes in bird population on the Muni-Pomadze Ramsar site may be due to the habitat destruction that have occurred the Ramsar site. The high levels of siltation and sedimentation due to pollution, encroachment, bushfires etc may have caused these dwindling numbers of birds population to the site as more waterbirds to a particular Ramsar

sites may serve as a bioindicator to water quality. It might also be that, these waterbirds have found a more favourable and efficient wetlands to the Muni-Pomadze Ramsar site.

Another participant from the Wildlife Division of the Forestry Commission had this to say:

> *"no fish, plant or birds species I know of have gone extinct, but the only thing is when the lagoon is disconnected from the sea by the sand bar, they usually do not get a variety of fish but when it is open to join the sea, we get their regular fish type they usually catch"*

Another participant stated they have not seen any bird go extinct. The participant had this to say:

> *"The number of birds that usually come here have reduced compared to the previous years. The birds do come in relation to the seasons. Some come to lay their eggs especially in the dry seasons. Their numbers have reduced because most of the roosting places for the birds have been cleared and either used as a farmlands or built-up."*

From the Wildlife Division of the Forestry Commission, a participant stated that:

> *"Pollution has affected birds and fish distribution and population a lot because there is no habitat. The mangroves have died out and the first do not have a place to spawn, birds do not also get habitat to nest. People also try to kill them and this scares them a lot, so the birds fly away to look for a more conducive place. Moreover, since the lagoon was closed for about 4 years, the only fish that was common was Tilapia but when it was open in 2019, variety of fish move from the sea to join the lagoon."*

This is more evident in table 14. On the issue of plant species that have either been introduced or have gone extinct, the responses from the participants were similar as most of them stated no plant they know of has gone extinct, just that their numbers have reduced due to our action and partly on pollution. A participant had this to support that claim:

> *"Most of the trees here were mangrove (white and red) and what the wildlife usually plant here doesn't thrive. They plant the red mangroves*

here which needs a mixture of both fresh and salt water but the white thrives well here. So when the lagoon is cut off from the sea, the red begin to die and moreover people also harvest the little ones for fuel wood. Moreover the quantity of fish catch has reduced because, most fish usually spawn on the roots of the mangroves, grass and weeds that grow in and around the Muni catchment. However these mangroves been cleared so the fish do not necessarily get a place to spawn and this has resulted in their limited numbers"

One participant from the division reiterated:

"The plants or mangroves have reduced or died out because the lagoon was closed for 4 years or more. This made the lagoon looked like fresh water due to the inflow of fresh water from the Ntakofa and Pratu rivers. Moreover, the red mangroves needs a mixture of fresh and salty water and hence a conducive environment for it is brackish water, so when the lagoon was closed for a long period, it literally tuned to a fresh water. But the white mangrove needs salty water. This and other human activities are some of the reasons why the mangroves don't thrive."

All these findings proves that indeed there have been negative changes to the biodiversity of the Muni catchment. These findings are therefore in conformity with a study conducted by Abdourahamane (2010) that found out that, habitat alterations have occurred at the Muni lagoon and its catchment which have led to the deterioration of its ecological character.

Plate 3 A: Mangroves
Source: Boanu, (2017)

Plate 3 B: Mangroves
Source: Field data, (2020)

Plate 3(A & B): Mangroves at the Muni lagoon
Source: Field Survey (2020)

Implications of pollution on socio-economic functions of the Muni catchment

Another section of the interview focused on how pollution or the changing regime of the Muni lagoon and its catchment has affected their social and economic life. Most of the participants stated that, the changes has affected them because sometimes they do not get enough catch so that they sell to make money. One participant had this to say:

> "*The lagoon mostly over flow its banks and floods a lot of homes or houses very close. This usually happens because there is more silt in the lagoon due to the inflow and dumping of refuse which has reduced the depth of the lagoon. The lagoon therefore needs to be desilted or dredged. Sometimes too when it floods people had to be contacted to create and artificial channel to link the lagoon and the sea when the channel closes. This practice helps to reduce flooding".*

This confirms what Managing Ghana's wetlands: A National Conservation Strategy (1999) asserted, that, if a wetland is modified or degraded, then the water that would usually utilise this wetland has nowhere to go and will consequently move into areas it would not otherwise have done. This is likely to result in an increased occurrence of floods, as well as soil erosion.

According to Ntambirweki, (1998), dumping of wastes into lagoons claim land and fill waterlogged areas, especially in towns and settlements that lack proper waste management practices. Moreover, development activities that cause infilling or draining of wetlands e.g., building of roads, ports and houses and farming. These activities could greatly affect the depth, size or area of wetlands.

Another participant from one of the deer hunt (Asafo) groups who has stayed in the community for more than 45 years stated that:

> *"The farming activities and clearing of the area coupled with pollution has driven most of the wild animals away. There were some species of monkeys in the Yenku forest but these days we hardly see*

them because they have been driven far into the forest. Some have even moved. One of the greatest impact is that most of the catchment areas have been cleared for either agriculture or built up. This attitude has driven the deer farther away from us, so sometimes we find it difficult to get the animal for our festival. This really hurt us a lot"

Confirming this, Managing Ghana's wetlands: A National Conservation Strategy (1999), affirms that wetland loss leads to loss of wildlife habitat. Removing the wetland directly removes the plants or animals that once existed in the wetland ecosystem.

Some of the participants stated that pollution and biodiversity change has resulted in low turnout visits to the lagoon site. One of them stated that:

"Though some people come to visit the lagoon and watch the scenery, but the turnout compared to the previous years have gone down drastically. Sometimes some student from outside Ghana and some from the University of Education come here to learn about the lagoon. It is not a regular visit"

The Wildlife Division also had this to say:

"People from various universities come here to do research. Almost every year students from different universities come, though not in groups but individually, they visit."

From this it is evident that the implication of pollution and biodiversity change does not only affect the life of organisms in the catchment, but also has a resultant effect on the socio-economic life of the people that depend on the Muni lagoon and its catchment. It is therefore clear that, all activities in an ecosystems are interlinked. It is like a domino effect and when one cause is initiated, it affects all other processes in an ecosystem.

Effectiveness of management strategies in maintaining the Muni Pomadze Ramsar site and its catchment

According to Zentner, (1988), management is the manipulation of an ecosystem to ensure maintenance of all functions and characteristics of the specific wetland type. The loss or impairment of a wetland ecosystem is usually accompanied by irreversible loss in both the valuable environmental functions and amenities important to the society. A wetland management program generally involves activities to protect, restore, manipulate, and provide for functions and values emphasizing both quality and acreage by advocating their sustainable usage (Walters, 1986). Management of wetland ecosystems require intense monitoring and increased interaction and co-operation among various agencies such as state departments concerned with the environment, soil, agriculture, forestry, urban planning and development, natural resource management; public interest groups; citizen's groups; research institutions; and policy makers. All these would help in understanding wetlands better and evolve a more comprehensive and long-term conservation and management strategies.

For this, an interview was conducted and the responses showed that there were some form of education from all parties. The participants from the communities were aware that there were some regulations and management strategies to protecting the Muni lagoon and its catchment area. Most of the participants mentioned that the laws to protect the muni lagoon and it catchment include; Taboos, use of drag net is an offense, education, sand winning is prohibited, etc. The responses from the participants from the Wildlife Division of the Forestry Commission indicated that there were or are a lot of effective management strategies to ensuring that the Muni lagoon and its catchment is protected. One participant from the Wildlife Division stated that:

> *"Yes we have what we call community participation, No logging, Providing dust bins, prevention of unapproved fishing gears, providing education, A Rocha also comes in to provide alternative livelihoods for the people and also Outreach programs. Sometimes the Environmental Protection Agency also comes in to help. So these are some of the management strategies the Wildlife Division together with some NGOs provide. We also work with other stakeholders like the chiefs, universities (local and international), Municipal assembly etc."*

Ethiopia Wetlands and Natural Resources Association (EWNRA, 2008), is of the view that, building partnerships with stakeholders to some extent help prevent the degradation. These partnerships could come from the Government agencies, NGO's or Community collaboration. The joint collaborative work among the concerned institutions and stakeholders is extremely vital in coming up with robust and holistic wetland management approach that supports a more natural, healthy ecosystem, one which is cost-efficient and secure - for people, businesses and wildlife.

In an interview, it was asked that if the Wildlife Division of the forestry department and any other stakeholder comes check and monitor the lagoon and to provide education to them,

One participant from one of the communities reiterated:

> *"Yes, they do come here to give education of dos and don'ts. The wildlife usually come to educate us to prevent us from dumping into the lagoon. The division doesn't come here often but at least every month they come"*

Another participant also stated that:

> *"No community based group or NGOs come here to give education, but sometimes the Wildlife Division come here to announce with a megaphone what they want and what they don't want.*

Sometimes they come 2 or 3 days continuous or sometimes a month"

On the issue of how effective this management practices has or would be, the participants were asked what they have been doing to make it very effective. Most of the participant stated that they are not doing anything because they have not been involved in the management processes and practices.

One of them stated that:

> *"For me, I'm not doing anything because they don't involve us. We stay very close to the lagoon and we are the best people to protect it but the sad news is they involve those in town who in turn flout the rules and fish or do bad things to the lagoon. So we also sit here and watch. If they want it to be very effective, they should involve us. "*

However one participant from the Wildlife Division had this to say:

> *"I don't know with which angle he/she was speaking from, but the truth is we involve them because the people know the benefit they get from the Lagoon so when we involve them, they will protect it. So we the Wildlife Division call it Community Collaboration and it I one of the most effective strategies. This because now the people are calling on us to come and plant the mangroves again, they also call to report people who flout the rules and regulations and if they see anything going wrong, we are the first people they contact."*

Another participant from the division also added that:

> *"To make it more effective, we go to schools, communities and radio stations and information centres to give out education. For schools and communities, we usually arrange with the authorities to fix a date for at least ones every two or three months. We are not able to go on regular basis because the division is in charge of Winneba, Apam, Bereku and Swedru and we have limited resources that sometimes prevents us from reaching our targets, but for the radio programs, we do it on regular basis every Wednesday on radio windy bay."*

This confirms what Eshete (2008) suggested. The people need to be educated on how important a preservation of wetland's biodiversity is for the planet as well as for humanity. Many people are so stressed from their jobs or their social lives that they are not even aware what a loss in biodiversity really means. This education on biodiversity should start quite early, probably in the early school age, so that children are already of this issue quite early and can adapt their behaviour into adulthood.

Apart from these activities carried out by the Wildlife Division, it was revealed that, they do carry out Outreach programs where megaphones are mounted to a Vehicle and be moving around to announce what they want and what they don't want in the various communities.

Further on how to assess the effectiveness of management strategies,

One participant also stated that:

> *"For us what we usually do is to observe Wednesday as a sacred day and sometimes give a maximum of 3 months before we go fishing. This long period will help the lagoon to regain and recover from the stresses".*

To make the management strategies more effective, the Wildlife Division of the Forestry Commission suggested that,

> *"Government agencies, Town and Country planning, Chiefs and any other stakeholder should work together to stop the illegal selling of wetlands and see that the lands belongs to the Government. Also the police and other law enforcement agencies should work together to prosecute defaulters of the laws on wetlands. It is only through this that our management systems and coordination will be successful."*

Another participant added that:

> *"There should be the redemarcation of these wetlands with stricter rules and regulations to deter people."*

Table 14: Summary of roles and effectiveness of various organizations

Institutional Organization	Roles/ Management Strategies						Effectiveness
	Intensive public education	Outreach Programmes	Community collaboration	Bye-laws	Desilting and Dredging	Research	
Wildlife Division	Routine education is done every Wednesday on radio Windy-Bay	Outreach program is carried out 2 - 3 months	The Division collaborate with the community towards management processes, especially towards the planting of mangroves	The Division has laws from National to community level to managing wetlands (laws prohibiting illegal fishing and fishing gear, illegal entry etc.)	No	The Division conducts routine research on water quality and bird count every Month	The activities of the Wildlife Division from their strategies are very effective except for the dredging. This has indeed yielded a positive result towards maintenance and sustaining the lagoon
Municipal Assembly (Town and Country Planning)	No intensive public education is given on the wetland management but rather, they do not give permit to people who want to acquire land close to the lagoon	They do not go on outreach programs towards maintaining the lagoon but sometimes render help the Wildlife Division in terms of resources	No serious collaborations takes place but only does not give permit to build close to the core and management zones	Since the area is not part of the developmental areas, permits are not given out to build. Mandate the Wildlife Division to demolish buildings	No	No, because everything is done by the Wildlife Division	Everything is wielded to the hands of the Wildlife Division. So they are not effective toward the management process. Not very effective

Universities (Local,International)	No intensive Public education is carried out	No outreach programs is carried out.	No	No	No	Research is conducted by both local UEW, UCC, UG) and International (UVA, TU Delft) to know the state of the Lagoon for further management strategies.	In the aspect of conducting research, they very effective.
Traditional Leaders	No intensive public education is given except on issues pertaining to the sacred days and taboos.	No outreach programs are carried out by the Traditional leaders.	Works with community when the need arises. It is not routine	Have taboos and sacred days used to protect the lagoon	No	No	Their bye laws are very effective, but apart from that all other things are left in the hand of Wildlife Division.
NGO's	Give education on sustainability of the lagoon and also provide alternative livelihoods	Outreach programs are carried out to educate people on new livelihood programs such are rearing of	Collaborate with communities from time to time on maintaining the Lagoon	No bye laws but rather works within the confines of the National and local laws for wetland management	No	Conduct research to know how the alternative livelihood rolled out is helping to	The NGOs especially A Rocha have been very effective towards maintaining the lagoon by providing the needed help and alternative livelihoods

			snails, glasscutter etc by A Rocha.				maintain the lagoon	
Non - Institutional Organization	Community leaders, Individuals and the general community	No education but rather make sure people obey and listen to the education that have been given.	No outreach programes	Sometimes works with the Wildlife Division to address issues on illegal fishing gears, help in planting of mangroves, etc.	Do not in their own have bye-laws but rather, adhere to those laws propounded by the traditional authorities and the Wildlife division.	No	No	The communities are effective to some extent.i.e. Obeying the sacred days and taboos. Apart from this, all other works and management issues are re left in the hands of the Wildlife Division.

Source : Field Survey (2020)

From the Table 12, it can be concluded that, the most effective or principal agent in terms of sustaining and managing the Muni lagoon is the Wildlife Division. Their activities have been fruitful towards conserving the Muni lagoon and it's Catchment. The NGOs, especially A Rocha has also been very supportive as confirmed by the Wildlife Division. Their support in providing alternative livelihoods has helped halted some pressures which otherwise would have been meted on the lagoon. Every wetland has three basic zones (Core, Management and Outer Zones). The core zone mostly, no activity is allowed to take place there. It is highly protected and prohibited. In the management zone however, some activities are allowed to take place but to some extent. In the Outer zone, all forms and sort of activity can take place there without any restrictions. The Muni Lagoon has these zones but people illegally encroach these areas and hence move as far towards the core zone. Therefore a consensus needs to be built and serious redemarcation exercises must take place. This will help revive the Muni lagoon and its catchment as well as help observe these zones.

All other institutional and non-institutional organizations however have not been all that active per the roles measured against, though some are active in some aspects. As it is seen, collaborative works from these organizations are very weak.

So from the discussions, it is quite clear that humans' activities infringe upon the smooth functioning of wetlands thereby changing or modifying the waters and biodiversity within a said environment. This modifications affects the life in the water body and around it. Confirming from the theory of Driver- Pressure- State- Impact- Response by, the European Environment Agency (EEA, 1998) and the adapted conceptual framework, it clear that humans do have needs they need to satisfy as confirmed in the study. That is the need for food, shelter etc. put stress on the resources. In the case of the Muni lagoon and its catchments, people living in that area do not have

specific alternative livelihoods to sustain them permanently. So they continuously resort to the lagoon for food which affect it due to the rate and type of gears used for fishing. In meeting a need, these human activities exert 'pressures' on the environment, as a result of production or consumption processes. (emissions, waste) to ‘states’, As a result of pressures, the ‘state’ of the environment is affected; that is, the quality of the various environmental compartments (air, water, soil, etc.) in relation to the functions that these compartments fulfil. this was confirmed by the Wildlife Division and the participants from the community that, the mangroves have died out, small fish size, the quantity of fish catch has reduced, birds population reduced, etc. the calculation of the water quality index also showed that the water quality has been altered due some chemicals from Ninsen paper factory to the Pratu river which in turn empties in the lagoon.

Other pollutants from the Ntakofa River also enters the lagoon. All these stressors affect the state of the water. So the physical, chemical and biological conditions are affected and this affects the quality of ecosystems and the welfare of human beings which will eventually lead to ‘response’ by society or policy makers as a result of an undesired impact and can affect any part of the chain. From the conceptual framework, whenever there is more biodiversity, it means better water quality and less pollution. From the results, WQI varies with seasons, so it means that the water is affected by human activities as confirmed in the study by Tay, Ashma and Biney, (2010) that the Muni lagoon is fairly polluted and hence needs continues monitoring to prevent further deterioration. The Wildlife Division also confirmed that in their preliminary study of the lagoon with the help of students from University of Education, University of Virginia (UVA, USA) and TU Delft (Netherland) all in 2019 indicated some mild pollution due to the continuous dumping of plastics and other wastes.

These activities coupled with continuous pollution from chemicals from Ninsen Paper factory changes in the water quality and affect the biodiversity in and around the lagoon. There is therefore the need for management strategies to curb it which in this case is the response. These response come from the Wildlife Division, NGO's and Community participation. As confirmed in the results, the Wildlife Division gives routine education on radio stations every Wednesday, outreach programs, and community dialogues to create awareness and to sensitize the people of the dos and don'ts in wetlands. Communities try as much as possible to observe the sacred day (Wednesday) and sometimes give 3 months period not to go to the lagoon. This they believe could make the lagoon recover from the stressors mounted on it. All these things strategies are put in place to solve the water quality problems, pollution and the dwindling of species in the Muni catchment. From the theory and the conceptual framework, the responses initiated in time cater for the life in the and around the muni catchment. So when all these measure are in place, it means there is going to be a better water quality with less pollution and more biodiversity.

Table 15: DPSIR applied within the Muni catchment

Driver (Human Activities)	Pressure	State	Impact	Response
Pollution • *Domestic* • *Industrial* • *agricultural*	The increase in the magnitude of domestic, industrial and agricultural wastes. Domestic wastes from household, hospitals, Hotels and Hostels. Industrial waste from Ninsen Paper factory. Waste from chemicals (pesticides, herbicides, etc) within the Muni catchment.	Change in values of parameters, contamination with physical pollutant, decrease in biodiversity	Altered water quality unstable Water Quality index (WQI), Damage to biodiversity.	Routine education on radio stations Outreach programs Community dialogues to create awareness Zoning and Redemarcation Regular research
Urban development	Increase in population leads to wetland reclamation for houses, shops and structures as well as the need for food.	Change in values of parameters, contamination with physical pollutant, decrease in biodiversity, reduction in size of the lagoon	Altered water quality and Water Quality index (WQI), Damage to biodiversity	Routine education on radio stations Outreach programs Community dialogues to create awareness Zoning and Redemarcation

Adapted from DPSIR framework (1998)
Source: Field Survey (2020)

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter is devoted to the summary of the study findings, conclusions that were drawn and recommendations that were made with areas for further research.

Summary

This study sought to investigate the water pollution and biodiversity change of the muni-Pomadze lagoon and its catchment in Winneba, Ghana. Purposive sampling technique was used to select fifteen (15) participants from the communities and the Wildlife Division of the Forestry Commission to participate in the study. These fifteen (15) participants were purposively selected because they had expert knowledge of the study area. Content analysis were also done to validate and authenticate the responses that were obtained from the field. The research instruments that were used for the study were unstructured interview guide, field observations, content analysis, field measurements in-situ, as well as photographs taken on the field. In all six(6) parameters were checked. A multi- parametric device called PC60 Premium Multi-Parameter Tester was used to test for pH, conductivity, salinity, temperature and total dissolved solids (TDS). dissolved oxygen Meter Kit 850081DOK was used to test for Dissolved Oxygen (DO).

Key findings of the study

1. The characteristics and nature of the Muni lagoon and its catchment areas in terms of its physic-chemicals parameters, exhibited changes due to their distribution and with respect to the seasons. The seasonal changes and breaching of the sand bar had a role to play in

regulating the behaviour of the parameters. The water quality analysis results obtained showed a significant difference and high average values concentration in the dry season compared to the rainy season. It showed that only pH exhibited almost sameness of values in both seasons. The more reason most studies have classified the Muni lagoon as being alkaline in nature. The salinity levels were very much high during the dry season compared to the rainy season. This was due to the access of the Muni catchment to the sea in the dry season compared to the rainy season which had no access to the sea. It was revealed that, TDS value of 3.5 mg/L for both Pratu and the Muni lagoon rose to 10.0 mg/L in the dry season with the Ntakofa having 233.8 mg/L to 259.5 mg/L in the dry season. This high value was recorded because the Ntakofa runs through dense populated areas and hence receives uncontrolled discharge from domestic and agricultural waste. It was also revealed that most of the high values for the parameters were within the threshold provided by USEPA, WHO etc. These high values recorded in the dry season could be as a result of difference in precipitation and evaporation as well as the link of the sea to the Muni catchment.

2. The study revealed that, there are a lot of factors that affect the status and nature of lagoons. The quality, status, and pollution levels were dependent on the seasons and the water quality index in the study area. The results showed that in the study area, water quality index was highly dependent on the seasons and anthropogenic activities as its index values were high in the rainy season than the dry season. The WQI for the three water bodies in the Muni catchment exhibited different index level values with descriptions ranging from fairly-good to good and to excellent in relation to the season. The water quality index of 58.33, 56.55, 57.92 for the Muni lagoon, Pratu and Ntakofa Rivers respectively for the rainy season were all of fair water quality. This means water quality is protected but

occasionally threatened or impaired and conditions sometimes depart from desirable levels. It was revealed in the dry season the WQI values changed significantly. The values were 44.16, 24.21 and 48.64 for Muni lagoon, Pratu and Ntakofa Rivers respectively for the dry season. These index values classified as. It was revealed the Muni lagoon and the Ntakofa River were good water quality due to their index values, hence it means the water quality is protected with minor degree of threat or impairment conditions rarely depart from desirable levels. However the Pratu River exhibited an excellent water quality. This change could be due to the Wildlife Division's action and caution against the Ninsen Paper factory to disconnect their channels from emptying into the Pratu River. This was the more reason why the WQI for the Muni catchment in the dry season changed.

3. The study also revealed that, fish is indeed derived from the lagoon but the quantity and size of fish have reduced drastically over the years. This could be due to the improper fishing gear such as drag nets used and also due to the closure of the lagoon from the sea by the sandbar. The study also revealed that, the rubbish being dumped into the lagoon and its catchment, and the spillage from the paper industry have resulted in changes in the water quality which affected its quality index. It was also revealed in the study by the Wildlife Division that, no new species of fish have been found and none has gone extinct, though the most dominant one is tilapia which is more resistant to the conditions that pertain in the study area. The study further revealed that, no tree or bird species has gone extinct and no new ones have been discovered, just that their numbers have reduced and the mangroves have died out. This was due to the long closure of the sea from the lagoon. This literally the turned the lagoon into a fresh water but mangroves need brackish water. The findings showed that the inhabitants of Akosua village are faced with frequent floods resulting from continuous deposition of refuse into the lagoon which has resulted in the silting of the

lagoon. Lastly it was discovered that, the quantity of fish catch has reduced and this greatly affect their economic lives as income levels have greatly dwindle.

4. The study again found out that, there were a lot of effective management systems that are already in place to care for the Muni lagoon and its catchment. Some of the management strategies revealed were, collaborative community participation, intensive education in schools and communities, laws banning unapproved fishing gears, laws banning logging, Wednesday radio presentations and outreach programs. It was revealed that these programs are carried out on routine basis to ensure its effectiveness though there are limited resources. A ROCHA being NGO too was known to be involved in the management and educating the public on the need to maintain and sustain the lagoon as well as providing alternative livelihoods.

Conclusion

Based on the findings of the study, the following conclusions could be drawn.

1. The water quality parameters analyzed did not exceed the threshold provided by the USEPA and WHO. However the closure and breaching of the sea to the lagoon and its catchment had a great effects on the results obtained during the period of study. Therefore it can be said that the values of the parameters and the health of the Muni lagoon and it catchment area are dependent on the sea to some extent. Though there were some slight changes and if not monitored will have a greater effect on biodiversity as experience now. The deteriorating status is a gradual process and could have a significant effects on flora and fauna within the Muni catchment some years to come if not monitored carefully.
2. It can be concluded that, though nature plays a role in influencing the nature of lagoons, but anthropogenic activities determined greatly the water quality index and status of

pollution in the study area. Human-induced factors that affected the Muni lagoon and its catchment were, pollution, farming activities, logging, encroachment, illegal fishing and fishing gear. These activities requires constant monitoring and effective collaborative management practices.

3. It can be said that, no fish, plant or birds species have gone extinct or new ones introduced in the Muni catchment but rather their numbers have reduced drastically to near extinction. This is due to constant bad practices meted on the lagoon and its catchment. The socio-economic life of people who depend on the Muni lagoon and it catchment are greatly affected due to frequent flooding, low fish catch and low turnout of visitors which could have generated some kind of revenue to mobilize their lives.
4. It can be said that, that though there are many effective management strategies that is carried out on timely basis but due to the inadequate resources at their disposal makes the work of the Wildlife Division a little bit difficult. So when bottom up approach to coastal management is integrated nationally, conservation and protection of lagoons would be reached. This therefore the cooperation and coordination between different agencies like (Wildlife Division of the Forestry Commission, the Town and country planning, the Community, Chiefs and various private organisations or NGOs such as A Rocha.) with varying interest will allow for management and development plans that reduces or eliminate conflicts.

Recommendations.

Based on the findings and conclusions of the study, the following recommendations could be made.

1. In view of the research findings, it is recommended that, there should be a thorough and continuous monthly water quality assessment of the Muni lagoon and its catchment in order to clearly ascertain the progress of pollution in the Muni catchment. This will help to make an informed and cogent decision on the right measures to adopt in conserving the quality of the Muni catchment. Moreover the lagoon should be opened to have access to the sea to ensure consistency of parameter results and create conditions to bring saltwater and fresh water together to help mangrove forest to grow. In this way a structure can be constructed to allow water from the lagoon to enter the Sea during high precipitation and water could also enter the lagoon during high tides. The closing and opening of the gates at either sides should correspond to the conditions that prevail in the sea and in the lagoon.
2. In a preliminary study conducted by the University of Education (Ghana) University of Virginia (USA) and TU Delft (Netherland), where water quality was tested before and after reeds in some section of the lagoon, it was discovered that, the water before the reeds were highly polluted than after the reeds. Reeds serve as a natural filtration system and the results proved it. Therefore, it is recommended that, reeds be planted 30 meters wide and across areas that flow into the lagoon and its catchment. This will naturally filter the waters that passes through it before it enters the lagoon.
3. To reduce or eliminate the implications, it is recommended that, the management of the site should also be reinforced and accompanied by a habitat and biodiversity restoration program. The Muni lagoon and its catchment needs to be restored, especially with the prevailing reduction in species, pollution and silting, to prevent it from drying up completely in the very near future.
4. It is also recommended that, there should be collaborative and intensive governance model that would be called the Muni Pomadze Management Committee. This committee should

encompass the Wildlife Division of the Forestry Commission, Municipal Assembly, and University Researchers, The Local community, Traditional Chiefs and Private organizations that will come together to better plan and propose policies to maintain the lagoon. Also government agencies and traditional authorities should stop the illegal sale of vested land and regard it as such. In this way, coordination and management will be easy. If the anthropogenic activities are not curtailed in the Muni catchment, future threats could be endangered ecological systems mass urbanization, loss of livelihoods, loss of critical resource

Areas for further research.

The present study focused on water pollution and biodiversity change of the muni-Pomadze lagoon and its catchment in Winneba, Ghana. Further studies may be carried out to investigate the siltation of the Muni lagoon as a result of waste deposition, taking into consideration how waste deposition has affected the depth and size of the lagoon over the year using 1992 as a benchmark.

Again, since the most common fish species in the Muni catchment is the Blackchin tilapia (Sarotherodon melanotheron), and considering the rate at which their population is dwindling so fast, a reproductive biology of Sarotherodon melanotheron (Blackchin tilapia).could be studied in the Muni catchment. This will help understand their reproductive cycle, their specific breeding season and breeding interval. Though Trewavas, (1983).stated that, Blackchin tilapia spawn throughout the year, but the spawning and breeding interval may be location specific.

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APPENDIX

APPENDIX (A)

UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF SOCIAL SCIENCE EDUCATION

DEPARTMENT OF GEOGRAPHY EDUCATION

IN-DEPTH INTERVIEW GUIDES FOR SELECTED KEY INFORMANTS

Preamble

This interview guide is to seek relevant primary data for the conduct of academic exercise on the topic **''WATER POLLUTION AND BIODIVERSITY CHANGE OF THE MUNI-POMADZE LAGOON AND ITS CATCHMENT IN WINNEBA, GHANA"** towards the award of Master's degree in Geography Education from the Department of, GEOGRAHPY EDUCATION, UEW. Any information you will provide in this exercise is first and foremost for academic purpose and the information will be treated with much confidentiality and anonymity.

In-depth interview guide for the communities.

PART ONE: Implication of pollutants on the ecological and socio-economic functioning of the Muni catchment.

1. Do you fish in the Muni lagoon?
2. What type of fish do you usually catch?
3. What do you use the fish for? (Sell, home consumption, Both)
4. Has the quantity of fish catch increased or decreased compared to the previous years?
5. Have you identified any new fish species?
6. Have you identify any fish species that have gone extinct?
7. Do you see plenty of birds in the Muni catchment as compared to the previous years?
8. Have you identified any new birds' species in the Catchment?
9. Has any of the already existing birds' species gone extinct?
10. Do people visit the lagoon these days

PART TWO. Effective Management strategies

1. Do you know any management strategies, laws, regulations, taboos, etc that is/arer used to protect life in the Muni catchment?
2. What are they?
3. Are these management strategies are more effective?
4. Which of the ones mentioned are most effective?
5. How often do these management authorities come to check on the lagoon
6. Has there been any intensive education from the management authorities on factors that causes degradation, pollution, and loss of biodiversity?
7. What type of education and warning has been given?
8. Do you obey these measures that are put in place by the authorities?
9. What is the community doing to help maintain the lagoon?
10. In your view, what management strategies can be implemented to help protect the lagoon against pollution, degradation and biodiversity loss?

In-depth interview guide for the Wildlife Division of the Forestry Department

PART THREE: Implications of pollution and Management strategeies.

1. How has pollution affected biodiversity (birds, plants, Fish) in the Muni lagoon in terms of population and extinction?
2. Has the size of the lagoon rduced or increased?
3. Do you have any management strategies to protect the Muni catchment?
4. What are the types of management strategies do you have?
5. Which of the above mentioned strategies is/are more effective and why?
6. Do you give education to the people?
7. What type of education is usually rolled out?
8. How often do you educate the people or the community?
9. Do you involve the people in the management strategies?
10. What role do you assign to the communities towards protecting the Muni catchment?
11. What other measures can be put in place to make it more effective?

APPENDICE B

Wet Season Values

Water sample points	Latitude	Longitude	PH	D.O	Salinity	Conductivity	Temperature	T.D.S
WSP1	05.32585N	000.65396W	8.2	6.8	2.5	5	28.7	3.6
WSP2	05.32587N	000.65333W	8.1	7	2.5	4.9	28.2	3.5
WSP3	05.32671N	000.65304W	8.2	7.1	2.4	4.9	27.9	3.5
WSP4	05.32697N	000.65236W	8.2	7.2	2.5	5.03	28.05	3.6
WSP5	05.32674N	000.65181W	8.2	6.8	2.5	4.9	27.8	3.5
WSP6	05.32646N	000.65032W	8.2	6.8	2.4	4.8	27.7	3.4
WSP7	05.32687N	000.64986W	8.3	6.7	2.6	5.1	27.8	3.7
WSP8	05.32785N	000.65061W	8.3	7	2.4	4.8	28.9	3.5
WSP9	05.32831N	000.64983W	8.2	7	2.5	5.1	28.2	3.5
WSP10	05.32790N	000.64897W	8.2	7	2.5	5.1	28	3.6
WSP11	05.32713N	000.64811W	8.2	7.1	2.5	5	27.5	3.6
WSP12	05.32839N	000.64801W	8.2	6.9	2.5	4.9	28	3.5
WSP13	05.32962N	000.64751W	8.2	7.1	2.5	5	28.1	3.5
WSP14	05.32713N	000.64463W	8.3	7.2	2.5	5.1	28.2	3.6
WSP15	05.33082N	000.64461W	8.3	6.6	2.5	4.8	28	3.5
WSP16	05.33019N	000.64144W	8.3	6.9	2.5	5	28.1	3.5
WSP17	05.33107N	000.64180W	8.2	6.8	2.5	5.1	28.2	3.6
WSP18	05.33244N	000.64231W	8.3	7.2	2.6	5.2	27.8	3.7
WSP19	05.33461N	000.64240W	8.3	7.4	2.6	5.1	28	3.6
WSP20	05.33707N	000.64340W	8.2	6.9	2.5	4.9	27.5	3.5
WSP21	05.34086N	000.64695W	8.2	7.2	2.5	5	28.1	3.5
WSP22	05.34103N	000.64913W	8.1	7.2	2.5	5.04	28.1	3.7
WSP23	05.34127N	000.64973W	8.2	7.4	2.6	5.1	27.6	3.6
WSP24	05.34159N	000.65063W	8.2	7.2	2.6	5.1	27.4	3.6
WSP25	05.34228N	000.65182W	8.2	7.4	2.5	5.1	27.7	3.6
WSP26	05.34287N	000.65327W	8.1	7.2	2.5	5	27.2	3.5
WSP27	05.34337N	000.64591W	8.2	7.5	2.2	4.1	27.2	3.2
WSP28	05.34538N	000.64548W	8.3	7.7	2.3	4.6	27.1	3.2
WSP29	05.36181N	000.63934W	7.4	5.8	0.3	588.5	29.8	420
WSP30	05.36326N	000.63795W	7.2	5	0.3	593	29.5	419
WSP31	05.36656N	000.63686W	7.4	5.2	0.23	453.5	28.7	323.5
WSP32	05.344203N	000.657428W	8.1	6.7	2.1	4.5	28.6	3.1
WSP33	05.348983N	000.659636W	8.2	7.4	2.3	4.9	27.1	3.6

APPENDICE C

Dry Season values

Water sample points	Latitude	Longitude	pH	D.O	Salinity	Conductivity	Temperature	T.D.S
WSP1	05.32585N	000.65396W	8.4	6.5	8.7	17.4	33.02	10
WSP2	05.32587N	000.65333W	8.1	8.1	8.9	17.5	32.4	10
WSP3	05.32671N	000.65304W	8	8.7	8.7	17.4	31.5	10
WSP4	05.32697N	000.65236W	8.1	8.9	8.7	17.4	31	10
WSP5	05.32674N	000.65181W	7.9	9.3	8.6	17.4	30.5	10
WSP6	05.32646N	000.65032W	8.01	9.3	8.7	17.3	30.3	10
WSP7	05.32687N	000.64986W	8.04	9.4	8.7	17.3	29.9	10
WSP8	05.32785N	000.65061W	8.04	7.8	8.7	17.4	29.6	10
WSP9	05.32831N	000.64983W	8.1	9.6	8.6	17.2	29.5	10
WSP10	05.32790N	000.64897W	8.1	9.6	8.6	17.3	29.8	10
WSP11	05.32713N	000.64811W	8.2	9.3	8.6	17.1	30.8	10
WSP12	05.32839N	000.64801W	8.2	9.4	8.5	17.1	30.7	10
WSP13	05.32962N	000.64751W	8.1	7.3	8.8	17.6	29.5	10
WSP14	05.32713N	000.64463W	8.1	8.8	8.6	17.3	29.4	10
WSP15	05.33082N	000.64461W	7.9	6.5	8.8	17.5	29.5	10
WSP16	05.33019N	000.64144W	8.02	13.5	8.6	17.2	32.3	10
WSP17	05.33107N	000.64180W	8.7	13.9	8.2	16.4	33.2	10
WSP18	05.33244N	000.64231W	8	11.6	8.5	16.9	31.4	10
WSP19	05.33461N	000.64240W	7.9	13.8	8.5	17	32.1	10
WSP20	05.33707N	000.64340W	7.9	12	8.5	16.9	32.2	10
WSP21	05.34086N	000.64695W	8.04	14	8.5	17.04	32.1	10
WSP22	05.34103N	000.64913W	8.1	13.8	8.5	16.9	32.3	10
WSP23	05.34127N	000.64973W	8.5	13.7	8.5	17.3	32.2	10
WSP24	05.34159N	000.65063W	8.6	13.9	8.5	16.9	31.8	10
WSP25	05.34228N	000.65182W	8	13.8	8.5	17.1	32.2	10
WSP26	05.34287N	000.65327W	8	13.9	8.5	17.1	32.1	10
WSP27	05.34337N	000.64591W	8.2	13.7	8.4	16.9	32.5	10
WSP28	05.34538N	000.64548W	8.4	11.5	8.5	17.1	32.6	10
WSP29	05.36181N	000.63934W	7.4	2.4	0.4	771.5	32.8	548
WSP30	05.36326N	000.63795W	7.5	9	0.4	714	30.6	507
WSP31	05.36656N	000.63686W	7.4	4.9	0.2	313.5	30	222.5
WSP32	05.344203N	000.657428W	7.9	12.5	7.8	17.7	32.3	10
WSP33	05.348983N	000.659636W	8.1	13.8	7.5	17.9	33	10

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Date: 7th August, 2019.

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF INTRODUCTION
MR. NELSON YEBOAH BOANU

We write to introduce to you **Mr. Nelson Yeboah Boanu**, a post graduate student in the Department of Geography Education, of the University of Education, Winneba.

As part of his programme for the award of Master of Philosophy in Geography, he is expected to collect data from the field for his research work on **"Water Pollution and Biodiversity Change in the Muni Lagoon and its Catchment in Winneba, Ghana"**. The information he will be collecting is strictly for academic purposes and has no financial implication or obligation.

We would be grateful if you could assist him with the necessary information and cooperation needed for the work.

Thank you.

Yours faithfully,

Dr. Seth Peter Frimpong
Ag. Dean, Faculty of Social Sciences Education